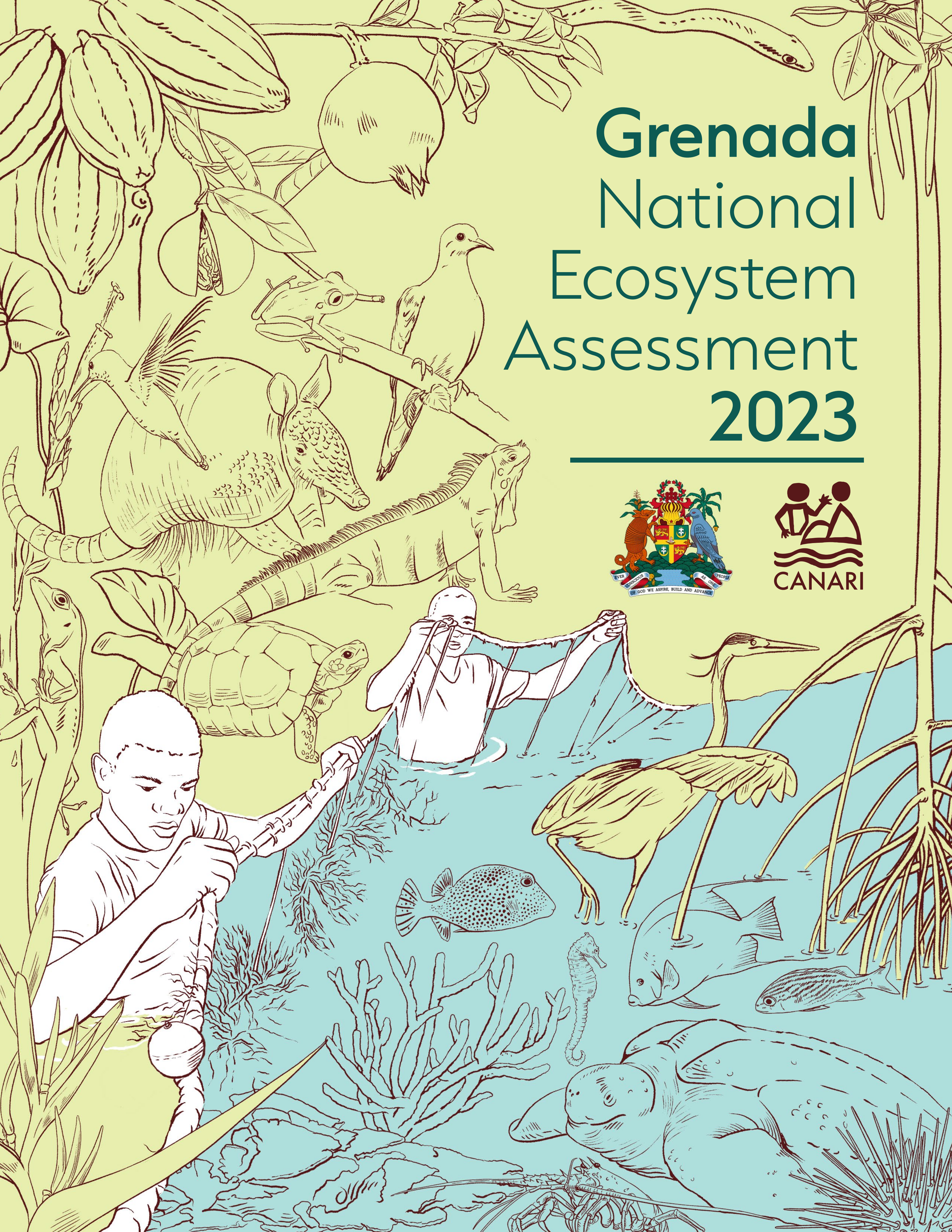

Grenada National Ecosystem Assessment **2023**

EVER CONSCIOUS OF GOD WE ASPIRE, BUILD AND ADVANCE AS ONE PEOPLE

CANARI

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Agency for Rural Transformation (ART)

Association of Caribbean Beekeeping Organisations

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Forestry Department, Ministry of Economic Development, Planning, Tourism, ICT, Creative Economy, Agriculture and Lands, Fisheries & Cooperatives

Gaea Conservation Network

Grenada Coral Reef Foundation

Grenada National Museum

Inter- Agency Group of Development Organisations

Kido Foundation

Land Use Division, Ministry of Economic Development, Planning, Tourism, ICT, Creative Economy, Agriculture and Lands, Fisheries & Cooperatives

Mirabeau Propagation Station, Ministry of Economic Development, Planning, Tourism, ICT, Creative Economy, Agriculture and Lands, Fisheries & Cooperatives

National Water and Sewerage Authority

Ocean Spirits

Planning and Development Authority (formerly Physical Planning Unit)

Rastafarian Heritage Society

St. George's University

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The Wider Caribbean Sea Turtle Conservation Network

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University of the West Indies- Centre for Resource Management and Environmental Studies

Foreword

Grenada, Carriacou, and Petite Martinique proudly stand as the first small island developing nation to undertake a national ecosystem assessment using the renowned Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) methodology. This pioneering initiative furnishes us with an unprecedented, centralised repository of evidence elucidating our nation's natural environment. More importantly, it sheds light on the indispensable environmental services that serve as the bedrock of our economy and are integral to the well-being of each Grenadian citizen.

The natural beauty of our islands is a source of immense pride and joy for Grenadians both at home and across the diaspora. However, it is crucial that we also recognise the intrinsic value of our natural capital. Our environment is not just a backdrop for life; it is the lifeblood that fuels our existence. From the food that sustains us, the freshwater that rejuvenates us, to the very oxygen that fills our lungs—nature provides a suite of essential services intricately woven into the fabric of our daily lives. The COVID-19 pandemic has underscored the undeniable symbiosis between humans and nature, a relationship that takes on even greater dimensions within the microcosm of a small island nation.

By assigning economic and social value to nature's goods and services, we equip ourselves with the tools necessary for enlightened decision-making. This, in turn, opens new vistas for sustainable investment, wealth generation, employment, and overall human well-being. Simultaneously, we fortify our resilience against the inevitable tides of change. As we proactively combat both the direct and indirect drivers of biodiversity loss, this assessment offers a timely opportunity to refine and integrate Grenada's National Biodiversity Strategy and Action Plan (NBSAP). The exhaustive insights, policy implications, and prospective scenarios presented in our National Ecosystem Assessment will serve as invaluable reference points, informing how we leverage our natural assets for the holistic development of our nation—both for the present and posterity.

Minister for Climate Resilience, the Environment and Renewable Energy – Hon. Kerryne Z. James

Preface

National ecosystem assessments (NEAs) collate and synthesise current knowledge on the status, trends and threats to biodiversity and ecosystem services in target countries. These assessments also provide information on the economic, social and intrinsic value of those ecosystems and ecosystem services for use in national and local level decision making, as it pertains to natural resources management and sustainable development of the country.

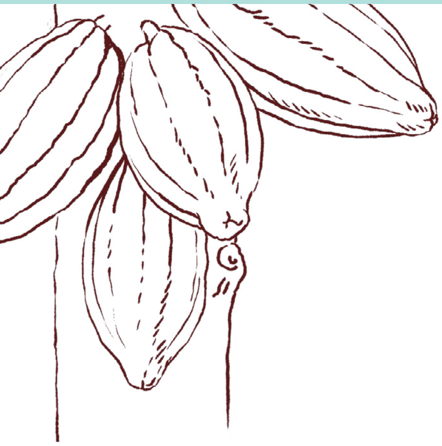
NEAs utilise processes developed by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) tailored for the specific national areas of interest as determined by stakeholders. Typically, the process starts with a scoping exercise to frame the assessment including identifying policy questions that the NEA will address. A multidisciplinary team of authors is then recruited to produce the NEA, utilising existing studies and data. Several drafts are developed and reviewed until the final assessment is produced along with a summary for policy makers (SPM). NEAs emphasise the engagement of a wide range of stakeholders and also incorporate local and indigenous knowledge.

The Grenada NEA was conducted using the general process outlined above. After the scoping exercise was completed in 2020, a multidisciplinary team of authors was engaged comprising of economists, anthropologists, climate change specialists, biologists and other natural resource management experts. However, to secure the expertise needed for the NEA, authors were recruited from other countries, for example, researchers based at Caribbean and international universities who had conducted relevant research in Grenada. Initially, 96 authors were engaged with a final core team of 72 authors completing the NEA.

At every stage of the NEA process, a wide range of stakeholders was involved, including civil society, youth, government, regional institutions and private citizens. These stakeholders framed the assessment, inputted data and local knowledge, and reviewed outputs. Stakeholders and authors alike participated in training on ecosystem valuation and foresight scenarios. Civil society stakeholders also benefited from training on the communication of environmental information to support the use of the material from the Grenada NEA. This included training on the design and execution of communication campaigns and capacity building on Information and Communication Technology (ICT) Tools like participatory videos and photojournals. A Citizen's Guide to the NEA was also developed to ensure that the NEA information was packaged in a format that Grenadian civil society can easily use to communicate with private sector, youth, policy makers and other stakeholders, regarding the value and importance of specific ecosystems and sites. The participation of civil society in the development and use of the Grenada NEA was guided by a civil society co-chair in addition to other co-chairs who directed the technical content of the assessment.

Regional capacity on ecosystem valuation was built through the development of the Grenada NEA with authors from varying disciplines and countries collaborating throughout the process. Junior authors and fellows were provided an opportunity to work alongside and learn from key Grenadian, regional and international experts in various fields related to ecosystem valuation, biodiversity and ecosystem management. Authors and civil society were provided with opportunities to engage with and learn from each other. The Grenada NEA is an important pilot for the Caribbean region and provides a launching point for the scaling out of regional work on ecosystem valuation and NEAs, in support of the sustainable development of the region.

Grenada NEA project manager and Senior Technical Officer at the Caribbean Natural Resources Institute – Dr. Natalie Boodram



Chapters

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List of Acronyms

ABS	Access and Benefit-Sharing
ACBO	Association of Caribbean Beekeepers Organisation
AI	Artificial intelligence
AICICT	Artificial Intelligence, Computing and Information and Communication Technology
AOSIS	Alliance of Small Island States
ART	Agency for Rural Transformation
AW	Artificial Wisdom
BBC	British Broadcasting Corporation
BEMC	Biodiversity and Ecosystems Management Committee
CarSIF	Caribbean Sea Innovation Fund
CANARI	Caribbean Natural Resources Institute
CARDI	Caribbean Agricultural Research and Development Institute
CARICOM	Caribbean Community
CARPHA	Caribbean Public Health Agency
CATIE	Tropical Agricultural Research and Higher Education Center
CATS	Caribbean Aqua-Terrestrial Solutions
CBD	Convention on Biological Diversity
CBF	Caribbean Biodiversity Fund
CBO	Community-based organisation
CC4FISH	Climate Change Adaptation in the Eastern Caribbean Fisheries Sector Project
CCA	Coastal Conservation Association
CCI	Caribbean Challenge Initiative
CCCCC	Caribbean Community Climate Change Centre
CCCRA	CARIBSAVE Climate Change Risk Atlas
CCRIF	Caribbean Catastrophe Risk Insurance Facility
CDB	Caribbean Development Bank
CDEMA	Caribbean Disaster Emergency Management Agency
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CEHI	Caribbean Environmental Health Institute
CERMES	Centre for Resource Management and Environmental Studies
CFP	Ciguatera fish poisoning
CHARIM	Caribbean Handbook on Risk Information Management
CIAT	International Center for Tropical Agriculture
CIMH	Caribbean Institute for Meteorology and Hydrology
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CLME	Caribbean Large Marine Ecosystem
CMIP5	Coupled Model Intercomparison Project Phase 5
CNFO	Caribbean Network of Fisherfolk Organisations
COAST	Caribbean Oceans and Aquaculture Sustainability Facility
CO_2	Carbon dioxide
COMES	Council of Ministers for Environmental Sustainability
COP	Conference of the Parties
COP27	27th session of the Conference of the Parties to the UNFCCC
CPUE	Catch per unit effort
CREWS	Coral Reef Early Warning System
CRDP	Climate resilient development pathway
CRFM	Caribbean Regional Fisheries Mechanism
CRISPR	Clustered regularly interspaced short palindromic repeats
CSME	Caribbean Community Single Market and Economy
CSO	Civil society organisation
DETC	Department of Economic and Technical Cooperation
DPSIR	Driver-Pressure-State-Impact-Response
EbA	Ecosystem-based Adaptation
EBSA	Ecologically and Biologically Significant Marine Areas
ECCB	Eastern Caribbean Central Bank
ECROP	Eastern Caribbean Regional Ocean Policy
EEZ	Exclusive Economic Zone

EIA	Environmental Impact Assessment
EMB	Environmental Management Bill
EPI	Environmental Performance Index
EPIC	Environmental Protection in the Caribbean
ES	Ecosystem services
ESG	Environmental, Social and Governance
FADS	Fish Aggregating Devices
FAO	Food and Agriculture Organization of the United Nations
FCPF	Forest Carbon Participation Facility
FDI	Foreign direct investment
FEWER	Fisheries Early Warning and Emergency Response
FGDC	Federal Geographic Data Committee
FOG	Fats, oil and grease
GAC	Grenada Agriculture Census
GBA	Grenville Bay Area
GBF	Global Biodiversity Framework
GBN	Grenada Broadcasting Network
GCA	Grenada Cocoa Association
GCF	Green Climate Fund
GCM	Global Climate Models
GCNA	Grenada Co-operative Nutmeg Association
G-CREWS	Grenada Climate Resilient Water Sector
GDP	Gross Domestic Product
GEPAP	Gender Equality Policy and Action Plan
GERRI	Grenada Ecological Resilience Research Institute
GFC	Grenada Fund for Conservation Inc.
GHG	Greenhouse Gas
GHTA	Grenada Hotel and Tourism Association
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
GMO	Genetically modified organism
GNNCSDS	Global Network of National Councils for Sustainable Development and Similar Bodies
GNP	Gross National Product
GNOW	Grenada National Organisation of Women
GoG	Government of Grenada
GPPA	Grenada Planned Parenthood Association
GRENCASE	Grenada Citizen Advice and Small Business Agency
GRENCODA	Grenada Community Development Agency
GRENED	Grenada Education and Development Programme
GSPCA	Grenada Society for Prevention of Cruelty to Animals
GSWMA	Grenada Solid Waste Management Authority
G-WaSP	Grenada Water Stakeholder Platform
HI	Hyper Intelligence
IADGO	Inter-Agency Group of Development Organisations
IAS	Invasive Alien Species
IBA	Important Bird Area
ICC	International Coastal Clean-up
ICCAS	Integrated Climate Change Adaptation Strategies
ICCAT	International Commission for the Conservation of Atlantic Tunas
ICCO	International Cocoa Organization
ICS	Inter College Selection
ICT	Information and Communication Technology
ICZM	Integrated Coastal Zone Management
IDB	Inter-American Development Bank
IFC PS	International Finance Corporation Performance Standards
IFAD	International Fund for Agricultural Development
IICA	Inter-American Institute for Cooperation on Agriculture
IIED	International Institute for Environment and Development
ILK	Indigenous and local knowledge
IMF	International Monetary Fund
IMO	International Maritime Organisation
INDC	Intended Nationally Determined Contribution

IO	Inter-governmental organisation
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IPCC	Intergovernmental Panel on Climate Change
IPLC	Indigenous people and local communities
IRP	International Resource Panel
IRR	Internal rate of return
ISDR	International Strategy for Disaster Reduction
IUU	Illegal, Unreported and Unregulated
JICA	Japan International Cooperation Agency
KAP	Knowledge, Attitudes and Practices
KPI	Key Performance Indicator
LDN	Land Degradation Neutrality
LMPA	Levera Marine Protected Area
LOS	Large ocean states
M&E	Monitoring and evaluation
MA	Millennium Ecosystem Assessment
MARPOL	International Convention for the Prevention of Pollution from Ships
MBIA	Maurice Bishop International Airport
MBMPA	Moliniere-Beausejour Marine Protected Area
MEAs	Multilateral environmental agreements
MNIB	Marketing and National Importing Board
MNPs	Marine natural products
MPA	Marine Protected Area
MRV	Measuring, Reporting and Verification
MS	Member States
MTAP	Medium-Term Action Plan
NaDMA	National Disaster Management Agency
NAP	National Adaptation Plan
NAWASA	National Water and Sewerage Authority
NBSAP	National Biodiversity Strategy and Action Plan
NCP	Nature's Contributions to People
NDC	Nationally Determined Contribution
NEA	National Ecosystem Assessment
NbS	Nature-based Solutions
NGO	Non-governmental organisation
NHI	National Health Insurance
NOAA	National Oceanic and Atmospheric Administration
NoT	Network of things
NPS	National Plan Secretariat
NTFP	Non-Timber Forest Products
NWP	National Water Policy
OAS	Organisation of American States
OBIS	Ocean Biodiversity Information System
ODA	Official Development Assistance
ODS-e	OECS Development Strategy
OECD	Organisation for Economic Co-operation and Development
OECMs	Other Effective Area-Based Conservation Measures
OECS	Organisation of Eastern Caribbean States
OECS-BEF	OECS Biodiversity and Ecosystems Management Framework
OGDS-e	OECS Growth and Development Strategy
OHHLEP	One Health High-Level Expert Panel
PA	Protected Area
PES	Payments for Ecosystem Services
PoA	Programme of Action
PPCR	Pilot Programme for Climate Resilience
PPP	Public private partnerships
PPR	Pentatricopeptide repeat
PSPs	Permanent sampling plots
PTSD	Post traumatic stress disorder
PTSS	Post-traumatic stress symptomatology
PURC	Public Utilities Regulatory Commission
PV	Photovoltaic
REACH	Registration, Evaluation, Authorisation and Restriction of Chemical Substances
REDD+	Reducing Emissions from Deforestation and Forest Degradation

RCM	Regional Climate Models
RCP	Representative Concentration Pathways
RFB	Regional fisheries body
ROV	Remotely Operated Vehicle
SAP	Strategic Action Plan
SCBD	Secretariat of the Convention on Biological Diversity
SDC	Sustainable Development Council
SDGs	Sustainable Development Goals
SGU	St. George's University
SIDS	Small Island Developing States
SIOBMPA	Sandy Island/Oyster Bed Marine Protected Area
SLM	Sustainable land management
SLR	Sea level rise
SMEs	Small and medium sized enterprises
SPECTO	St. Patrick Environmental and Community Tourism Organisation
SSP	Shared socioeconomic pathway
SST	Sea surface temperature
SWOT	Strengths, Weaknesses, Opportunities, and Threats
tC	Total carbon
tCO2e	Tonnes of carbon dioxide equivalent
TEEB	The Economics of Ecosystems and Biodiversity
TLK	Traditional and local knowledge
TNC	The Nature Conservancy
TVET	Technical and vocational education and training
UBEC	Unleashing of the Blue Economy of the Caribbean Project
UKHO	United Kingdom Hydrographic Office
UN	United Nations
UNCCCD	United Nations Convention to Combat Desertification
UNCED	United Nations Conference on Environment and Development
UNCTAD	United Nations Conference on Trade and Development
UNDESA	United Nations Department of Economic and Social Affairs
UNDRR	United Nations Office for Disaster Risk Reduction
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNEP-WCMC	United Nations Environment Programme World Conservation Monitoring Centre
UNICEF	United Nations Children's Fund/ United National International Children's Emergency Fund
UNFCCC	United Nations Framework Convention on Climate Change
UN-OHRLLS	United Nations Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States
UNWomen	The United Nations Entity for Gender Equality and the Empowerment of Women.
UNWTO	United Nations World Tourism Organization
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
USNIC	United States National Intelligence Committee
VME	Vulnerable Marine Ecosystems
VMS	Vessel monitoring systems
WCED	World Commission on Environment and Development
WCR	Wider Caribbean Region
WECAFC	Western Central Atlantic Fishery Commission
WINREF	Windward Island Research Foundation
WMO	World Meteorological Organization
WRI	World Resources Institute
WRMU	Water Resources Management Unit

Town of Hillsborough in Carriacou, Grenada
Photo credit: Natalie Boodram

1. Setting the scene: How a National Ecosystem Assessment (NEA) will contribute to better decision making

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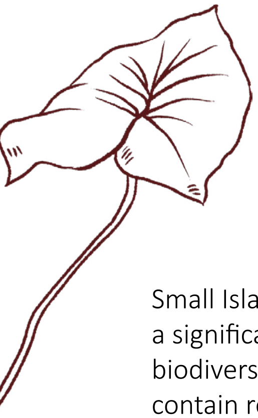


Summary

Small Island Developing States (SIDS) account for a significant percentage of the world's unique biodiversity and ecosystems (Cherian, 2007). They contain resources that can contribute positively to economic and social development, within individual SIDS and globally. However, the extent to which they can is not fully known. Thus, there is a vital need to properly assess and document these resources to understand their current condition, the stressors that affect them (natural and anthropogenic) and the landscapes they occupy. National Ecosystem Assessments (NEAs) can provide quantifiable knowledge, along with keenly observed qualitative data, to help develop policies aimed at making island ecosystems sustainably beneficial to their flora, fauna and human populations.

Grenada's diverse biomes are representative of those found throughout the Caribbean region, including high-elevation rainforests and natural springs, coastal mangroves, and coral reefs (Moore, Gilmer and Schill, 2015). However, due to Grenada's relatively small human population, challenges related to human capital, and scientific and administrative capacity are accentuated. A NEA can help by providing policy-relevant information that empowers Grenadians to conserve national ecosystems through a combination of national and regional efforts and to take action, in concert with other SIDS, to influence international decision making on preventing biodiversity loss.

Ecosystems services and mainstreaming environmental sustainability

The Grenada NEA follows the model established by *The Millennium Ecosystem Assessment* (MA) which analyses the benefits of biodiversity through the lens of ecosystems services and establishes preservation of Nature's Contributions to People (NCP) as a primary goal. Like the MA, this study holds that preserving specific benefits for humans requires conservation of entire ecosystems. However, in this chapter, we also emphasise that the concern for NCP should not lead to policies that disaggregate ecosystems into baskets of extractable resources for human use. This report also considers the benefits of mainstreaming biodiversity conservation in virtually every policy realm.

Grenada's accomplishments, in this regard, are considerable, but the challenges it faces are substantial as well. This chapter discusses institutions—national, regional, and international—as decision making venues, and possible sources of support for applying an ecosystem services methodology and a mainstreamed approach to policy making.

Effective mainstreaming also requires inclusiveness of knowledge and participation from wide arrays of stakeholders. Historical and practical knowledge of locals is invaluable to the NEA's success (Magni, 2017). Knowledge that has been cultivated over years of hands-on experience—used in conjunction with scientific knowledge—is vital to understanding changes that natural systems have gone through and provides lessons on how to conserve them (Berkes, Folke and Gadgil, 1995; Hiwasaki *et al.*, 2014).

A myriad of institutions and processes

Enhancement and preservation of ecosystem services, through mainstreaming biodiversity conservation, require an active appreciation of the fundamental interconnectedness among ecosystems, human well-being and society. Moreover, it is important to understand how those connections are embedded in complex decision making processes in the public, private and civil society sectors across international, national, sub-national and local levels (Maes *et al.*, 2012).

From local to global, each economic sector, region and community has its distinct needs in managing trade-offs among a range of development goals and targets in a context of competing national priorities and limited resources. Adjudicating disputes over decision making authority, collecting and analysing relevant data and procuring support (material and political) are all common components in making those trade-offs and negotiating the needed agreements among competing interests.

This chapter makes note of the complexity, complementarity, and occasional confusion of changing and overlapping government ministries and departments; some that have already moved toward mainstreaming biodiversity conservation, and others that could benefit from doing so. We describe regional organisations with significant capacity for advising, guiding and supporting Grenada's biodiversity conservation efforts—including the Organisation of Eastern Caribbean States (OECS) and the Caribbean Community (CARICOM); and this chapter provides a comprehensive list of the multilateral environmental agreements (MEAs) to which Grenada belongs. Taken together, these institutional resources can be the basis of a collaborative and comprehensive approach to biodiversity conservation. Such representative institutions provide the top-down participatory approach of a formal democracy if they are complemented by a vibrant civil society engaged in bottom-up participatory methods of governance (Gaymer *et al.*, 2014; Semeraro *et al.*, 2020).

To highlight the need and potential for local and regional capacity building (human capital in particular) this chapter also examines educational resources in Grenada. There is mention of primary and secondary school resources and attention given to the post-secondary educational contributions of public and private institutions.

Chapter 1 also provides data and descriptions of basic characteristics of Grenadian society, government and economy that affect biodiversity and can benefit from effective biodiversity conservation. We briefly examine leading economic sectors—especially tourism—to provide baseline information for later discussions of their environmental impacts. Finally, we discuss key aspects of public finances and related issues; among them, budgetary constraints, sovereign debt and foreign investment figure prominently.

1.1. Functions of a national ecosystem assessment for Small Island Developing States (SIDS)

National Ecosystem Assessments (NEAs) follow the precedents and model established by the *Millennium Ecosystem Assessment* (MA) conducted from 2001 to 2005 under the auspices of the United Nations Environment Programme (UNEP). The MA has been defined as "an international work programme designed to meet the needs of decision makers and the public for scientific information concerning the consequences of ecosystem change for human well-being and options for responding to those changes" (Millennium Ecosystem Assessment, n.d.). The World Resources Institute (WRI) describes the MA as providing "an indispensable baseline of information for researchers, scholars and students, as well as informing public decision making for decades to come" (World Resources Institute, 2005).

This baseline of information is particularly important for SIDS, a group of 52 geographically disparate states that face a similar set of social, economic and environmental threats to their biodiversity resources related to their geography and geology, small size and developing status (United Nations Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States [UN-OHRLLS], 2017).

For global efforts at ecosystem conservation, islands are of particular importance because they contain critical biodiversity hotspots and support about 8.5% of the world's population (Singh, Fischer-Kowalski and Chertow, 2020). Furthermore, SIDS are notably vulnerable to the effects of both climate change and extreme natural events, when compared to mainland countries. Many are tropical or pantropical and thus subject to yearly tropical cyclones; while the active volcanoes found on or near many SIDS increase their risk sensitivity as well (Wilkinson *et al.*, 2016; Singh, Fischer-Kowalski and Chertow, 2020).

Though such vulnerabilities are not unique to SIDS, the risks they pose will be intensified due to limited natural resources, higher levels of dependence on coastal and marine resources, small populations, high energy and infrastructure costs, and resulting limitations on disaster resilience (UN-OHRLLS, 2017). So, although SIDS contribute negligible amounts to total global carbon emissions (<1%), many are already grappling with climate change-induced sea-level rise, with significant proportions of their lands, populations and ecosystems threatened (UN-OHRLLS, 2017).

Grenada is no exception to the challenges faced by SIDS worldwide. Therefore, it is essential that Grenada take stock of the current state of its ecosystems, and its existing capacity—administrative, technical and societal—to address the environmental challenges it currently faces and that we can predict, with a high level of certainty, will intensify in the near future (Intergovernmental Panel on Climate Change [IPCC], 2019). Therefore, a NEA should be seen as a key source of policy-relevant information. Such information can empower Grenada's response to biodiversity loss and influence decision making related to threats caused by external and global processes such as climate change and ocean pollution.

With those challenges in mind, a core purpose of this study is to aid Grenada's policy makers in accessing available instruments, institutions and resources and overcoming the constraints that limit Government's capacity to make and implement effective policies. By doing so, the Grenada NEA can also:

- inform of and potentially influence Grenada's current and future capacity to adapt to local, regional, and global environmental change;
- determine Grenada's capacity to ensure political and socioeconomic resilience;
- inform of the needs of Grenada's most vulnerable populations; and
- highlight the special role that Grenada, along with other SIDS, plays in addressing global environmental crises.

1.1.1. SIDS and NEAs: of global importance

SIDS account for a significant percentage of the world's unique biodiversity and ecosystems (Cherian, 2007). Many such natural assets can contribute positively to economic and social development, within individual SIDS and globally. However, the full extent to which they can is still unknown. Thus, there is a vital need to properly assess and document these resources to understand their current condition, the stressors that affect them (natural and anthropogenic) and the landscapes they occupy. Having quantifiable knowledge, along with keenly observed qualitative data, can help in the development of policies designed to protect important areas and make them sustainably beneficial for Grenada and its international partners, through the provision of ecosystem services that contribute to resilient and equitable development.

That information can also aid in scaling adaptation and mitigation measures—often designed by and for larger, more developed countries and regions—to fit the needs of SIDS, and to foster cooperation among SIDS and a variety of other international partners. Therefore, for the Grenada NEA, Grenada pulls expertise, not only from its own population, but also from several other Caribbean countries and abroad, adding to the expertise available in-country and across the Wider Caribbean Region (WCR).

1.1.2. Local and regional importance and potential impact of NEAs

The Millennium Ecosystem Assessment provided a global baseline and a model to apply at various national scales, but there is still a common need among SIDS for island-focused frameworks and support systems that scale down important evaluation methods and policy recommendations. Grenada's NEA can provide such transferable knowledge, lessons learnt and skills to facilitate the completion of NEAs in other SIDS. That will include cooperative efforts to make major international environmental agreements and institutions work more effectively for SIDS.

Therefore, contributions from Grenada's NEA extend into the realm of possible partnerships, not only with other SIDS, but also with larger countries and global institutions to further the progress of sustainable development. Additionally, while the focus is biodiversity, such an effort can benefit different aspects of development, including improved education and training, economic and social development, international trade and capacity building in public and private sectors (Inter-American Development Bank [IDB], 2013).

To date, NEAs have been completed for several developed countries, including eight European countries, but have been more limited in developing countries until now (Schröter *et al.*, 2016). At the time of this writing, there were 12 national NEAs underway, with support from the United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC), including Grenada and the Dominican Republic (UNEP-WCMC, 2021). Figure 1.1 below highlights members of the Grenada Team at a meeting hosted by WCMC for the NEA country teams.

Grenada is conducting a pioneering NEA for the region; one that can support local decision making and provide a blueprint for future NEAs to be executed in the WCR. Grenada's relatively small population facilitates widespread stakeholder engagement–a critical component of effective environmental research and policy implementation–and already has a number of available datasets from various non-governmental organisations (NGOs) and inter-governmental organisations (IOs) for potential use in the NEA.

Ecosystems in Grenada are also diverse and representative of the biomes found throughout the WCR, including high elevation forests and natural springs, coastal mangroves, and coral reefs (Moore, Gilmer and Schill, 2015). Methods useful in Grenada for assessing and valuing these various ecosystems are sure to be applicable to other countries in the region. Therefore, Grenada's NEA can assist in building

Figure 1.1. Grenada NEA co-chairs and authors (foreground) participating in a capacity building workshop hosted by UNEP-WCMC for all NEA country teams in October 2022 (Photo credit: CANARI)

regional cooperation and capacity and aid the efforts of key existing regional organisations, including governmental, IOs and NGOs.

1.2. Ecosystem services

Two core assumptions of the Grenada NEA are that: 1) robust biodiversity rests on a foundation of healthy ecosystems, and 2) healthy ecosystems provide a wide array of valuable services that contribute, directly and indirectly, to human well-being (MA, n.d.; Food and Agriculture Organization [FAO], 2021). The ecosystem services framework is foundational to all the NEAs that have been completed, on both national and global levels. As a concept that informs practice, ecosystem services provide tools and methods for understanding the value of ecosystems to people. It can inform policy makers and stakeholders of what is gained by maintaining existing ecosystems in all of their complexity, what is lost when ecosystems are in decline, what the major threats and stressors are, and how to make policies that reach beyond specific and short-term interests. This long(er)-term and more holistic view of ecosystem valuation can provide a more accurate understanding of current threats. It can also guide the formulation of strategies for adaptation to, and mitigation and prevention of both current and future harms. In those ways, the ecosystem services approach encourages policy makers and stakeholders to look beyond policies that focus solely on the development of a country's specific natural assets for economic gain and is more consistent with the guiding principles of sustainable development.

Figure 1.2 shows how the interconnectedness and interaction of the three dimensions of sustainable development, as evidenced by the sides and interior of the triangle, provide a greater opportunity for transformation of economies. Placing issues such as poverty, equity and sustainability at the centre is a reminder of the need to analyse and address these challenges using an interdisciplinary approach that relies on the interconnectedness of these dimensions. In particular, note the inclusion of biodiversity as essentially connected to resilience and how "valuation/internalisation" makes the direct, two-way causal linkage between economic and environmental sustainability.

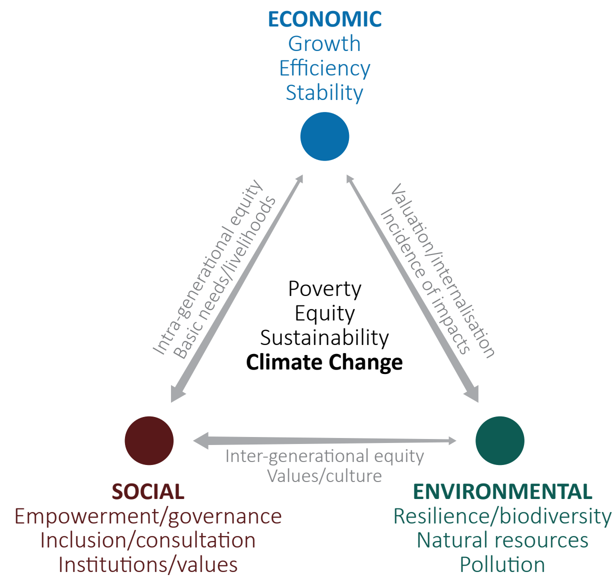


Figure 1.2. Key elements of sustainable development and interconnections (Munasinghe, 2010)

This approach to valuing a nation's resources recognises that there are direct and significant economic benefits to making conservation of ecosystems and biodiversity an integral part of economic and social policy making. Additionally, the approach is not just theoretically indicated, but it is also practical.

In practice, putting a monetary value on environmental and social impacts usually increases the chance of anthropogenic impacts being considered in decision making (van Beukering *et al.*, 2007; Finau, 2020). In a developing country context, particularly that of SIDS, a tremendous amount is known about the importance and value of the natural systems that underpin the economy, yet there is a need for this information to be appropriately synthesised and effectively conveyed to decision makers and the general public (van Beukering *et al.*, 2007; Acharya, Maraseni and Cockfield, 2020).

Finally, the ecosystem services approach alerts all concerned to the central importance of indirect and not-easily-quantifiable contributions that ecosystems make to human well-being. For one, healthy ecosystems are essential to traditional values and cultures unique to Grenada. NEAs, informed by the concept of ecosystem services, represent an important step forward in that regard, bridging gaps between scientific knowledge and traditional and local knowledge and between policies aimed at economic growth and development, on the one hand, and natural and cultural preservation, on the other (Reid, 2005).

Therefore, in this document, the term ecosystem services is used to identify the benefits people obtain from ecosystems; because continuing to access resources beneficial to human well-being will involve environmental regulations—including support of biosphere processes, inputs to culture and the intrinsic values of the systems themselves—that maintain and, where appropriate, restore particular ecological structures and functions (Holzman, 2012). This ecosystemic approach to meeting the current and future needs of all states and communities—regardless of levels of development—adds dimensions to policy making that are consistent with well-established concepts and increasingly-common practices in both the natural and social sciences. These include such foundational concepts as intergenerational equity—the core concept underlying sustainable development—and the tripartite construction of sustainable development, which demands an integrated and mutually-supportive approach to the economic, social and environmental needs of human populations (World Commission on Environment and Development [WCED], 1987; United Nations Conference on Environment and Development [UNCED], 1992).

This National Ecosystem Assessment, like its predecessors, is initiated with the confidence that integrating biodiversity conservation into all types of policy is required in order to build resilience in the face of profound changes in global, regional and local environments. The task, then, is to provide a body of information, knowledge and expertise from the widest possible array of stakeholders, with an eye towards building scientific and institutional capacity, human resources and a nuanced understanding of the value of Grenada's ecosystems in multiple policy areas. In a practical sense, this requires detailed and actionable information on the current state of Grenada's biodiversity and the challenges the country faces for conserving it. The Grenada NEA concludes with recommendations on ways to integrate biodiversity conservation into every aspect of economic, social and environmental policy.

1.2.1. Key concepts and metrics in ecosystem services

Policy makers must acknowledge that ecosystem services are complex with intricately linked sets of benefits to be derived from healthy ecosystems while considering that many of 'nature's contributions to people' will fit into one or more of four categories: provisioning, regulation, cultural and supporting (Millennium Ecosystem Assessment, 2003). Therefore, the full array of any ecosystem service can present challenges and opportunities for effective policy making in virtually every policy area, and biodiversity conservation is integral to the sustainable provision of all such services. Because a core purpose of this study is to identify ways in which Grenada's various ecosystems provide those services, we highlight key relationships between biodiversity conservation and the improvement of ecosystem services; and provide data—gleaned from a wide range of scientific studies and stakeholder consultations—to aid policy makers.

Provisioning services, such as food, water and land–and the regulatory services they provide–are felt both directly and indirectly. Cultural services and key constituents of well-being such as mental health, recreation, tourism and spiritual experiences are all supported by protecting habitat for species and genetic diversity (FAO, 2021). Apropos to the challenges of effective policy making and implementation, it is also important to note that ecosystem services can be grouped into final and intermediate services, depending on whether they play a supportive function to another service or they themselves are directly consumed by people (Feeley *et al.*, 2017).

Whether direct or indirect, intermediate or final, these services are interconnected and, as such, any increase in our knowledge of these services–and the connections among them–will help Grenadians make the valuations and decisions essential to securing our natural stock for future generations. For decision makers in public and private sectors and civil society, this complexity and interconnectedness, which mirrors the complex and interdependent structures of ecosystems, highlights the importance of mainstreaming ecosystem conservation as an integral part of all policy realms.

Figure 1.3 presents a comprehensive list of the basic types of services and their connections to human well-being. This list should be thought of as a set of general categories applicable to the assessment of the needs and goals of any policy affecting the well-being of the Grenadian people. Some of those services are 'direct' in that they are consumed, utilised or experienced by human populations. Others are 'indirect' in that they are the valued outcomes or positive (if sometimes intangible) effects of maintaining intact ecosystems and a rich store of biodiversity.

Direct services are often regarded as provisioning services. Provisioning ecosystem services present clear examples of services utilised by human populations

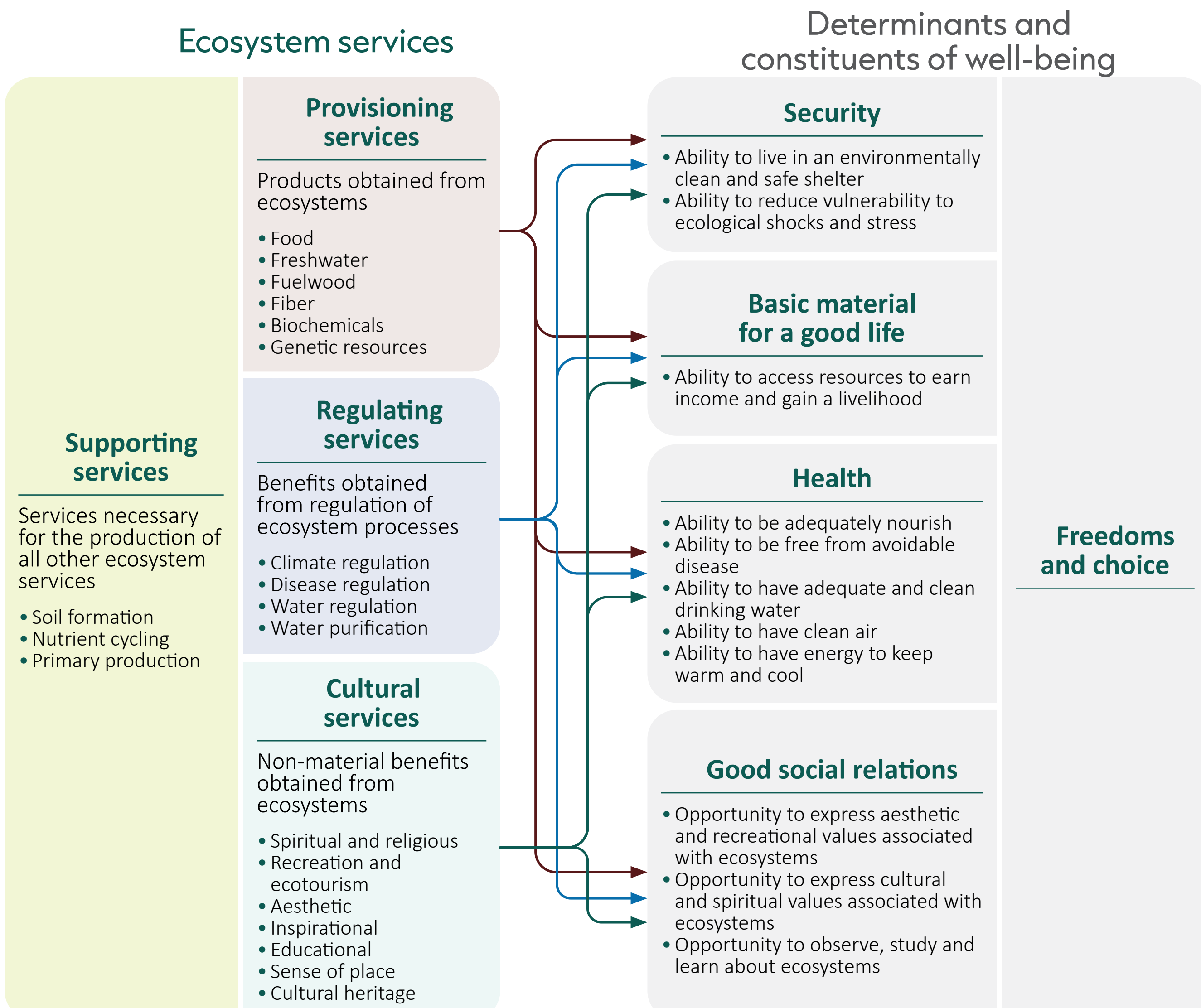


Figure 1.3. Ecosystem services and human well-being (Millennium Ecosystem Assessment, 2003)

and directly associated with a variety of measures of well-being, including good health and opportunities for economic development. A healthy ecosystem provides direct services in the form of fresh food, clean water, fuel and a host of raw materials and medicinal properties that support several major industries, now and in the future (Hernández-Blanco *et al.*, 2022). The demands placed by people on those services generally increase with economic development. For example, today the current supply of food is 17% more per person than 30 years ago. With the global population growth rate at 2% per annum, our ability to meet food demands in the future becomes a cause for immediate concern that is exacerbated by the various environmental pressures placed on the agricultural industry today. Thus, in our quest for environmentally-sustainable development, we must be ever mindful that income growth and changes in consumer preferences, which are main drivers associated with a country's development, will have implications on maintaining these direct services (Baumgärtner *et al.*, 2011).

Indirect or regulating ecosystem services highlight the importance of taking an ecological approach to policy making, rather than one that treats different aspects of economic and social policy as separate from biodiversity conservation. These are the services that maintain the environmental conditions that support life, but they may be invisible or silent until they can no longer provide the service efficiently. Trees, for example, provide many regulatory services. The role of trees in sequestering carbon emissions to mitigate climate change or prevent soil erosion may become apparent to those who depend on those services only when the tree populations decline in ways that measurably affect livelihoods. The careful consideration of regulating services further indicates the complex relationships among all ecosystem services and the need to integrate biodiversity conservation goals into all types of policy. For example, Figure 1.3 includes fuelwood in the list of provisioning services and climate regulation in the list of regulating services. Both services will benefit from maintaining diverse forest ecosystems, managed sustainable use by local stakeholders and sustainable watershed management practices. They are also valued as assets of Grenada's tourism economy as providers of raw materials for woodworkers and craftspeople. Additionally, intact forest ecosystems provide numerous cultural, spiritual, social and psychological benefits essential to human well-being.

The direct and indirect benefits derived from cultural ecosystem services can be difficult to separate. Furthermore, policy makers will face challenges related to quantifying such services in ways that make their value comparable to services that produce direct economic benefits. For example, a remote and inaccessible location of a historic event may not be a valuable asset for the tourism industry but could be considered essential to a people's cultural heritage. So, the list of cultural services presented in Figure 1.3 indicates their importance to human well-being and shows why policy made to govern ecosystems for the provision of direct services needs to actively consider the cultural services provided as well.

1.2.2. Integrating and applying diverse sources of knowledge to core policy issues

A usable assessment of ecosystems services requires a robust methodology that integrates scientific knowledge of various kinds—including from the natural and social sciences, and traditional and local knowledge (TLK)—compiled from various sources (Guerrero-Gatica *et al.*, 2020; Hill *et al.*, 2020). The Driver-Pressure-State-Impact-Response (DPSIR) framework has been used by several international organisations for evaluating a variety of social-ecological systems and is highly regarded as a tool for linking scientific and social-scientific information to guide the conservation of ecosystems. It has been particularly useful for studying marine ecosystems and has been successfully adapted to terrestrial systems such as "river catchments and coastal zones, as well" (Gari, Newton and Icely, 2015). "It is policy-oriented and provides a framework for categorising a problem domain, along the cause-effect chain" (Patrício *et al.*, 2016).

With the inclusion of traditional and local knowledge obtained through stakeholder consultations, DPSIR is a complementary methodology to the ecosystem services orientation of the Grenada NEA. It has been applied to making policies that address a variety of environmental challenges, such as the "protection of groundwater, inland surface waters, estuaries and coastal waters" and "for assessment and evaluation of the impacts of development activities..." (Patrício *et al.*, 2016).

Chapter 3 in the Grenada NEA applies the DPSIR framework to determine the causes and effects of human interactions with Grenada's ecosystems, thus providing data and descriptions that can be integrated into policies that would conserve Grenada's biodiversity to optimise key ecosystem services (both direct and indirect).

1.3. Governance of biodiversity conservation in Grenada

As with other SIDS, the threats to Grenada's biodiversity are national, regional and global in their origins. While Grenada has sovereign control over conditions and practices affecting flora, fauna and natural landscapes within the lands of the tri-island state and its offshore Exclusive Economic Zone (EEZ), many of the stressors that negatively affect its biodiversity—such as climate change, ocean acidification and pollution, the overharvesting of marine species and marine habitat degradation—fall outside of its sovereign control and national institutional capacity to govern (Figure 1.4). Global challenges such as climate change and biodiversity loss affect multiple aspects of Grenada's economy. Therefore, the Grenada NEA can support efforts by the Government and its agencies to mainstream considerations of ecosystem conservation in all major policy areas at the national, regional and international levels.

To be an effective aid in conserving ecosystems, the Grenada NEA critically evaluates environmental governance capacity, as well as the current state of the ecosystems themselves. We also examine the resources needed to make and implement policies that mainstream ecosystem conservation in multiple sectors and look for ways to integrate ecosystem health into policies affecting all economic sectors, administrative bodies and institutions of representative government, from the local to national, regional and global levels.

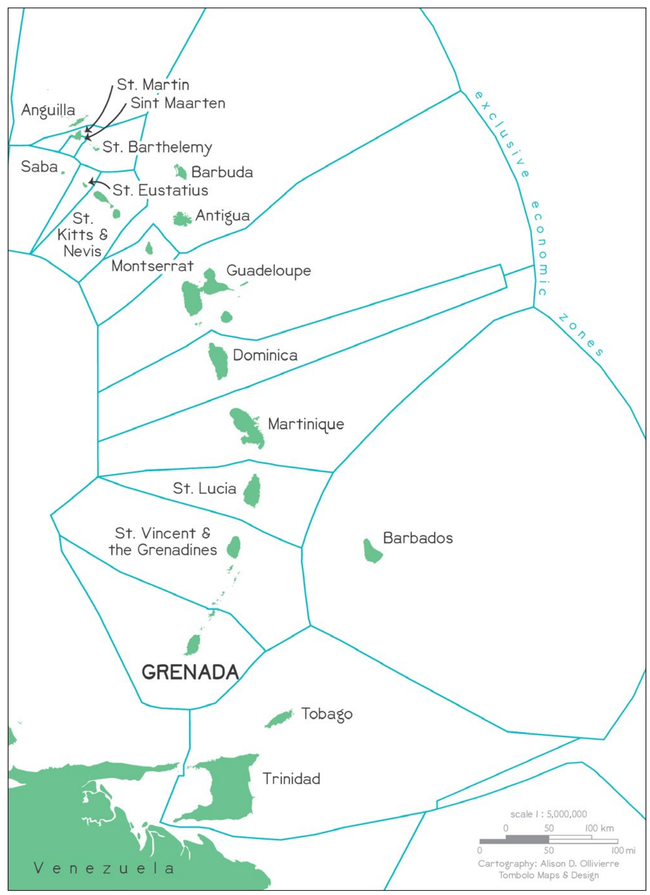


Figure 1.4. Map of the eastern Caribbean showing Grenada and its Exclusive Economic Zone (EEZ) (Data sources: 1) Caribbean Islands Data Set (The Nature Conservancy [TNC]); 2) Caribbean Exclusive Economic Zones, Version 8 (Feb 2014)- (TNC provided by the Physical Planning Authority of Grenada – under the OECS Coastal and Marine Spatial Planning Project [car_poli_eez_2014.shp])

1.3.1. Policy Integration: Mainstreaming ecosystem services, sustainability and resilience

The core requirement of mainstreaming is the integration of goals and targets for ecosystem conservation into multiple policy areas at multiple levels of governance. In the following sections of this chapter, we consider Grenada's accomplishments and challenges in that regard. First, we identify the general governance challenges. Second, we note some representative accomplishments and shortcomings to provide context. Third, we show Grenada's potential for maintaining biodiversity and building resilience.

For any country, mainstreaming the protection of ecosystems throughout diverse areas of its economy and society means finding ways to contend with the following: 'complex and competing jurisdictions', 'a proliferation of policy goals', 'insufficient capacity and weak institutional structures', and tensions among country- and sector-level initiatives and responsibilities. Strategies needed to meet these challenges include decision making that is inclusive of multiple stakeholders at all stages: from policy formulation, to implementation, monitoring and evaluation of outcomes and the making of necessary revisions.

From local to global, each economic sector has its distinct needs in managing trade-offs with other development goals and targets, primarily based on national priorities and limited resources. Adjudicating disputes over decision making authority, collecting and analysing relevant data and procuring support (material and political) are all common components in making those trade-offs and negotiating the needed agreements among competing interests. Furthermore, SIDS' relationships with external providers of financial and technical assistance add a dimension that large, developed countries do not face: the shifting interests and priorities of donor states and institutions (Persson, 2005; Rosenberg, 2020). In short, taking a holistic approach to ensure that Grenada's ecosystems are resilient will be both complex and necessary.

1.3.2. A holistic approach to achieving sustainability goals

Given the multiple policy and decision making areas entailed, mainstreaming ecosystem conservation requires enhanced understanding and appreciation of the fundamental interconnectedness among ecosystems, human well-being and society. Moreover, it is important to understand how those connections are embedded in complex, decision making processes in the public, private and civil society sectors across national, sub-national and local levels (Maes *et al.*, 2012). Placing ecosystem services in a broader decision making context is necessary to affect transformational change in policy making, investment decisions and practices within and across multiple policy areas and economic sectors (Guerry *et al.*, 2015). Therefore, mainstreaming is not about imposing or forcing a single perspective or method across economic sectors but involves the widening of perspectives and improved access to relevant knowledge for policy makers, decision makers and leaders.

Such inclusiveness–of economic interests, diverse peoples and communities, sources of knowledge, institutions and organisations–should also foster adaptability in the policy realm and enhance responsiveness to new information and changing conditions affecting biodiversity, human health and well-being, economic prosperity and social development outcomes (The Economics of Ecosystems Biodiversity [TEEB], 2009). So, enhanced participation amongst decision makers and leaders to support policy integration at the local, sub-national and national levels is also required. This approach to participation can serve to better mainstream ecosystem services, sustainability, and resilience while also balancing trade-offs amongst competing priorities and needs for investments and resources in multiple policy areas (Schreckenberg, Mace and Poudyal, 2018).

Still, successful mainstreaming of the ecosystem services approach to policy making requires developing and sharing solid evidence about the state of ecosystems and the policies that affect them. Grenada's NEA will enable policy makers, decision makers and leaders to better understand the linkages and context of ecosystem services and Grenada's natural assets to policies, investments and actions in their respective sectors, thereby encouraging a more thorough and consistent mainstreaming of ecosystem services, sustainable development and resilience into their decision making processes.

In sum, applying the concept of ecosystem services as a tool of governance highlights the impact of conservation in multiple areas of policy making. Mainstreaming ecosystem conservation, although challenging to achieve, will be worth the effort. It can help break through environmental policy silos–in both legislative and administrative functions of government–and thereby make active consideration of ecosystem services (lost, preserved or gained) integral to all areas of policy making and implementation. This chapter further develops this theme by examining the existing institutional structures of the Government of Grenada (GoG), and the regional organisations and international environmental agreements to which Grenada belongs. Chapter 5 provides a more detailed discussion of Grenada's current capacity and ongoing needs for making biodiversity conservation mainstreaming a core consideration for economic development and effective governance.

1.3.3. Combining science, traditional and local knowledge

Inclusiveness is key to effective mainstreaming. Scientific information alone, while necessary, can be insufficient for understanding natural systems. Historical and practical knowledge of locals is invaluable to a NEA's success (Magni, 2017). It has been shown that indigenous channels have high intrinsic value, and particularly high credibility, because they have been passed down through generations (Mundy and Compton, 1991). This means that this knowledge has been cultivated over years of hands-on experience with local ecosystems and is vital to understanding the history of changes that these natural systems have gone through. Additionally, because local and indigenous communities would have had to conserve these natural systems and resources for the prolonged longevity of their societies, they have insight into methods for ecosystem and biodiversity enhancement (Berkes, Folke and Gadgil, 1995; Hiwasaki *et al.*, 2014).

The inclusion of indigenous and local knowledge (ILK) provides many additional benefits through what we can call 'proportional development' (termed 'appropriate development' by Mundy and Compton, 1991). This boils down to developing the people of the country along with the institutions and technical aspects of the country. Building internal capacity in this way reduces dependence on often costly external sources of training and data collection; the results can provide models for increasing local capacity in other regions of the world as well. Local inclusion in projects, especially conservation efforts, also increases their resilience (Berkes, Folke and Gadgil, 1995). The local populace will be more knowledgeable and better equipped to continue conservation efforts. Such efforts can create important avenues for local employment and local community development, increase internal revenue cycling within and among communities, and thereby contribute to reducing poverty and increasing the overall standard of living for the entire country.

1.4. Biodiversity conservation and resilience

The International Strategy for Disaster Reduction (ISDR) defines resilience as the capacity of a system to absorb change and keep functioning (United Nations Office for Disaster Risk Reduction [UNDRR], 2009). Resilience originated as an ecological concept, describing the ability of an ecosystem to persist when faced with disturbances (Holling, 1973). A key feature of resilience is the retention of vital "structures and functions" (UNDRR, 2009). The more biodiverse an ecosystem, the more likely it will contain multiple structures that can provide similar services. Since ecosystemic change is inevitable (often caused by forces beyond the control of national governments or affected communities), biodiversity is fundamental to resilience, and management for resilience should focus on maintaining biodiversity (Biggs *et al.*, 2020).

Therefore, like mainstreaming in the policy realm, resilience in the natural environment relies on flexibility and the ability to react to disturbances and adapt where necessary while maintaining the essential functions of that ecosystem (Oliver *et al.*, 2015; Farley and Voinov, 2016). This type of adaptability entails both the adaptive management of ecosystems based on combined scientific and local knowledge and governing institutions capable of responding to change (Biggs *et al.*, 2020).

In the last few decades, the concept of resilience has been expanded to include socioeconomic resilience—such as the ability of a country to recover from natural disasters—and this latter form relies heavily on the existence and resilience of robust and complex natural systems (Adger, 2000). For instance, low-lying coastal communities in Grenada, like the Grenville Bay Area (GBA), are very vulnerable to coastal erosion and wave action (Roberts, 2016). Nearshore ecosystems like mangrove forests, seagrass beds and coral reefs interact to significantly reduce wave energy reaching the shore (Guannel *et al.*, 2016). The maintenance of these three ecosystems is critical for protecting life and property along the coastline. The *At Water's Edge project,* an undertaking by The Nature Conservancy (TNC) and local partners, provides one example of efforts to do that. The project took a multi-pronged approach to increasing community resilience in the GBA through both mangrove and coral restoration, and community engagement and empowerment (Roberts, 2016).

Socioeconomic resilience can also be achieved through appropriate infrastructure and planning, when the government or individuals put measures in place to ensure functional redundancy, and thus resilience, in their responses to natural disasters. Examples include the use of "off-grid water technologies" like tanks to supplement water supply during times of drought (Simpson, Shearing and Dupont, 2020) or alternative communication technologies like radios to disseminate information and maintain contact during disasters (Nowell, Bodkin and Bayoumi, 2017).

Such examples further demonstrate the need to understand the dynamic relationship between preservation of ecosystems services and the social and economic sustainability of communities, and for responsiveness to a variety of human needs at community, parish, national and regional levels. These examples also illustrate the value of partnerships among government agencies, community-based organisations (CBOs) and NGOs, along with businesses in multiple economic sectors (Osbahr, 2007; Vogel *et al.*, 2007; Biagini and Miller, 2013; Pelizzaro, 2015; Manyise and Dentoni, 2021).

1.4.1. Resilience and sustainable use of ecosystems services

Thus, mainstreaming, resilience and sustainability are functionally related. Sustainability is rooted in intergenerational justice, with interdependent economic, social and environmental dimensions, and can therefore be framed as a distributional issue between current and future resources (Norgaard, 2010). An essential goal of applying an ecosystem services approach to policy making, therefore, will be to ensure that ecosystems continue providing resources to current and future generations (Secretariat of the Convention on Biological Diversity [SCBD], 2005). According to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), as long as usage does not exceed the natural threshold, the ecosystem will retain its structure, function and thus its resilience (IPBES, n.d.). For instance, mangrove wood is often harvested for charcoal production in rural communities in Grenada, which can be sustainable at small scales. If, however, the mangroves are overharvested to the point that the reproductive capacity of the harvested species is compromised, the ecosystem will no longer be resilient to unexpected disturbances like hurricanes and will no longer provide ecosystem services to the communities that depend upon them. Unsustainable use thus impairs both ecological and socioeconomic resilience. Therefore, a resilient ecosystem, while not static, requires an optimal level of biodiversity, and although sustainable use refers to the benefits accruing to people, its requirements reach well beyond measurements of direct economic benefits.

1.4.2. The need for adaptive, forward-looking policies

Achieving sustainability, particularly with regards to ecosystems and natural resource use, is a difficult and continuous endeavour. This is largely due to the changing nature of human behaviours, and ideas (Barr, Shaw and Coles, 2011). As such, national policies need to be defined and structured to account for this. One important consideration for policy makers is that their policies and institutions be adaptable to changes in human and natural patterns. Such flexibility can seem like a weakness in terms of the enforceability of policies, but it is, in fact, a strength, since in both ecosystems and human behaviour change is a constant (Swart, Robinson and Cohen, 2003; Schoon *et al.*, 2015).

That is not to say that policy development and subsequent enforcement should be open-ended or directionless. Flexibility needs to be paired with forward-looking techniques, such as scenario mapping (see Chapter 6 of the Grenada NEA). These techniques—implemented by effective institutions capable of representing a wide range of interests and orientations--allow policy makers, and other stakeholders, to propose possible variations of future scenarios (Aggestam and Wolfslehner, 2018). Future scenarios are then fleshed out, and the most desirable ones used to guide decision makers toward continuously effective adaptations. The strength of combining both flexibility and forward-looking perspectives is that while the future itself is uncertain, and capacity may not always be readily available—in the form of technologies, knowledge or institutions—policies can still guide human development toward greater resilience by adapting to new inputs, including feedback from their own successes or failures.

1.4.3. Resilience, ecosystem services and disaster risk management

There is a complex two-way relationship between resilience and disaster preparedness. First ecological and socioeconomic resilience can facilitate effective disaster responses. Second, a well-designed disaster preparedness strategy makes a country more socioeconomically resilient (Almedom and Tumwine, 2008). Disaster preparedness also benefits from iterative learning and adaptability, where lessons from past disturbances are applied to better prepare for future disturbances, thus making the country more resilient each time. A prime example of this is Grenada's *Build back better campaign* after Hurricane Ivan, where reconstruction efforts prioritised more hurricane-proof methods and practices like using hurricane straps on roofs (National Disaster Management Agency [NaDMA], 2014).

While not all uncertainties can be accounted for, the ability to adapt to change and incorporate new ideas and information can contribute to more sustainable governance and policy making (Djalante, Holley and Thomalla, 2011). This is especially relevant when considering the fact that 'shock events' such as natural disasters are likely to become more frequent and intense in coming years (Allen *et al.*, 2018).

Grenada is vulnerable to several types of natural hazards due to its geographic position. Although located 'below the hurricane belt', Grenada occasionally experiences hurricanes during the Atlantic hurricane season (typically, June-November each year). The last major storms to afflict the country were Hurricanes Ivan and Emily in 2004 and 2005 respectively, causing several hundred million US dollars in damages (NaDMA, 2014). Damage from Ivan alone incapacitated 80% of the nation's power distribution grid, rendered approximately 70% of tourism infrastructure unusable, and caused significant damage to agricultural resources, including long-term damage to the main export crop, nutmeg (ReliefWeb, 2009).

Torrential rain, landslides, rock falls and storm surges are also regular threats (NaDMA, 2014). While just north of mainland Grenada are two underwater volcanoes called Kick-'em-Jenny and Kick-'em-Jack. The former is active and prone to frequent, small eruptions that can pose a hazard to shipping in the immediate vicinity. Although the risk of an eruption that breaches the water's surface is considered low-to-moderate, such an eruption could emit debris with the potential for significant damage to land and a tsunami threat to Grenada, Carriacou, and Petite Martinique, as well as other islands in the eastern Caribbean (Organisation of American States [OAS], 1998; Global Volcanism Program, 2020).

Due to its proximity to the Caribbean-South American plate boundary, Grenada is also vulnerable to earthquakes, with the most recent being a 4.4mb (body wave magnitude) tremor off the coast of Venezuela in late March 2021 (Wang *et al.*, 2019; United States Geological Survey [USGS], 2021). According to the Caribbean Disaster Emergency Management Agency (CDEMA, 2016), Grenada is often subject to tremors from earthquakes near Trinidad or Venezuela. Moreover, in this century alone, over 1,200 events occurred, although their magnitudes rarely have exceeded 6.0mb (USGS, 2021).

In addition to these geological threats, climate change is expected to increase the incidence of major hurricanes, excessive rainfall and/or droughts, heat waves, and more. Carriacou and Petite Martinique are particularly vulnerable to changes in rainfall patterns as neither island has any rivers, and they both rely on rainfall for their water supply throughout the year (NaDMA, 2014).

In the face of these potential disasters, resilience is especially important, both in natural systems and in the socioeconomic framework of the country. Disaster preparedness refers to measures put in place to effectively respond to natural hazards (UNDRR, 2009), such as the designation of shelters to which people can retreat if evacuated from their homes (OAS, 1998). As natural hazards are spontaneous and few can be accurately predicted far in advance, disaster preparedness requires flexibility and some functional redundancy, as described in the above discussion of resilience (Nowell, Bodkin and Bayoumi, 2017; Simpson, Shearing and Dupont, 2020).

Changes from iterative learning can also be institutionalised, such as the restructuring of the national emergency organisation and updating of the *National Disaster Management Plan (2005)* after Ivan (NaDMA, 2014). These post-hurricane changes have improved the overall disaster preparedness of Grenada, and thus make it more resilient to future hurricanes or other hazards.

Furthermore, lessons from the recent past, combined with increasing likelihood and unpredictability of future risks indicate the need for a more holistic and less reactive approach. The UNDRR recommends developing a disaster risk management strategy, which it defines as "the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses" (UNDRR, n.d.).

1.5. Building capacity for mainstreaming and environmental policy integration

Mainstreaming biodiversity conservation requires the collaboration of policy makers at multiple levels and effective and inclusive networks of stakeholders from multiple sectors. Such collaboration can build capacity not only for policy making and implementation, but for effective monitoring and evaluation of policies and programmes already in place. Grenada's Sustainable Development Council (SDC) is an already existing mechanism for such collaboration. This national body has been in existence since 1996 with a mission to focus on fundamental issues of development affecting the island, with emphasis on social issues and environmental sustainability in Grenada.

Grenada already has substantial institutional capacity for the purposes of gathering, interpreting and sharing biodiversity information. These include civil society organisations (CSOs), educational institutions, government ministries, departments and agencies already involved with implementation of conservation-related projects and a broad array of economic and social development initiatives.

Also, there should be consideration for technological capacity to build and maintain tools needed for shared storage and use of biodiversity informatics, which may benefit from regional efforts (for example, through agencies of the OECS and CARICOM) and programmes funded under the auspices of international environmental agreements and with official development assistance from multilateral and bilateral aid agencies.

Capacity in the form of administrative and technical expertise is also crucial for determining the effectiveness of any policy, portfolio, programme, project or system and for recommending improvements. At the portfolio level, monitoring and evaluation (M&E) capacity is needed to evaluate the design of projects and programmes for achieving their objectives. Ideally, regular evaluations, informed by the monitoring of activities and outputs, may be used not only to measure successes and failures, but also to improve the design of a portfolio, programme or project over time.

A principal aim of such efforts should be to build awareness of the value of biodiversity to Grenada, and the capacity of Grenadians in all walks of life to contribute to effective policy making (Gaymer *et al.*, 2014; Semeraro *et al.*, 2020). This local capacity should build on a foundation of collaboration among the scientific community and local experts whose direct observations and experiences will be essential to information gathering for policy formulation and implementation, and the assessment of policy impacts (Albagli and Iwama, 2022).

1.6. Emphasis on adaptation and mitigation

The holistic approach recommended in the Grenada NEA recognises that no action in isolation can be effective, and the GoG has pledged commitment on both the adaptation and mitigation platforms; goals that often cannot be practically separated. It is also paramount that policy makers keep in mind—when making and implementing national responses—that a reinforcing feedback loop exists between global and biodiversity loss. For example, climate change-related harms make coastal ecosystems more difficult to restore and the ecosystem services they provide more expensive to replace.

Grenada's active membership in several MEAs (see Table 1.1 on page 51) effectively recognises the importance of making policy that considers the importance of those feedback loops for biodiversity conservation. For example, to establish its commitments under the *United Nations Framework Convention on Climate Change* (UNFCCC), Grenada submitted its Intended Nationally Determined Contribution (INDC) in September 2015. The INDC served as an outline of the climate action plan focused on mitigation and adaptation and complemented Grenada's updated *National Climate Change Policy for Grenada, Carriacou and Petite Martinique (2017-2021)* and the *National Climate Change Adaptation Plan (NAP) for Grenada, Carriacou and Petite Martinique (2017-2021)*. Grenada committed to mitigation and adaptation, with the goal of reducing greenhouse gas (GHG) emissions by 30% of 2010 levels by 2025, with an indicative reduction of 40% of 2010 levels by 2030 within the energy (electricity), transport, waste and forestry sectors (UNFCCC, n.d.).

On the adaptation side, there is the *NAP for Grenada, Carriacou and Petite Martinique (2017-2021)* and on the mitigation side, there is the *Nationally Determined Contribution (NDC) Partnership Plan (2019)*. Addressing both mitigation and adaptation, the Government has prepared an enhanced NDC, entitled the *Second Nationally Determined Contribution, November 30, 2020* (Northrup *et al.*, 2020). The GoG is also preparing the second NAP to ensure more robust adaptation to climatic risks and has prepared a progress report on the implementation of the first NAP. These documents outline the commitments for Grenada at the policy level. The NAP outlines the twelve-part Programme of Actions (PoA), and the 2017 status and priority actions. Amongst the PoAs, ecosystem resilience is the fifth goal discussed in the NAP. The primary goal of that PoA is to improve the management and conservation of protected areas and other key ecosystems areas (GoG, 2017a).

The NAP and NDC initiatives outline Grenada's climate priorities and align implementing partners around common objectives, in a simple matrix framework. The framework highlights: output statements, baselines, key performance indicators (KPIs), activities, targets, sector gaps, budget and timelines, lead government institutions and other stakeholders, and the partners supporting implementation. The policies can serve as useful tools to identify opportunities for enhancement of Grenada's climate change initiatives for submission to the UNFCCC. In those regards, they could be considered models of the goals and functions of policies to be informed by the Grenada NEA as each one mainstreams sustainability and has implications, direct or indirect, for biodiversity.

1.7. Biodiversity, development and Grenada's economy

When considering the relationship between diverse economic interests and the ecosystem services derived from biodiversity, we need to consider the interactions among all three dimensions of sustainable development, recognising that development of social, economic and environmental systems is a continuous process which requires a transdisciplinary approach for "improving their resilience and adaptive capacity" (Munasinghe, 2016; see Figure 1.2 on page 30).

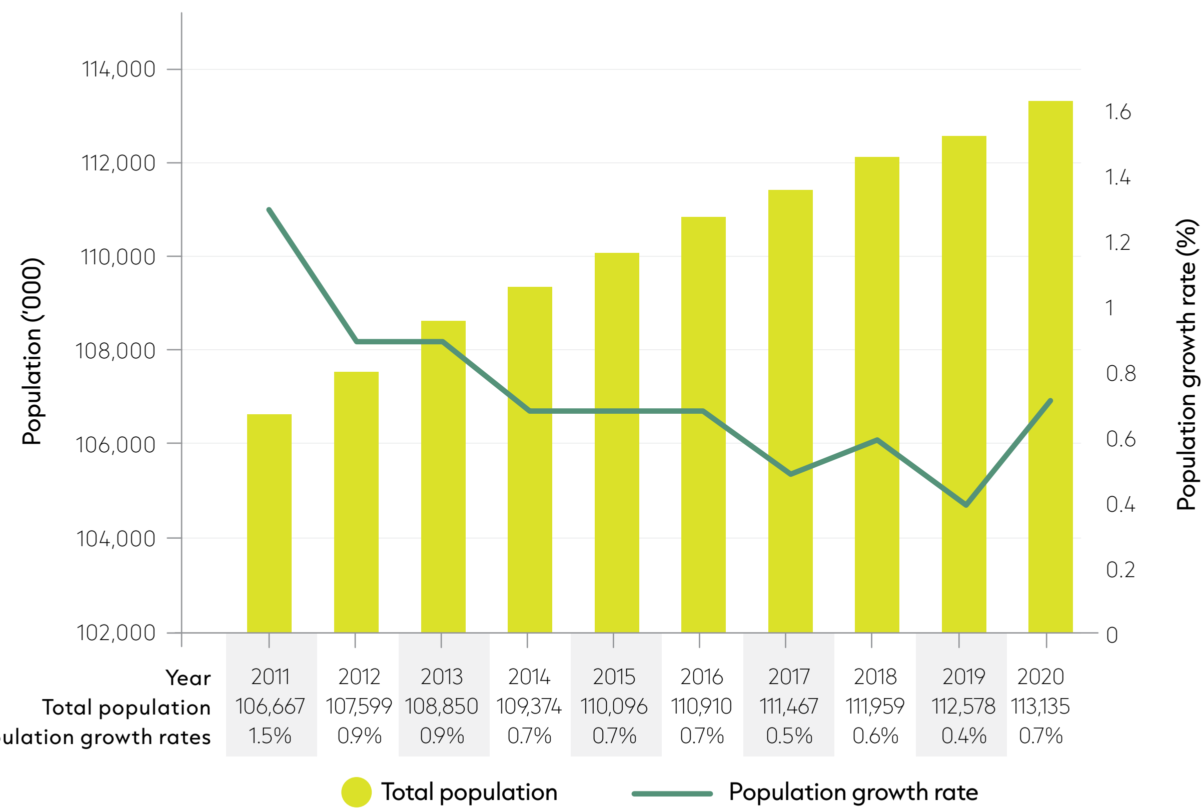
Biodiversity and ecosystem services are critical to the Grenadian economy–securing livelihoods whilst creating new business and employment opportunities–and fostering human well-being in ways that are not as easily quantified. While the value of these services may not be fully appreciated or are marked with uncertainty, they provide indispensable services which extend to "human health, food and water security, climate change mitigation and adaptation, and disaster risk reduction" (Organisation for Economic Co-operation and Development [OECD],2019).

1.7.1. Biodiversity and economic development- benefits, threats and challenges

Available scientific data on global and regional biodiversity loss and the impacts of climate change on biodiversity make it clear that action by governing authorities in SIDS to mitigate and adapt to threats and change should be undertaken with a sense of great urgency. In addition, democratic SIDS like Grenada face several challenges which slow their economic development process and hinder efforts to build resilience. These challenges arise for a number of reasons, including the difference between relatively short electoral cycles which may motivate elected officials to deliver measurable economic achievements (including rapid increases in tourism earnings, foreign investment and job creation) compared to the much longer time it takes to build resilience and realise the benefits of policies that enhance ecosystem services (DeSombre, 2020). Furthermore, different economic sectors will be affected differently by biodiversity loss, will experience its negative impacts across different timeframes, and will incur different costs and benefits from transitioning away from 'business as usual'.

With tourism being a main driver of Grenada's economy, biodiversity provides a source of wealth and income through conservation of the natural environment, cultural assets and traditions which have spillover effects on job creation, while reducing poverty and inequality (see Figure 1.3 on page 32). A study by the Wildlife Society shows that "more biodiversity means more ecotourism...with each 1 percent increase in biodiversity in protected areas, nature-based tourism rose by 0.87 percent" (Kobilinsky, 2018). Ecotourism is not currently the major source of economic growth in the tourism sector, and the potential economic gains from biodiversity conservation that would increase its share of the tourism sector are imperilled by predictable changes to the global climate and less predictable events, such as disasters.

Tourism is not the only economic sector affecting and affected by challenges to Grenada's biodiversity. Generally, activities associated with the production of goods and services can generate pollution and other threats to biodiversity. Similarly, changes in consumption–consumer spending and consumption patterns alongside growing populations–affect biodiversity in complex ways. This can be reflected by dietary changes (more meat and processed foods versus traditional, natural and plant-based sources of nutrition), expanding household numbers, more dependence on imported products, and faster replacement of consumer products (higher turnover rates in consumption). For example, according to Liu (2022), a more meat-based diet "requires more resources, affecting more habitat area and emitting more carbon dioxide (CO_2)". Similarly, greater household numbers increase household resource consumption and more household wastes. Essentially, direct and spillover effects of environmental degradation undermine the resilience of economic and social systems, particularly of developing



Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total population	106,667	107,599	108,850	109,374	110,096	110,910	111,467	111,959	112,578	113,135
Population growth rates	1.5%	0.9%	0.9%	0.7%	0.7%	0.7%	0.5%	0.6%	0.4%	0.7%

Figure 1.5. Population ('000) and population growth rates (%) in Grenada (2011-2020) (ECCB, 2021)

countries which are often most vulnerable to climate and non-climate-related shocks.

Therefore, the interests that industries and communities bring to the politics of environmental policies can be highly competitive; even conflictual. Grenada's parliamentary system, vibrant civil society and membership in a dense web of regional and international organisations can be seen as both assets and complicating factors in the rapid and effective pursuit of biodiversity conservation. Economic sectors—and different types of activities within sectors—bring different policy orientations to the table. In addition, CSOs (discussed further below) struggle to bring the interests, orientations and knowledge of often under-represented communities to the table as well (DeSombre, 2020).

Providing healthy ecosystems remains one of the key sustainability challenges to Grenada's economy, including the often difficult prospect of balancing economic development needs with the social and environmental impacts of growth (see Figure 1.2 on page 30). Ecosystems are negatively affected by climate change, industrialisation and the various impacts of globalisation. Global increases in mean temperatures (climate extremes and changing conditions), have been major threats to biodiversity with "losses of species, increased disease, extinction, loss of habitat and declines in ecosystem services" (Kapnick, 2022).

While the economic effects of globalisation can be positive, effects on the environment can be catastrophic, including pollution from industrial activity and increased stress on the very assets that provide both direct and indirect ecosystem services. Indirect consequences can include loss of cultural identity and behavioural changes which are intimately linked to current and projected degradation of natural resources. Therefore, economic growth and engagement with the global economy may, at the same time, help SIDS achieve economic development goals in the short to medium term while negatively impacting the full array of ecosystem services associated with biodiversity, now and in the future. These would include declining environmental health, increased poverty, food insecurity, declining human health, increasing conflict and competition for resources, and poor governance.

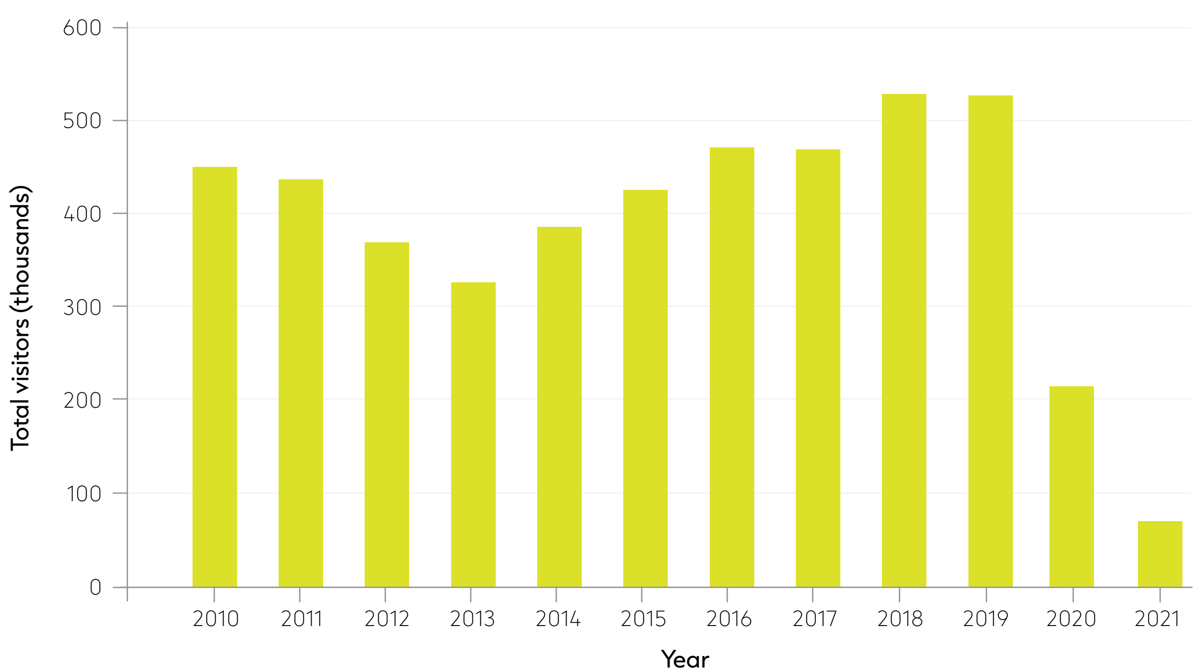


Figure 1.6. Total visitors to Grenada ('000) (2010-2021) (ECCB, 2021)

1.7.2. Biodiversity and demographic change

In the assessment of ecosystems, population growth is of concern since this can be linked to habitat loss, unsustainable consumption patterns and overexploitation of natural resources. As of 2020, the population of Grenada was 113,135 with an annual population growth rate of less than 1% between 2012 and 2020 (see Figure 1.5 on page 42). Over the period 2011-2019, the overall trend in the growth rate of the population shows a decline which was followed by a 0.3% rise from 2019 (Eastern Caribbean Central Bank [ECCB], 2021). Even when ignoring the impact of other factors such as climate change, sustained population growth is expected to result in biodiversity loss (Mogelgaard, 2013). While for Grenada, the data shows slow growth, even with slight increases in the population, the need for food, space and raw materials can lead to accelerated environmental degradation. This reality makes the challenges of biodiversity more daunting, particularly for small open economies such as Grenada. In most cases, the rural poor remain most affected by issues of environmental degradation since their livelihoods and daily subsistence depend on natural resources.

1.7.3. Biodiversity and tourism

Above and beyond the effects of a growing resident population, visitors to the islands represent a significant, additional source of human impact on ecosystems. Biodiversity provides essential and economic benefits to many countries such as Grenada, where the economy is largely dependent on ecosystem services delivered through the tourism sector. Over the period 2010 to 2020, there have been fluctuations in the total visitors to the islands. The 2010 to 2013 period saw decreases in tourist arrivals. However, from 2014 to 2019, there was a general-increasing trend followed by a sharp decline between 2019 and 2020 which can be attributed to the onset of the COVID-19 pandemic (see Figure 1.6).

In 2020, cruise ship passengers accounted for approximately 75% of total visitors whereas stay-over visitors accounted for 20% (ECCB, 2021). For the period 2010-2020, these two categories of visitors

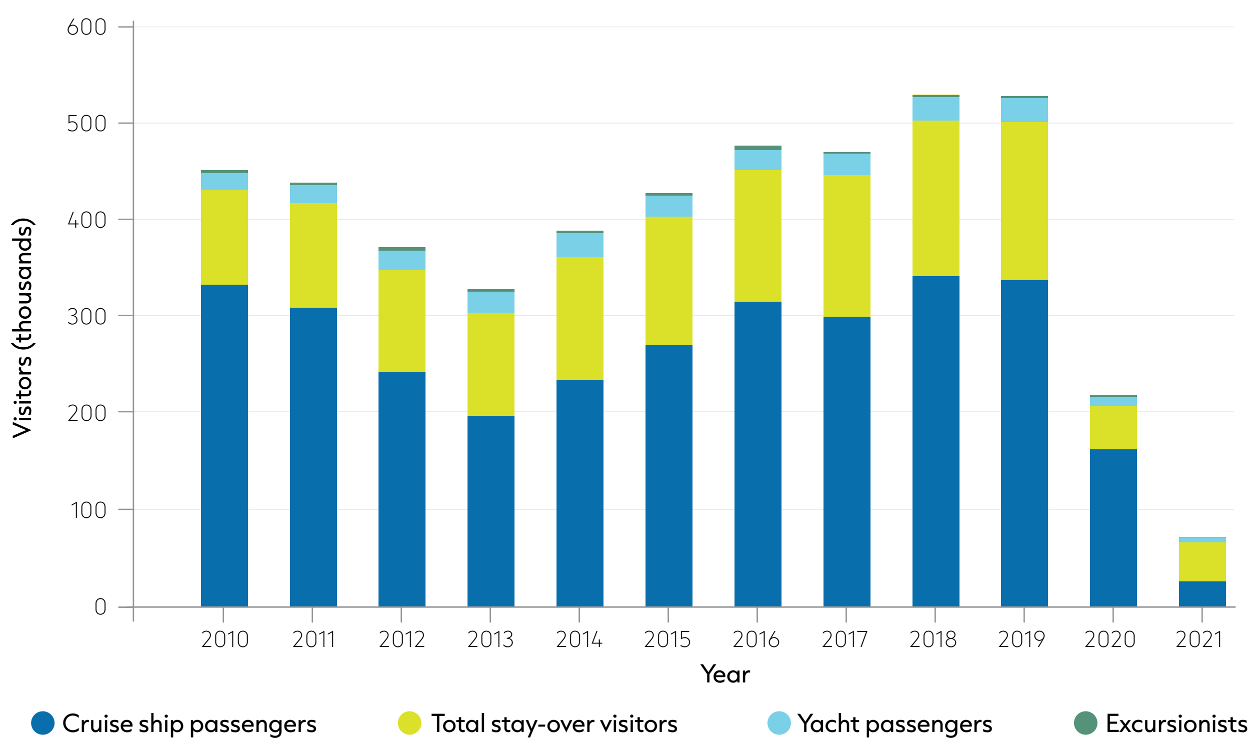


Figure 1.7. Total visitors to Grenada by type ('000) (2010-2020) (ECCB, 2021)

have accounted for the most visitors to the island of Grenada (see Figure 1.7). While the portion of tourism expenditure accounted for by cruise tourism may be relatively small, the impact on the environment can be substantial and even greater than stay-over visitors.

Environmentally, externalities associated with cruise ships include pollution and emission of GHGs that contribute to climate change, and, in turn, reduce the resilience of marine ecosystems and damage marine and coastal environments. Total cruise ship wastewater production is estimated to exceed average residential wastewater production (MacDonald, 2019). Furthermore, the designation of the WCR as a Special Area under the International Convention for the Prevention of Pollution from Ships (MARPOL) requires that ships hold their solid wastes for disposal on land, thus increasing pressure on the islands' limited solid waste management capacity (International Maritime Organisation [IMO], n.d.).

Notably, ship-generated solid wastes received at Grenada's main landfills rise substantially during prime tourism season, running from November through March. In addition, the Grenada Solid Waste Management Authority (GSWMA) projected an increase in solid waste collection of approximately 20% (by weight) from 2018 to 2028 with a projected population increase of only 2% over the same period (GSWMA, 2021). Therefore, being able to track, monetise and develop best practices for these negative effects is of critical importance in the move towards sustainable tourism.

Given the competition amongst Caribbean destinations for tourism, diversification of the tourism product to include initiatives linked to ecotourism, geo-tourism, geo-development and community tourism can provide a distinct competitive advantage by leveraging Grenada's unique ecosystems, landscapes and species. In the language of ecosystem services, these 'alternative' types of tourism make intact and vibrant ecosystems direct sources of measurable economic benefits to a wider array of Grenadian stakeholders. They also open the door to expanding sources of revenues devoted to the conservation of biodiversity, including: environmental levies, users' and entry fees for parks and protected

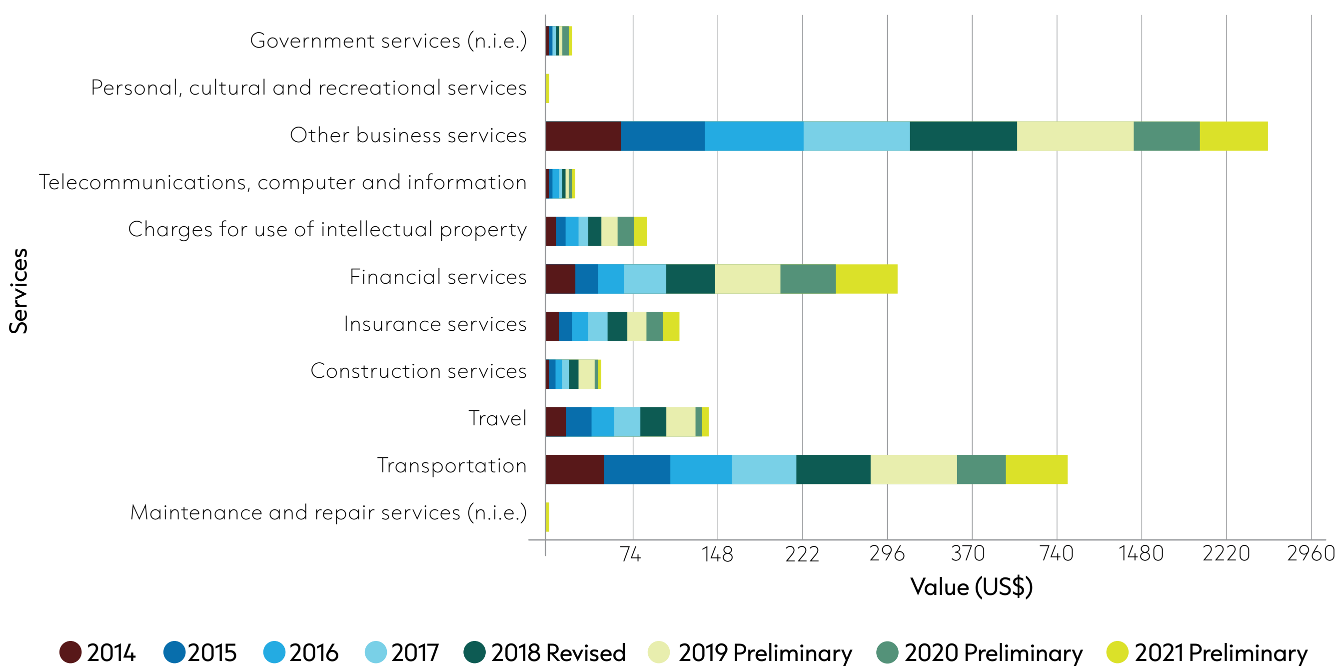


Figure 1.8. Trades in services (import) for the period 2014-2021 (ECCB, 2021)

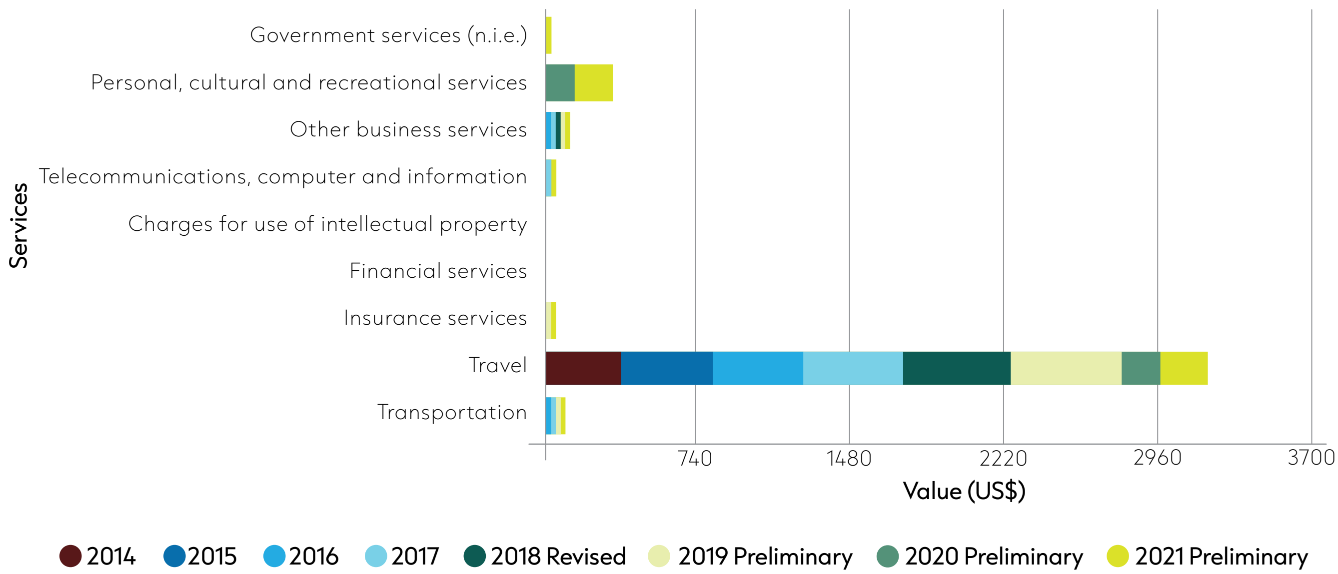


Figure 1.9. Trades in services (export) for the period 2014-2021 (ECCB, 2021)

areas, international aid (from several governmental and non-governmental sources) and new sources of taxable business profits and incomes.

Additionally, the importance of tourism to the Grenadian economy is highlighted in recent data showing that while tourism-related imports accounted for approximately 10% of total trade in services, tourism-related exports accounted for approximately 90% of total trade in services, for the period 2014-2019. Imports of trade in services are mainly accounted for by business services, transportation and financial services (see Figure 1.8 and Figure 1.9 on page 46). Even during the 2019-2020 period when tourism declined steeply due to the onset of the COVID-19 pandemic, these figures were still 3% (imports) and 51% (exports) respectively. This highlights the importance/value of trade in travel as an export commodity of Grenada (ECCB, 2021).

To optimise ecosystem services derived from biodiversity, policies must manage a bi-causal relationship; one in which tourism can adversely affect biodiversity and/or be a beneficiary of biodiversity.

While the revenues from tourism can be used to protect biodiversity, it is recognised that tourism puts tremendous pressure on the ecosystems and, as such, ensuring sustainable tourism practices is critical. In countries such as Grenada, it is important to protect ecosystem services and biodiversity which are vital for tourism with spillover effects to other sectors.

Through international and national governmental and non-governmental support for financing and in-kind services, Caribbean countries have access to a flow of resources aimed at the conservation, maintenance and protection of biodiversity (Constantine, 2017). For example, the Caribbean Biodiversity Fund (CBF) has been a source of funding for conservation of biodiversity and natural ecosystems of the coastal and marine environments in Grenada. In 2017, Grenada added Grand Anse to its list of Marine Protected Areas (MPAs) which highlights the country's commitment to conservation (Constantine, 2017).

Grenada has prior experience with leveraging biodiversity conservation as a source of revenue via projects and programmes that largely aim to support ecosystem services related to ecotourism. For example, the *Environmental Levy Act 1997* authorised the Ministry of Finance to collect fees, to be transferred to the GSWMA, for the environmentally-responsible collection and disposal of various categories of household wastes. Additionally, in support of the Grenada component of the OECS *Solid Waste Management Project (2003)*, beginning 2001, an environmental levy on visitor arrivals applied at both the seaport and the airport averaging US$1.50 per visitor was implemented (World Bank, 2003).

The *Final Draft National Waste Management Strategy* for Grenada lists "support of tourism and foreign direct investment" as a desired economic impact (GoG, 2003).

Grenada has some recent positive experiences, policies and programmes on which to build a more extensive ecotourism sector. Given the need to recover from the decline in visitations resulting from the COVID-19 pandemic, and the highly competitive Caribbean-wide tourism market, it may be hard for Government and businesses to forgo more investment in the country's capacity to accommodate cruise ships and other forms of conventional tourism. Thus, we see in the tourism industry, a clear and important example of the need for mainstreaming biodiversity conservation, and the political and economic challenges entailed in doing so.

In Grenada, the other sectors contributing substantially to gross domestic product (GDP) include education, real estate and business activities, transport, storage and communication (Figure 1.10 on page 47). Most of these economic sectors are also linked with biodiversity and ecosystem services as GDP builds on multiple forms of capital, including natural capital. Where the relationship between these

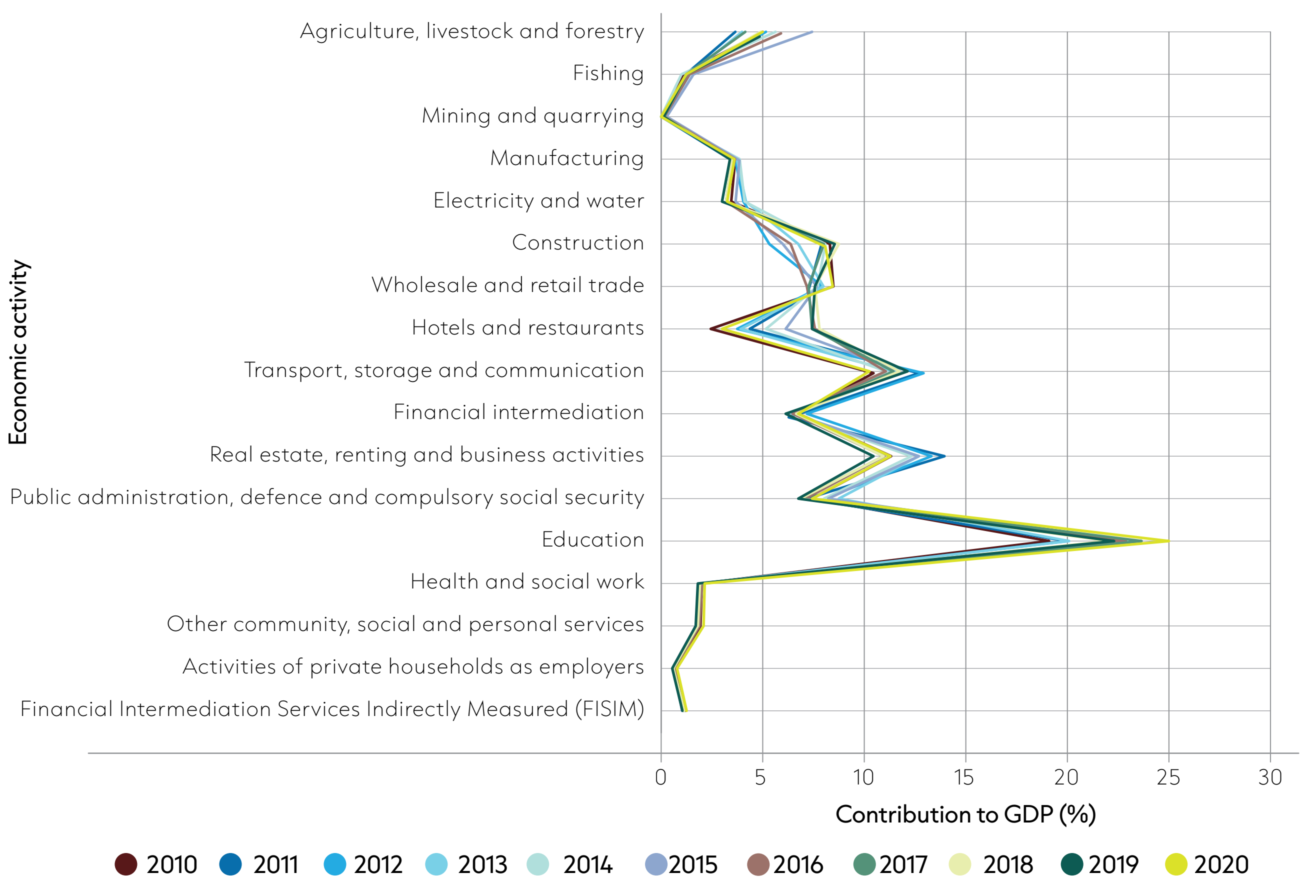


Figure 1.10. Contribution of GDP by economic activity in current prices (%) (ECCB, 2021)

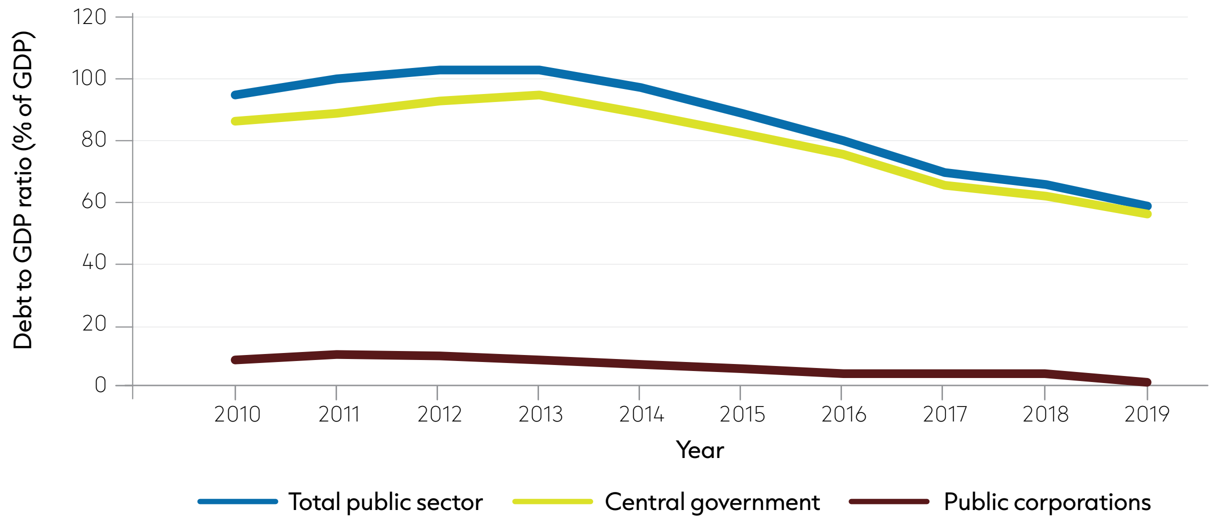


Figure 1.11. Debt to GDP ratios (% GDP) from 2010-2019 (ECCB, 2021)

sectors, ecosystems and biodiversity is indirect, its importance may be under-estimated, under-stated or overlooked due to a lack of understanding of the linkages between ecosystems and those sources of economic value. Furthermore, these linkages underpin and connect sustainable livelihoods and human development affecting the entire population and, as such, no one discipline can adequately address the scope and complexity of biodiversity and ecosystems.

1.7.4. Biodiversity considerations for macroeconomic and fiscal policy

As noted above, economic exigencies, the need for rapid recovery from disasters and prioritisation by policy makers of their constituents' most immediate needs, continue to be powerful motivations for making economic policies that do not fully consider the impacts on social and environmental systems (DeSombre, 2020; Rosenberg, 2020). Therefore, in order to integrate the value of biodiversity and ecosystems into fiscal and macroeconomic policy, there is the need to understand what is being lost and express this in monetary terms (Sukhdev *et al.*, 2010). For example, to mainstream a long-term and holistic perspective on the economic potential of coral reefs would require knowing not only their value to the tourism industry, as it is currently constituted, but the long(er)-term economic risks attached to the degradation or loss of those vulnerable ecosystems under multiple scenarios. Globally, while initiatives such as the United Nations Sustainable Development Goals (SDGs) may advocate a paradigm shift in economic development thinking, with an increased focus on social and environmental concerns, there still exists a lag in implementation, including shortfalls in the support needed by SIDS to achieve the SDGs while still achieving their near-term economic development goals (United Nations Development Programme [UNDP], 2022a).

Nevertheless, in an economy such as Grenada's, characterised by limited fiscal space, avoiding unnecessary costs because of damages to ecosystems is a pertinent objective to maintaining fiscal discipline and efficient administration. As highlighted by the International Monetary Fund (IMF) in its fiscal policy objectives for Grenada, "efficient and prudent use of the fiscal space would be crucial to maximising the economy's productive potential and resilience to shocks" (IMF, 2022). The last decade has seen improvements in Grenada's fiscal capacity, with debt-to-GDP ratios declining from 95.41% in 2010 to 58.92% in 2019 (Figure 1.11). Still, unforeseen occurrences may erode this progress, making continued attention to efficiency in spending critical.

Efficiency in spending and using Grenada's limited resources requires a concerted effort. One of the key challenges in valuing Grenada's natural assets is being able to monetise and measure their value in ways that allow them to be included in decision making. Suffice to say, there can be biases of exclusion that can lead to misguided policies. Therefore, the value of these assets should not be ignored simply because there are difficulties in monetising them. Rather it should be recognised, in making fiscal and macroeconomic policy, that their inclusion is essential for their sustainability, in light of their contributions to human well-being and the full array of more direct and easily-quantifiable ecosystem services. The key challenge is to apply an ecosystem services framework to broaden and lengthen the time and policy horizons used to determine what is "efficient and prudent". Successfully integrating ecosystem and biodiversity values into policy making, implementation and assessment requires a strong information base from which to calculate the value of and threats to biodiversity and the ecosystem services it provides. That, in turn, requires that tools to measure and provide information are made available to decision makers.

1.8. Grenada and environmental governance—complexity, coordination and sharing capacity.

The challenges that Grenada faces to preserve its biodiversity are also challenges to effective environmental governance that will test the efficacy of policies and institutions over extended periods of time. One of the most prominent challenges involves achieving consistent environmental governance. As with SIDS more generally, some of Grenada's environmental governance gaps and inconsistencies can be attributed to top-down governance approaches with lack of a participatory process (Fraser *et al.*, 2006). As discussed above, the capacity of national governments may be limited. So, CBOs, local level governing bodies, parish level and national institutions and processes, and an array of regional and international organisations can and must all contribute. Sustainable environmental outcomes must become common; integrated goals of policies affecting multiple areas of the economy and society, and approaches to governing are needed to mainstream ongoing efforts, fulfil existing and future domestic and international commitments, and build administrative and technical capacity at multiple levels.

In the following sections, we look at some of the resources related to environmental governance and optimising ecosystem services available to Grenada; noting that some have had significant impacts, some are available but under-utilised and others remain potential contributors. Such memberships, institutions and organisations can provide venues for: advocating biodiversity conservation; building institutional capacity and human capital; producing and disseminating information; making and implementing policy; effectively representing stakeholders; and making alliances and relationships that can provide aid and assistance as needed (Mitchell, 2003).

1.8.1. Multilateral environmental agreements and ecosystem protection in Grenada

Over the last few decades, ecosystem protection has become a priority at both national and international levels. At the international level, Grenada has joined a range of MEAs that entail Grenada's commitment to their obligations but also provide opportunities for Grenada to get financial and technical assistance from international sources to support national efforts aimed at ecosystem protection. This section provides a brief overview of Grenada's current obligations and opportunities under several selected MEAs and points to several other MEAs that Grenada has not joined but that could provide additional support for future efforts in ecosystem protection.

Efforts through UNEP, the 2030 Agenda for Sustainable Development and its Sustainable Development Goals (SDGs) and the United Nations Convention on Biological Diversity (CBD), as well as other regional and issue-specific efforts, are helping mainstream biodiversity conservation by providing goals, targets, support and venues for shared information and cooperation as well as helping align national policies with regional and international strategies and goals. The SDGs, in particular, provide a central reference point to a mainstreamed approach to environmental sustainability in development policy by emphasising global principles, implemented through regional, national and local action (UNDP, 2022a). As an active member in a wide range of international efforts relevant to biodiversity conservation, Grenada can leverage its unique position as the first SIDS and first Caribbean country to complete a NEA. Table 1.1[1] documents characteristics of 21 MEAs that address issues related to ecosystem protection. The global agreements listed address: biodiversity, plant and animal species, fisheries, climate and ozone, habitat and world heritage, and ocean pollution. The regional agreements also cover the marine environment, fisheries, climate change, sustainable tourism and environmental health.

These MEAs take three forms: some regulate, some create institutions and some promote enforcement of regulatory MEAs. Few of them directly address ecosystem protection *per se*, but all of them have objectives to protect some part of one or more natural ecosystems by addressing habitats, the plants or animals that live in them, or the human activities that harm them. Grenada has already developed and begun implementing a comprehensive sustainable development plan that seeks to promote the goals of SDG-15 to protect terrestrial ecosystems and forests and reduce biodiversity loss (National Plan Secretariat [NPS], 2019). Additionally, there are specific programmes already underway engaged in promoting coastal zone protection and management as well as developing and enhancing MPAs. This notably includes a cabinet-approved protected area system plan, the *Grenada Protected Area System Plan Part 1 - Identification and Designation of Protected Areas (2009)*, that identifies existing and proposed marine and terrestrial sites for ecosystem protection (Turner, 2009).

Because MEAs have the status of international law, it is tempting to see them as delineating legal obligations with which states must comply; membership in MEAs does create the obligation that national-level legislation and regulations will be made and that sufficient resources are committed to build the national capacity for implementing them.

Table 1.2 on page 53 lists MEAs that Grenada has not joined but that could provide Grenada with additional support in its efforts to address specific aspects of ecosystem protection. The potential benefits of membership in these MEAs are worthy of consideration after examining the findings of the Grenada NEA. For each, the table identifies whether the MEA's text contains provisions related to financial assistance, technological transfer and regular meetings of the Parties. Keeping in mind that Grenada, like most other SIDS, has limited human resources for active participation in the full array of MEAs, a review of the potential benefits of membership through an ecosystem services lens would help determine whether membership would be beneficial.

[1] Table 1.1 provides a summary of 21 MEA that are relevant to this assessment. Only original agreements are described, not the associated protocols.

Table 1.1. Selected MEAs addressing ecosystem protection which Grenada has joined (University of Oregon, 2021)

Topic	Selected MEAs relevant to ecosystem protection	Grenada's membership	Objectives	Type of MEA	Finance	Technology transfer	Meetings
Biodiversity, species, and fisheries	Convention on Biological Diversity (1992)	09/11/1994	To conserve biological diversity	Regulatory	yes	yes	yes
	Convention on International Trade in Endangered Species of Wild Fauna and Flora (1973)	28/11/1999	To protect wild fauna and flora from over-exploitation through trade	Regulatory	no	no	yes
	International Plant Protection Convention (1979 Revised Text) (1979)	04/04/1991	To prevent introduction of plant pests	Regulatory	no	no	no
	International Convention for the Conservation of Atlantic Tunas (1966)	05/10/2017	To maintain tuna stocks at maximum sustainable catch levels	Institutional	no	no	yes
	Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated (IUU) Fishing (2009)	16/08/2016	To promote enforcement to prevent IUU fishing	Enforcement	yes	yes	no
Caribbean	Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region (1983)	16/09/1987	To protect marine environment	Regulatory	no	no	yes
	Agreement Establishing the Caribbean Community Climate Change Centre (2002)	27/01/2006	To protect the climate system	Institutional	yes	yes	yes
	Agreement Establishing the Caribbean Environmental Health Institute (1980)	31/08/1988	To promote environmental management and health	Institutional	no	no	yes
Caribbean	Agreement Establishing Common Fisheries Surveillance Zones of Participating Member States of the Organisation of Eastern Caribbean States (1991)	01/03/1991	To conduct surveillance and ensure enforcement of fisheries laws	Enforcement	no	no	no
	Convention Establishing the Sustainable Tourism Zone of the Caribbean (2001)	06/11/2013	To develop tourism in a sustainable manner	Regulatory	no	no	no
	Agreement Establishing the Caribbean Regional Fisheries Mechanism (2002)	04/02/2002	To promote sustainable use of living marine resources	Institutional	yes	yes	yes

Topic	Selected MEAs relevant to ecosystem protection	Grenada's membership	Objectives	Type of MEA	Finance	Technology transfer	Meetings
Climate and ozone protection	United Nations Framework Convention on Climate Change (1992)	09/11/1994	To protect the climate system	Regulatory	yes	yes	yes
	Statute of the International Renewable Energy Agency (2009)	15/07/2011	To promote adoption and use of renewable energy	Institutional	yes	yes	yes
	Paris Agreement under the United Nations Framework Convention on Climate Change (2015)	04/11/2016	To strengthen response to threat of climate change	Regulatory	yes	yes	yes
	Convention for the Protection of the Ozone Layer (1985)	29/06/1993	To protect human health and environment against effects of modification of ozone layer	Regulatory	no	yes	yes
Habitat and world heritage	United Nations Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification, particularly in Africa (1994)	26/08/1997	To combat desertification	Regulatory	yes	yes	yes
	Convention on Wetlands of International Importance Especially as Waterfowl Habitat (1971)	22/09/2012	To address stem loss of wetlands	Regulatory	no	no	yes
	Convention for the Protection of the World Cultural and Natural Heritage (1972)	13/11/1998	To protect cultural and natural heritage	Regulatory	yes	no	yes
Oceans	International Convention on Civil Liability for Bunker Oil Pollution Damage (2001)	26/10/2018	To establish liability for oil pollution	Enforcement	yes	no	no
	International Convention on the Control of Harmful Anti-Fouling Systems on Ships (2001)	26/10/2018	To reduce effects on marine environment of anti-fouling systems	Regulatory	no	no	yes
	International Convention for the Control and Management of Ships' Ballast Water and Sediments (2004)	26/10/2018	To prevent risks of aquatic organisms and pathogens transferred through ships' ballast	Regulatory	no	yes	yes

*Table 1.2. Selected MEAs which Grenada has not yet joined** (MEA Signature date) (University of Oregon, 2021)

Topic	MEAs Grenada might consider joining	Date of MEA Signature	Objectives	Type of MEA	Finance	Technology transfer	Meetings
Climate change	Framework Agreement on the establishment of the International Solar Alliance	15/11/2016	Address key common challenges to the scaling up of solar energy	Institutional	yes	yes	yes
Fisheries	Convention on Fishing and Conservation of the Living Resources of the High Seas	29/04/1958	To determine measures rendering possible the optimum sustainable yield from those resources so as to secure a maximum supply of food and other marine products	Regulatory	no	no	no
	Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas	24/11/1993	To adopt "measures for their respective nationals as may be necessary for the conservation of the living resources of the high seas"	Enforcement	no	no	no
	Agreement for the Implementation of the Provisions of the United Nations Convention on the Law of the Sea of 10 December 1982 relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (UN Fish Stocks Agreement)	04/08/1995	To ensure the long-term conservation and sustainable use of straddling fish stocks and highly migratory fish stocks	Institutional	yes	yes	no
General	Convention on Access to Information, Public Participation in Decision Making and Access to Justice in Environmental Matters	25/06/1998	To guarantee the rights of access to information, public participation in decision making, and access to justice in environmental matters	Regulatory	no	no	yes
	Agreement on the establishment of the Global Green Growth Institute	20/06/2012	To promote sustainable development of developing and emerging countries, including the least developed countries	Institutional	yes	no	yes
Habitat	Agreement for the Establishment on a Permanent Basis of a Latin-American Forest Research and Training Institute	18/11/1959	To create institute to conduct research, especially applied research, which may effectively contribute to proper conservation utilisation and development of the forest resources of Latin America	Institutional	no	no	yes

Topic	MEAs Grenada might consider joining	Date of MEA Signature	Objectives	Type of MEA	Finance	Technology transfer	Meetings
Oceans	Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter	29/12/1972	To prevent the pollution of the sea by the dumping of waste and other matter that is liable to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other legitimate uses of the sea	Regulatory	no	no	yes
	International Convention for the Prevention of Pollution from Ships	02/11/1973	To prevent the pollution of the marine environment by the discharge of harmful substances or effluents containing such substances	Regulatory	no	yes	yes
	International Convention on Oil Pollution Preparedness, Response and Cooperation	30/11/1990	To promote international cooperation and to enhance existing national, regional and global capabilities concerning oil pollution preparedness and response	Regulatory	yes	yes	no
	International Convention on Liability and Compensation for Damage in Connection with the Carriage of Hazardous and Noxious Substances by Sea	03/05/1996	To ensure that adequate, prompt and effective compensation is available to persons who suffer damage caused by incidents in connection with the carriage by sea of such substances	Institutional	yes	no	yes
Oceans	International Convention on the Removal of Wrecks	18/05/2007	To adopt uniform international rules and procedures to ensure the prompt and effective removal of wrecks and payment of compensation for the costs therein involved	Institutional	yes	no	no
	International Convention for the Safe and Environmentally Sound Recycling of Ships	15/05/2009	To prevent, reduce, minimise and, to the extent practicable, eliminate accidents, injuries and other adverse effects on human health and the environment caused by ship recycling, and enhance ship safety, protection of human health and the environment	Regulatory	no	yes	no

Topic	MEAs Grenada might consider joining	Date of MEA Signature	Objectives	Type of MEA	Finance	Technology transfer	Meetings
Pollution	Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade	10/09/1998	To promote shared responsibility and cooperative efforts among Parties in the international trade of certain hazardous chemicals in order to protect human health and the environment from potential harm and to contribute to their environmentally sound use	Institutional	no	yes	yes
	Convention on Persistent Organic Pollutants	22/05/2001	To protect human health and the environment from persistent organic pollutants	Regulatory	yes	yes	yes
Pollution	Minamata Convention on Mercury	10/10/2013	To protect the human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds	Regulatory	yes	yes	yes
Species	International Convention for the Protection of Birds	18/10/1950	To protect birds in the wild state	Regulatory	no	no	no
	Convention on the Conservation of Migratory Species of Wild Animals	23/06/1979	To provide protection for endangered migratory species and sign agreements to conserve and manage threatened migratory species	Regulatory	no	no	yes
Species	Inter-American Convention for the Protection and Conservation of Sea Turtles	01/12/1996	To promote the protection, conservation and recovery of sea turtle populations and of the habitats on which they depend	Regulatory	yes	yes	yes
	International Treaty on Plant Genetic Resources for Food and Agriculture	03/11/2001	To conserve and sustainably use plant genetic resources for food and agriculture and the fair and equitable sharing of the benefits arising out of their use	Regulatory	yes	yes	yes
	Agreement for the Establishment of the Global Crop Diversity Trust	01/04/2004	To provide a permanent source of funds to support the long-term conservation of the *ex situ* germplasm	Institutional	no	no	yes

1.8.2. Regional inter-governmental agencies: CARICOM and the OECS

Taking an ecosystemic approach means that multilateral governance will be increasingly important to national biodiversity conservation. For SIDS, multilateral organisations can provide enhanced administrative and scientific capacity, economies of scale for projects and programmes, and coordinated representation at the international level. As such, Grenada benefits from its membership in organisations at various levels, including the OECS, CARICOM, and the Alliance of Small Island States (AOSIS—a global alliance of SIDS) (Corbett, Yi-Chong and Weller, 2018; Sforna, 2019; Rosenberg, 2020).

Both CARICOM and the OECS provide resources—actual and potential—for integrating biodiversity conservation and promoting and preserving valuable ecosystem services for the benefit of individual Member States (MS) and the WCR. These include widely-ranging mandates related to economic growth, social development and environmental sustainability that add layers of complexity to the governance of the Caribbean ecosystems. Therefore, the ability of Member States to access these resources and utilise the integrative functions of regional and sub-regional IOs to mainstream biodiversity conservation still remains a significant challenge. Organisations face seemingly chronic limitations on staffing relative to the breadth and intensity of their responsibilities and tend to prioritise more immediate economic needs over long(er)-term interests in environmental sustainability. Given that emphasis is placed on economic growth and development through regional integration, the environment can be an afterthought in setting policy and staffing priorities.

The *OECS Development Strategy* (ODS-*e*), has a biodiversity and ecosystems management programme as one of its six thematic areas. The OECS *Biodiversity and Ecosystems Management Framework 2020-2035* (OECS-BEF) supports national level biodiversity and ecosystem priorities by applying a regional approach in areas where regional level interventions are found to be more effective. The overarching goal of the OECS-BEF is to provide a framework for a strategic, coordinated and transformational approach to the management of biodiversity and ecosystems in the OECS, in order to achieve healthy and resilient ecosystems that provide goods and services to support socioeconomic development and livelihoods for the people in the OECS, while conserving the rich natural heritage of the region (OECS, 2020b). The OECS-BEF builds on the Caribbean Biodiversity Strategy coordinated by the CARICOM Secretariat and speaks to five priority themes including:

Theme 1: Protecting, maintaining and restoring ecosystems:

Objective: secure ecosystem goods and services through protection, maintenance and restoration efforts for key ecosystems both within national territories and spanning transboundary areas.

Targets include: the protection of terrestrial and marine ecosystems of importance while emphasising pollution abatement measures.

Theme 2: Invasive species management, biosecurity and biosafety:

Objective: protect the OECS region against invasive alien species (IAS), biosafety and biosecurity threats.

Targets include: implementation of a focused regional IAS action plan and strengthening national level legislation and regulations associated with the Cartagena Convention Protocol on Biosafety.

Theme 3: Climate and disaster resilience:

Objective: build the resilience of the region's biodiversity to climate change and natural hazards.

Targets include: advancing research, information sharing and data analysis on climate change impacts on the OECS region and use of protected area networks as a tool to enhance climate resilience.

Theme 4: Fair and equitable access to and sharing of benefits from biodiversity resources:

Objective: equip OECS stakeholders with the capacity, entry points and mechanisms for participatory management of biodiversity and ecosystems while protecting their rights and benefits.

Targets include: advancing the ratification of the Nagoya Protocol amongst OECS MS and developing a regional Access and Benefit-Sharing (ABS) model policy and guidelines to assist MS in developing their national systems as well as ensuring more harmonised systems within the region.

Theme 5: Assessing and integrating biodiversity and ecosystems into national development processes:

Objective: assess and integrate biodiversity and ecosystems information into national development processes.

Targets include: the integration of ecosystem valuation and national ecosystems assessments into decision making and testing and promoting alternative economic development options that protect biodiversity and ecosystems.

Strategic Action Plans (SAPs) were developed for three of these themes (1, 3 and 5), which included short, medium and long-term interventions. One of the long-term targets under the OECS-BEF SAP "Assessing and integrating biodiversity and ecosystems into national development processes" is the conducting of national economic assessments in all of the MS. Anguilla and Grenada, currently, are the only two Member States that have sought to conduct NEAs within the OECS region.

1.8.3. National political and governing structures

After its independence in 1974, Grenada joined the British Commonwealth of Nations and was admitted to membership in the United Nations (UN). It is a unitary state governed by a parliamentary constitutional monarchy nominally headed by King Charles III who is represented by the Governor-General. Executive power is vested in the Prime Minister, the majority party leader of the lower house of the bicameral legislature, through public servants organised into ministries and departments (see Table 1.3). This legislature consists of an upper house–a 13-member appointed Senate–and a lower house–a 15-member House of Representatives elected by popular vote. These represent the country's 15 constituencies. The judicial branch of Grenada is rooted in British common law and administered regionally by the Eastern Caribbean Supreme Court. The Court includes a High Court of Justice with 16 judges, two of whom permanently reside in the country, and the three-judge Court of Appeal which sits three times a year in Grenada (GoG, 2022a).

Table 1.3. Overview of the government ministries in Grenada (GoG, 2022b)

Ministry	Mission or responsibility
Office of the Prime Minister	"To facilitate the Cabinet of Government Ministers in the execution of its responsibilities as stated in the Constitution and to ensure that the public service performs optimally and with due ethics"
Ministry of Finance	"Efficient and effective delivery of finance and economic services to the national, regional and international communities"
Ministry of National Security, Home Affairs, Public Administration, Information and Disaster Management	"This Ministry provides administrative leadership, coordination and support for the implementation of policies and programmes to enable execution of The Prime Minister's portfolio"
Ministry of Foreign Affairs, Trade and Export Development	"The Ministry is the entity responsible for the formulation and execution of the foreign policy of the State of Grenada as it involves the bilateral or multilateral relations with other states and with regional and international organisations"
Ministry of Economic Development, Planning, Tourism, ICT, Creative Economy, Agriculture and Lands, Fisheries and Cooperatives	"Driving the process of transforming the economic well-being and quality of life of the nation in accordance with targeted goals and objectives"

Ministry of Infrastructure and Physical Development, Public Utilities, Civil Aviation and Transportation	"The Ministry protects and enhances the nation's investment in infrastructure and provides regulatory oversight for Public Utilities"
Ministry of Carriacou and Petite Martinique Affairs and Local Government	"Enhancing and improving the way of life and well-being of the people of Carriacou and Petite Martinique"
Ministry of Social and Community Development, Housing and Gender Affairs	"Improving the quality of life for Grenadians"
Ministry of Mobilisation, Implementation and Transformation	"Monitoring, reporting and driving the implementation of the Government's Transformation"
Ministry of Climate Resilience, the Environment and Renewable Energy	"Enhancing Grenada's ability to anticipate, prepare for and respond to hazardous events, trends or disturbances related to climate"
Ministry of Education, Youth, Sports and Culture	"A resilient education system developing well rounded, global citizens committed to lifelong learning"
Ministry of Health, Wellness and Religious Affairs	"The Ministry engages with the Grenadian community at home and abroad"
Ministry of Legal Affairs, Labour and Consumer Affairs	"To ensure that all actions taken by the Government and its various Ministries and Departments are within the laws of the land and in conformity with our international obligations"

This governance structure presents a variety of challenges and opportunities for an integrated approach to biodiversity conservation. Notably, the Ministry of Economic Development, Planning, Tourism, ICT, Creative Economy, Agriculture and Lands, Fisheries and Cooperatives, previously, the Ministry of Agriculture and Lands, has historically served as a focal point for biodiversity conservation initiatives. However, ministerial re-organisation saw the shift of its environmentally-related portfolio to the Ministry of Climate Resilience, the Environment and Renewable Energy. In addition to overseeing projects aimed at ensuring healthy, productive and sustainable terrestrial and marine environments, this Ministry houses a unit for the Management of Forest Reserve and Protected Areas, including sub-units for Forest Conservation, Tree Establishment and Management, Wildlife Conservation, Environmental Education, Up-land Watershed Management, Mangrove Conservation, and Forest Recreation. The Ministry of Economic Development, Planning, Tourism, ICT, Creative Economy, Agriculture and Lands, Fisheries and Cooperatives retains environmentally-focused units such as the Land Use Division and the Pest Management Unit. The Ministry of Health, currently combined with Social Security and International Business, manages the Environmental Health Division and provides oversight of the statutory body, the National Water and Sewerage Authority (NAWASA), through a Sanitary Authority (Mitchell, Forde and Neptune, 2019).

Thus, responsibilities for particular aspects of a given economic sector may be spread out across multiple ministries. This, along with frequent changes in the areas of responsibility, both within ministerial portfolios and in the movement of departments among different ministries,results in reduced efficacy in promoting biodiversity conservation. Historically, such changes have affected the ways that environmental concerns are prioritised in matters of economic and social development (Rosenberg, 2006). Whether these patterns represent a strong potential for mainstreaming or for fragmentation, going forward, is a matter for serious consideration in how the findings of the Grenada NEA are applied.

Table 1.4 lists national policies–some enacted and some still in draft form–made by Government over the past two decades. Some take an ecosystem approach to policy making while others focus on the technical and administrative needs for building capacity in specific issue-areas affected by environmental threats and stressors. Systematic review of these policies may contribute to an evaluation of Grenada's ecosystem services and institutional capacity, as well as accomplishments to date in the implementation of national, regional and international policies and programmes. They may also indicate issue-areas that would benefit from a more mainstreamed approach to ecosystem and biodiversity conservation for achieving their specific goals.

Table 1.4. Existing national policies in Grenada

Policy	Status: Final	Status: Draft
Resources and Ecosystems		
Grenada National Water Policy (2020)	Y	
Revised Forest Policy for Grenada, Carriacou and Petite Martinique (2018)	Y	
Integrated Coastal Zone Management Policy for Grenada, Carriacou and Petite Martinique (2015)	Y	
National Energy Policy of Grenada (2011)	Y	
Grenada National Land Policy (2019)		Y
Grenada Food and Nutrition Security Policy (2013)	Y	
Threats (Natural and Anthropogenic)		
National Biosafety Policy (2014)	Y	
National Climate Change Policy for Grenada Carriacou and Petite Martinique (2017-2021)	Y	
Grenada National Hazard Mitigation Policy (2003)	Y	
Gender Equality Policy and Action Plan (2014-2024)	Y	
Gender Equality Policy and Action Plan (2014-2024)	Y	

Recent developments at the national and regional levels (noted above) would seem to address the challenges to mainstreaming but also raise unresolved questions about national level governance. Measuring their impacts will require further examination, using the kinds of inclusive processes and M&E discussed above. For example, in the last five years (since about 2016), Grenada has embarked on a public sector reform and adopted a whole-of-government approach. The government has since launched the *National Sustainable Development Plan 2020-2035*, and it has ambitious timelines to accelerate shared prosperity at the national level, while simultaneously addressing climate change challenges. The synergistic effect is, however, not yet felt among and within ministries; and only a holistic approach can improve the proposed actions.

1.8.4. Civil society

In any integrated approach to biodiversity conservation, CSOs, educational institutions and informal networks of citizens will be essential partners. Grenada has a variety of such organisations, several of which are dedicated to environmental issues and others which integrate all aspects of sustainable development. At times they have partnered with, and/or advocated to government agencies and regional organisations on issues regarding the tensions between economic development and environmental sustainability.

Through Grenada's educational system, there is a strong potential for a synergistic relationship between the goal of mainstreaming ecological and biodiversity conservation in policy with educational programmes that build ecologically-informed and motivated citizens from 'the ground up'. Educational institutions are essential for building institutional capacity, developing human capital and mainstreaming the importance of biodiversity. Local and regional institutions can and should play a particularly important role in combining scientific knowledge with local knowledge and scaling ecological perspective on sustainable development in primary and secondary schools.

The structure of Grenada's current curriculum at primary and secondary levels provides several opportunities for the integration of environmental science and biodiversity conservation. Whether it is integrated as a compulsory subject or injected into science curricula or other relevant curricula, there is a clear need for it. Grenada can learn from the example of other countries of the WCR that are now adapting their curricula to reflect the environmental changes that are challenging the region today. Case in point is the Caribbean Community Climate Change Centre (CCCCC) in Belize which has had some success with a primary school programme on climate change, called the *1.5˚ to Stay Alive* education initiative, that includes curricula and teaching materials with strong biodiversity content and an ecosystemic orientation (Rosenberg, 2020).

At post-secondary levels, within the last couple of decades, the T.A. Marryshow Community College has introduced its Environmental Science programme, and St. George's University (SGU) has implemented its Marine, Wildlife and Conservation programme. According to the GoG (2017b), science subjects at the secondary and tertiary level, including Environmental Sciences at the tertiary level, can deliver the foundational knowledge and understanding of the functions of nature and ecosystems. With a curriculum focused on developing a sense of values, behaviours and skills necessary for the preservation of the environment, the education sector can be an invaluable stakeholder in driving initiatives for ecosystem conservation (GoG, 2017b).

Institutions of post-secondary education, in particular, can contribute to a sustainable supply of ecosystem services by helping to fill knowledge and governance gaps and building human capital. Programmes at the undergraduate and graduate levels can integrate environmental considerations into all scientific, social scientific, humanistic and technical curricula and normalise the full inclusion of traditional and local knowledge through research and pedagogy that engages local stakeholders. In addition, schools and universities can model sustainable practices in the built environment with their own management practices and community outreach activities (Anderson, 2012; Dick-Forde, 2013; van Kerkhoff and Lebel, 2015; Berkes, 2017). Additionally, educational institutions at all levels, through programmes that include experiential learning and community engagement, can help build social capital in the form of connections to communities of resource users (e.g. fishers and farmers), and CBOs involved in economic and social development.

Making the connections that build the kind of social capital discussed above are greatly facilitated by CSOs, including, but not limited to, environmental NGOs and CBOs. Research shows an expanding and increasingly-influential role for environmental NGOs at all levels of environmental governance; that includes networking and cooperative activities among local and international organisations, and support by NGOs for more effective participation by SIDS in international environmental organisations, treaties and conventions

(Nasiritousi, 2019). Work done in Grenada by large international NGOs to design and implement programmes and projects are referenced above. Table 1.5 provides a partial list of Grenadian NGOs and CBOs that have been and/or could be enlisted for researching policy needs using bottom-up methods of stakeholder participation and achieving buy-in that would facilitate the implementation of such policies at the national and local levels. Grenadian CSOs were the first stakeholder group consulted for the Grenada NEA, including representatives from the Agency for Rural Transformation, Friends of the Earth and the Caribbean Youth Environment Network (see Figure 1.12 on page 62).

Table 1.5. ***Grenadian NGOs and CBOs: a partial list*** *(Barbados & Grenada None in Three, n.d.; Peters and McDonald, 2010; Grenada Fund for Conservation Inc. [GFC], 2019; NGO Explorer, 2022; UNDP, 2022b)*

Grenadian	• Agency for Rural Transformation • Friends of the Earth, Grenada • Grenada Citizen Advice and Small Business Agency (GRENCASE) • Grenada Community Development Organisation (GRENCODA) • Grenada Council of Churches plus several religious, ecumenical and denominational church institutions and organisations • Grenada Education and Development Programme (GRENED) • Grenada Fund for Conservation Inc. • Grenada National Organisation of Women (GNOW) • Grenada National Development Foundation • Grenada National Trust • Grenada Society for Prevention of Cruelty to Animals (GSPCA) • Inter-Agency Group of Development Organisations (IADGO)—an umbrella organisation of several Grenadian community-based, not-for-profit organisations • People in Action • Producers' organisations (trade associations)—for most sectors affecting and affected by ecological resilience; organised at the Parish and/or national level, including: ◦ St. Andrews Progressive Farmer Association; ◦ Grenada Rural Women Producers; ◦ St. Patricks Environmental Community Tourism Organisation; ◦ Grenada Co-Operative Nutmeg Association; and ◦ Southern Fishermen Association, Inc.
Regional and international	• Caribbean Natural Resources Institute (CANARI) • Grenada Microfin Ltd. (microfinance bank) • National offices and/or representatives of numerous international environmental, development, educational, disaster relief and public health-oriented NGOs including (but not limited to): ◦ The Grenada Red Cross Society; ◦ Grenada Planned Parenthood Association (GPPA); ◦ Caribbean Youth Environment Network and ◦ The Nature Conservancy (TNC)

1.8.5. Sustainable Development Council

Agenda 21, one of the seminal documents produced by the United National Conference on Environment and Development (commonly called the Rio Earth Summit of 1992) called for the creation of national Sustainable Development Councils in developing countries. The Grenada Sustainable Development Council (SDC) is one of the few still in existence that was patterned on the Agenda 21 recommended

Figure 1.12. Civil society consultation held in June 2019 to design the Grenada NEA (Photo credit: CANARI)

model. The Grenada SDC has met, more or less consistently, since 1996. Its tripartite membership—including representatives of government and state agencies, businesses and CSOs—provides a venue for networking, information sharing and partnerships that can help mainstream biodiversity conservation across several economic sectors (Global Network of National Councils for Sustainable Development and Similar Bodies [GNNCSDS], n.d.).

The SDC has been an important institutional contributor and a model for institutionalising a mainstreamed approach to environmental sustainability. Indeed, SDC meetings have

Figure 1.13. Launch of the Grenada NEA at the June 2019 Sustainable Development Council Meeting (Photo credit: CANARI)

discussed biodiversity issues and have opened lines of communication with national and regional authorities (including the OECS). Its direct influence on government policy making has, however, been limited, and its membership has not always represented grassroots stakeholders in proportion to their importance for making and implementing biodiversity conservation strategies (Rosenberg and Thomas, 2005). Nevertheless, its longevity indicates the existence and persistence of cooperative efforts that could make positive impacts on biodiversity conservation integration into a variety of policy areas and private sector activities.

The SDC has been designated the National Biodiversity Platform for the Grenada NEA (see Figure 1.13 on page 62)

Conclusions: moving forward

Biodiversity impacts virtually all sectors of the Grenadian economy, and the general well-being of the Grenadian people. NEAs like this one, modelled on the Millennium Ecosystem Assessment (2003), can be valuable toolkits for accurately assessing current conditions, anticipating future needs, and maintaining a resilient balance among the three pillars of sustainable development—economic, social and environmental—as Grenada faces inevitable change.

Clearly, like all SIDS, Grenada is experiencing pressing challenges to its biodiversity, emanating both from its own practices and policies and global forces over which Grenada has very little direct control. The overview presented in this chapter, however, indicates a strong potential for Grenada to take immediate and effective action to conserve its biodiversity.

With its dense web of international memberships, networks and alliances, and an existing foundation of policies, governing institutions and CSOs concerned with sustainable development, there is much to build upon. Additionally, Grenada's relatively small size can facilitate more inclusive policy making processes that make fuller use of the traditional and local knowledge that will be so vital to effective policy making, implementation, and monitoring and evaluation.

The Grenada NEA proceeds with more detailed analyses of Grenada's ecosystems, at present and in possible future scenarios. Each chapter contributes to a detailed and comprehensive picture of the services Grenada's ecosystems provide; threats to the resilience of those ecosystems; and ways that the Government and people can mainstream biodiversity conservation to conserve, utilise and enhance a robust and resilient set of ecosystem services, for the general and long-term benefit of the Grenadian people.

Chapters 2-7: brief previews of each chapter

Based on the priorities identified through the initial scoping process, the five following report chapters will aid in assessing the status and trends of Grenada's ecosystems and identifying the drivers and responses to these trends.

Chapter 2 provides an overview of the status, trends and threats to Grenada's forest, coastal, marine, freshwater and agricultural ecosystems. The chapter first discusses the geological background of Grenada as well as the impact of Amerindians and Europeans on the environment. Secondly, the chapter examines the status of agriculture and agrosystems, coastal ecosystems, the deep ocean, forests, freshwater, offshore and uninhabited islands as well as the threats to ecosystems, both anthropogenic and natural. The chapter then ends with a discussion on the various information gaps for the ecosystems, discussed previously, in the chapter. Although challenged by the issues of weak enforcement and threats to the development of natural resources as outlined in Chapter 2, ecosystems in Grenada contribute to economic and national well-being.

Chapter 3 describes the contribution of Grenada's ecosystems to climate resilience (food and water security, disaster resilience, climate change adaptation/mitigation) and first outlines the broad concepts of climate adaptation, climate mitigation and climate resilience. The chapter then considers the impact of climate change on the physical ecosystems, human populations and well-being of small islands. It looks at the importance of ecosystems to climate resilience in Grenada with special focus on the adaptive capacity of ecosystems, households and businesses, and gender relations. The chapter also discusses the factors that impede Grenada's climate resilient potential such as mangrove removal and sand mining as well as the drivers, pressures, state, impact and responses with respect to a wide variety of ecosystems (terrestrial, freshwater, agriculture, coastal and marine).

Chapter 4 provides an overview of the economic value and contribution to human well-being of Grenada's ecosystem services, focusing on forest ecosystems, coastal and marine ecosystems, and agricultural ecosystems. It also provides a conservation overview of the value of Grenada's biodiversity, with a special focus on those flora and fauna of agricultural interest. It provides the justification, at the molecular level, for the value of Grenada's living diversity and is the link between all other chapters of Grenada's NEA and the opportunities and challenges for the conservation, sustainable use and benefit sharing of genetic resources. It examines global trends in the evaluation of genetic resources, then moves to an examination of marine and freshwater resources (including bioactive compounds), terrestrial resources, medicinal resources (with relevant case studies on mangroves), agricultural ecosystems, and key emerging issues and recommendations.

Chapter 5 examines the opportunities which exist to support, enhance, and amplify the delivery of ecosystem services for the economic and social well-being of Grenadians. The chapter first discusses the various legislative and policy tools used in Grenada. The chapter then looks at the ways that certain bodies of knowledge, tools and cultural context may contribute to a decline of ecosystem services and the options for encouraging development of cross-sectoral policy, legislation and economic responses to improve ecosystem services. The chapter then provides an analysis of national policy with respect to terrestrial ecosystems and the prospect of innovating and adapting these tools. The chapter also provides an overview of agroecosystems, ecosystem services and disservices in relation to sustainability. Thereafter, the chapter describes the enabling environment (formal institutions, policies, governance arrangements) for agroecosystems and discusses the mechanisms in place for protecting agroecosystems and their services. The chapter ends with a gap analysis of policy instruments and national financial mechanisms.

Finally, Chapter 6 provides an overview of the usefulness to policy makers of scenarios as well as the need for Grenadian national scenarios. The chapter then provides an analysis of the relationship to the previous chapters. The chapter outlines the process and coverage used in developing the scenarios presented in the chapter and then provides the background narratives that describe each of the scenarios developed. In addition, the particular implications of each scenario for Grenada's supporting ecosystems and concomitant policy implications are discussed, followed by an assessment of the policy options available and their projected outcomes along with suggestions for possible ways forward. These assessment report chapters will contribute to the mainstreaming of biodiversity and ecosystem services into Grenadian policy making.

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Elkhorn Coral (*Acropra palmata*), Grenada
Photo credit: Jerry Mitchell

2. Status, trends, and threats to Grenada's coastal, deep ocean, forest, freshwater, offshore and agricultural ecosystems

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Summary

Since Grenada's formation over 50 million years ago, ecosystems have undergone numerous changes due to natural processes and anthropogenic stressors, which are detailed in this chapter. After providing a brief overview of Grenada's past environment (up until 1970s) the chapter covers the status and trends of the island's agricultural, coastal, deep ocean, forest, freshwater and offshore island ecosystems. Threats to these ecosystems are then discussed and then broad knowledge gaps are highlighted.

The main ecosystem types discussed in this chapter are as follows:

- Agriculture and Agrosystems: though Agriculture and Agrosystems may not be considered 'natural' as they are modified landscapes for human food production, they provide habitat for native and domesticated fauna.
- Coastal Ecosystems: beaches, mangroves, seagrass beds and coral reefs account for Grenada's coastal ecosystems- they are part of a complex, supporting various life stages of marine fauna.
- Deep Ocean Ecosystems: although Grenada's open ocean and deep ocean occupy a large proportion of its exclusive economic zone (EEZ) and are home to many species, including commercially important and highly valuable species, they remain largely understudied.
- Freshwater Ecosystems: Grenada is divided into 71 watersheds. There are no permanent streams on Carriacou, Petite Martinique or any of the offshore islands.
- Forest Ecosystems: Grenada's forest vegetation, not inclusive of Carriacou and Petite Martinique or other offshore islands, covers approximately 58% of its surface, belonging to three broad classes- Dry Scrub Woodland, Rainforest and Montane Thicket- and supports diverse animal communities.
- Offshore Island Ecosystems: Proportionally, island ecosystems support more biodiversity than their respective mainland areas; as such, they are the focus for global biodiversity preservation. Grenada has approximately 60 uninhabited islands, islets, cays and rocks.

The main threats to these ecosystems discussed in this chapter are as follows:

- Diseases: numerous epizootic events and disease outbreaks have been reported in coral reefs and among sea turtles within the Caribbean Region. Rabies, Leptospirosis, infectious brochantite and blood parasites have also been reported among mammals and birds in Grenada.
- Habitat loss and degradation: the loss and degradation of habitat can be largely attributed to deforestation, development, and pollution, but there are consistent threats due to sand mining, storms and hurricanes, rainfall events, resource extraction, maritime vessels, and recreational activities.
- Invasive species: Sargassum and lionfish have had notable impacts on coastal ecosystems while mongoose is a major threat to birds in forests, and livestock are a primary driver of degraded habitat on offshore islands.
- Pollution: regardless of the source of pollution - agriculture, domestic, sewage, industrial waste and anthropogenic litter- both marine and terrestrial ecosystems are often impacted.

There are gaps in species and ecosystem data availability, in particular, due to an absence of continual monitoring of biotas in the ecosystems in Grenada. However, based on spatial data from 1982 to 2014, changes in land cover class areas have been noted. In some cases, there were consistent declines in wetlands/mangroves and pastures/cultivated lands but increases in forest cover and nutmeg/wooded agriculture.

2.1. Introduction

Situated 12 degrees north and 61.5 degrees west, Grenada is the southernmost island in the Antillean archipelago and the Windward Island group of the Lesser Antilles (see Figure 1.4 on page 34). The country comprises the main island, Grenada, and many smaller islands and islets, of which Carriacou and Petite Martinique are the largest. Grenada is a mountainous, volcanic island roughly 133km^2 with a population of about 110,000 inhabitants (Central Intelligence Agency [CIA], 2022). Carriacou has a lower, volcanic-sedimentary relief, at 34km^2 and ~5,000 inhabitants, while Petite Martinique surrounds one large volcanic peak, 2.3km^2 with ~1,000 inhabitants (Caribbean Conservation Association, 1991). Most of the other islands in Grenadines are uninhabited, although a small population (<50 people) live on Isle de Ronde, between Grenada and Carriacou (Martin, 2022). Carriacou is the largest island in the Grenadines, the island chain between Grenada and St. Vincent, of which all were once (until 1784) part of colonial Grenada under the French and British (Martin, 2020).

Grenada may have had several names in pre-Columbian times, but at contact, it was called 'Camáhogne' (now anglicised as Camerhogne) (Breton, 1999)[1]. The name 'Grenada' was originally 'La Granada' to the Spanish in the early 16th century, in reference to Granada, Spain (and thus, the Grenadines were 'los Granadillos'). Under the French, the first Europeans with a permanent settlement, it was changed to 'La Grenade', which was later anglicised by the British to simply 'Grenada'. Carriacou's name is derived from its indigenous name at the time of European contact.

2.2. Past environments

2.2.1. Paleogeography and geologic background

To understand the processes that led to Grenada's modern biota, the past must be reconstructed. The Caribbean tectonic plate formed about 200 million years ago (mya) during the late Jurassic Period. As the plate moved eastward, the Greater Antilles and the Aves Ridge were formed around 110 mya, followed by the Lesser Antilles 60 mya (Bouysse and Westercamp, 1990; Macdonald *et al.*, 2000). Some of Grenada's basal sedimentary deposits may date from the proto-Maracaibo River around this time (Rojas-Agramonte *et al.*, 2017).

It is actually Carriacou where one can find Grenada's earliest exposed geology. Foraminifera (shelled, single-cell organisms) detected within the majority of sedimentary layers date as early as the middle Eocene, 40-50 mya (Speed *et al.*, 1993). However, most of the exposed volcanics on Carriacou (e.g. around High North) date to the mid-Pleistocene Epoch (<1 mya) (Speed *et al.*, 1993).

The earliest detectable geologic layer on mainland Grenada itself is the volcanic-sedimentary Tufton Hall formation, which contains foraminifera dating to the late Eocene/early Oligocene (23-56 mya) (Arculus, 1973; White *et al.*, 2017). The subsequent volcanic events that formed Grenada's modern topography occurred in successive clusters (Figure 2.1 on page 78). The earliest volcanics may come from the Mt. Craven/Northern Domes in St. Patrick, dated to the early Miocene, 20-23 mya (Brinden *et al.*, 1979), but this date was contested in a later study (Speed *et al.*, 1993). The earliest, demonstratable volcanics from the Lesser Antillean arc all date slightly later (~14 mya), when oblique convergence of the

[1] There are other recorded variations of this word from mainland South America (Whitehead, 1995, pp.94–95)

Figure 2.1. Geological map of Grenada showing geological features and associated time period (see Appendix 1 for references and data sources)

Caribbean and South American plates induced its uplift (Rojas-Agramonte *et al.*, 2017).[2]

Nonetheless, it is agreed that the vast majority of Grenada's surface geology dates after the Miocene (<5 mya) (White *et al.*, 2017). Indeed, the next earliest date comes at the end of the Miocene, when the Levera Piton last exploded, 5-8 mya (Robertson, 2005). The next detectible volcanics come from Grand Anse and Point Salines during the early Pliocene, 3-5 mya (Brinden *et al.*, 1979; Rojas-Agramonte *et al.*, 2017; White *et al.*, 2017), with mudstone from subsequent lahar events dating to 2-4 mya (MacPhee *et al.*, 2000). Several other late Pliocene dates appear anomalous amidst nearby samples (from the Pleistocene) and require further corroboration, including Fedon's Camp at 3-4 mya (Brinden *et al.*, 1979), Mt. Ellington at 2-3 mya (Brinden *et al.*, 1979), Grand Mal at ~2 mya (White *et al.*, 2017), and Diego Piece at ~2 mya (Brinden *et al.*, 1979).

Perhaps the most studied geological feature in Grenada is Lake Antoine, a maar whose long succession of explosions began as early as ~5 mya and ran through 0.30 mya (300,000 years or 300 thousand years ago [kya]) with samples from throughout that timeframe across the northeast coastline (from Bedford Point to High Cliff Point) (Robertson, 2005; White *et al.*, 2017). That said, several soil cores have suggested that the lake began infilling just 9-12 kya, with the last volcanic event around 16 kya (McAndrews and Ramcharan, 2003; Fritz *et al.*, 2011; Siegel *et al.*, 2015). Similarly, soil cores from Grand Etang Lake have indicated infilling began shortly after its last eruption between ~20 kya (Fritz *et al.*, 2011) and ~25 kya (McAndrews, 1996).

As with these crater lakes, the vast majority of surface volcanics on Grenada date to the Pleistocene epoch < 1.9 mya. These later eruptions also represent the largest massifs (the aforementioned chronometric discrepancy with Fedon's Camp notwithstanding). The five tallest mountains today are Mt. St. Catherine (840 m, 200-300 kya), Fedon's Camp (765m, date unknown), Mt. Qua Qua (735m, date unknown), Mts. Sinai/Lebanon/SE Mountains (715m, 0.6-1 mya), and Mt. Granby (683 m, 500-800 kya) (Beard, 1949; Grenada Government, 1985; Rojas-Agramonte *et al.*, 2017; White *et al.*, 2017). Other recent explosion craters include the Punchbowl (in Mt. Rich), Green Island, Isle de Caille, and the calderas at St. George's Town and Queen's Park. Centered around some of these (particularly Mt. St. Catherine) are active thermal features, such as the hot springs at River Sallee, Chambord, Belair, Peggy's Whim, Mt. Hope, Clabony, Plaisance, and Adelphi-St. Cyr (Benavente *et al.*, 2015).

Mt. St. Catherine and Isle de Caille (the youngest of the Grenadines) are still considered live and capable of future explosions, although the most likely events are steam venting and phreatomagmatic ash, respectively (Robertson, 2005). However, just 8km to the west of Grenada's northern coast lies Kick-'em-Jenny, the most active underwater volcano in the Caribbean, which has erupted over a dozen times since its discovery in 1939 (Lindsay and Shepherd, 2005). Jenny likely formed over 43 kya but moved slightly, leaving a debris field and the extinct Kick-'em-Jack crater behind (Camejo-Harry *et al.*, 2019).

These past volcanic events are significant, not just for the land mass they created but because ancient flora and fauna were present during these tumultuous times. However, whereas volcanic events helped create the land mass, sea level was a main determinant in the shape and size of dry land.

2.2.2. Past changes in sea level

Throughout the formation of early Grenada, sea level fluctuated irregularly. For the past 1 mya, however, it has mostly been lower than today, with notable exceptions. The highest ('high stand') level occurred 400 kya, during the mid-Pleistocene 2 when sea levels reached 20m above the present (Hearty *et al.*, 1999). Several times since then, however, water levels have plunged 60+m lower than present, with the lowest (at 120m below present level) during the Last Glacial Maximum (LGM), 21-26 kya (Peltier and Fairbanks, 2006). This LGM 'low stand' occurred just prior to the deglaciation of the Laurentide and Antarctic Ice

[2] This is also when the Piton of Petite Martinique formed (Rojas-Agramonte et al., 2017).

Sheets that caused sea levels to rise rapidly after 16 kya (Peltier and Fairbanks, 2006; Deschamps *et al.*, 2012).

At the time of the LGM, the entire Grenada Bank was dry land, from ~35km southwest of Point Salines to the Bequia Channel (between Bequia and St. Vincent). The aforesaid rapid sea level rise after ~16 kya generally levelled out by 7 kya, with an estimated rise of just 1.2 (±2.6)m/kya since then (i.e. about one meter every thousand years) (Khan *et al.*, 2017). However, while this general (eustatic) rise does pertain to the immediate region, it does not account for highly local conditions, including short-term climate effects, terrestrial/isostatic changes, and storm/astronomical surges.

2.2.3. Pleistocene fauna arrivals and extinctions

Periods of lower sea levels facilitated the arrival of early flora and fauna, but despite the extended land mass, Grenada was never directly connected to South America (Ricklefs and Bermingham, 2008). Thus, biogeographic dispersal constraints played a strong role in the islands' assemblage dynamics of floral and faunal communities. Indeed, molecular dating of evolutionary lineages has indicated that over-water dispersal (from South America) is likely for most inhabitants of the West Indies (cf. Iturralde-Vinent and MacPhee, 2019; Hedges, 2001). However, prior to the Panamanian Isthmus formation (~3.5 mya), it is possible that the Caribbean was the main route for some continental exchanges (Ricklefs and Bermingham, 2008). *A terminus ante quem* for the earliest biological colonisation of the region is offered by the micro-biota recovered from early to mid-Miocene (25-15 mya) amber deposits in the Dominican Republic, from pollen to insects to even (on occasion) infant vertebrates (Poinar and Poinar, 1999; Iturralde-Vinent and MacPhee, 2019).

Prior to Holocene warming, climate records indicate periods averaging 8°C lower than today, with most of the region considerably xeric (Curtis *et al.*, 2001). However, the early advantage of xerophilic plants on larger islands was later lost to mesic conditions, providing an example of one of three major causes of natural habitat loss (and extinction), along with area reduction (e.g. via sea level rise) and flooding of viable habitats (e.g. caves) (Cooke *et al.*, 2017).

In the last 250,000 years, there were between 73-93 terrestrial, non-volant mammals in the Caribbean, of which just 15 are extant today (not including post-European introductions (MacPhee, 2009). Fossils of several large mammals have been found in the Lesser Antilles, suggesting conditions conducive to sustaining diverse fauna, including megafauna such as giant sloths (*Megalonychid* sp.), solenodons (*Solenodontidae* spp.), primates (*Pitheciidae* spp.), and capybara (*Hydrochoerus* spp.), among others (White and MacPhee, 2001; MacPhee, 2009). Fossilised teeth of an extinct sloth species (*Megalonychidae* spp.) and previously unknown capybara (*Hydrochoerus gaylordi*) dating to 2-3 mya, were found at Prickly Point, apparently swept up by lahars and mudslides that formed the mudstone across much of Grenada's eastern/Atlantic coastline (MacPhee *et al.*, 2000). In addition, a recently discovered giant rice rat (*Megalomys camerhogne*), that likely evolved on the Grenada Bank, is the largest known of its genus, possibly an example of island gigantism (Mistretta *et al.*, 2021).

As mentioned, Grenada was part of a much larger landmass (the Grenada Bank) during the LGM, and the eventual reduction of this landmass likely played a role in the extinctions of large-bodied megafauna. The effects are still evident today, as seen by the higher number of mainland mammals (e.g. bats) south of the Bequia Channel than to the north (a phenomenon dubbed "Koopman's Line") (Genoways *et al.*, 2010).

2.2.4. Arrival of humans

Human occupation of the Caribbean archipelago began 5-7,000 years ago (3-5000 BC), during what archaeologists call the "Archaic Age," when lithic blade producers (known collectively as the Casimiroid) left Central or South America for Cuba (Rouse, 1992; Wilson *et al.*, 1998). By 2000 BC, lithic groundstone foragers from Trinidad and Venezuela (known as the Ortoiroid) are believed to have moved into the Lesser Antilles and interacted with Casimiroid groups (Rouse, 1992; Keegan, 1994; Wilson, 2007). The former Central American route is not well-supported (Napolitano *et al.*, 2019), but if it happened, it was only during a short interval — every other human migration to the Caribbean (prior to 1492) originated in South America. Additionally, just a handful of questionable radiocarbon dates from Grenada and Barbados represent the only direct evidence for either group's presence between Montserrat and Trinidad (Fitzpatrick, 2011; Giovas and Fitzpatrick, 2014; Hanna, 2018a).

While Archaic Age cultural material has remained elusive in the Windwards, various proxy evidence has provided tantalising clues. Siegel *et al.* (2015; 2018) analysed soil cores across nine islands in the Lesser Antilles, documenting charcoal signals, the decline in arboreal pollen, and other changes in vegetation beginning in Grenada ~3650 BC and progressively moving northward through the Windwards (Figure 2.2 on page 82.). At Lake Antoine, in northeastern Grenada, two separate paleolimnological studies have analyzed preserved pollen (McAndrews and Ramcharan, 2003; Siegel *et al.*, 2015), and both retained long sequences going back to ~10000 BC, when the lake formed (see above). Siegel *et al.* (2015) focused mostly on the sustained charcoal signals beginning 3-4000 BC, which they interpret as evidence of human disturbance (e.g. clear-cutting), both in the Lake Antoine core and another at Meadow Beach, just to the south. But charcoal signals could be natural (e.g. lightning ignitions) (Caffrey and Horn, 2015) and given Grenada's modern and relatively recent volcanic activity over the last 10,000 years (discussed above), consonance between charcoal peaks and arboreal decline could simply reflect volcanic activity.

However, the most compelling data recovered from these cores are phytoliths of *Marantaceae* sp. cultigens (arrowroot family) dating as early as 3840 BC and correlated to the decline of arboreal pollen and a surge in charcoal (Figure 2.2 on page 82) (Jones *et al.*, 2018, pp.142, 149). Figure 2.2 shows the comparison of regional precipitation and chronological records with local vegetation and archaeological records. Above the timeline, the short sequences are from Levera Pond (Sharman, 1994), while longer sequences are from Meadow Beach and Lake Antoine (Siegel *et al.*, 2015; 2018); volcanic tephra (Fritz *et al.*, 2011) recorded from Grand Etang and Lake Antoine (n.b. tephra could include explosions elsewhere as well as local non-magmatic activity); sum probability distribution (SPD) depicts the relative population for Grenada based on radiocarbon dates (Hanna, 2018b); 'herbs' are herbaceous taxa identified by Siegel *et al.* (2015) as potential indicators of anthropogenic landscapes, and which may overlap with Sharman's (1994) 'weeds' category of disturbance indicators; *Spondias* taxa may also indicate anthropogenic introductions (though not exclusively), whereas *Marantaceae phytoliths* (Siegel, 2018) are stronger indicators of human presence; methods for recalibrating and re-plotting these graphs are described in Hanna (2018b, p.10).There are no *Marantaceae* taxa native to Grenada, so their appearance in paleolimnological cores is a reasonable indicator of human presence (Pearsall *et al.*, 2018, pp.69–71). This highlights the complexity of such ancient signals because volcanic tephra deposited in another set of cores from Grand Etang and Lake Antoine (Fritz *et al.*, 2011) also loosely correspond to some charcoal peaks (suggesting volcanic–not human–activity). But charcoal signals seem correlated to *Marantaceae phytoliths* more than any other indicator, even a proxy frequency distribution for Ceramic Age human population based on radiocarbon dates (Sum Probability Distribution (SPD) in Figure 2.2) (Hanna, 2018b). In fact, charcoal drops right at the height of this projected population, which could indicate that Ceramic groups were not engaged in slash and burn agriculture as enthusiastically as their forebearers. Ultimately, however, more direct evidence is needed before we can understand the nature of Archaic Age presence in Grenada.

2.2.5. Amerindian ecology

Since the Late Quaternary, 160 endemic species have gone extinct in the Caribbean (including more mammals than any other region of the world), most surviving well into the Holocene (and many up until 500 years ago), suggesting human impacts led to these extinctions (Turvey, 2009). Cooke *et al.* (2017) discern two main extinction events in the Caribbean,

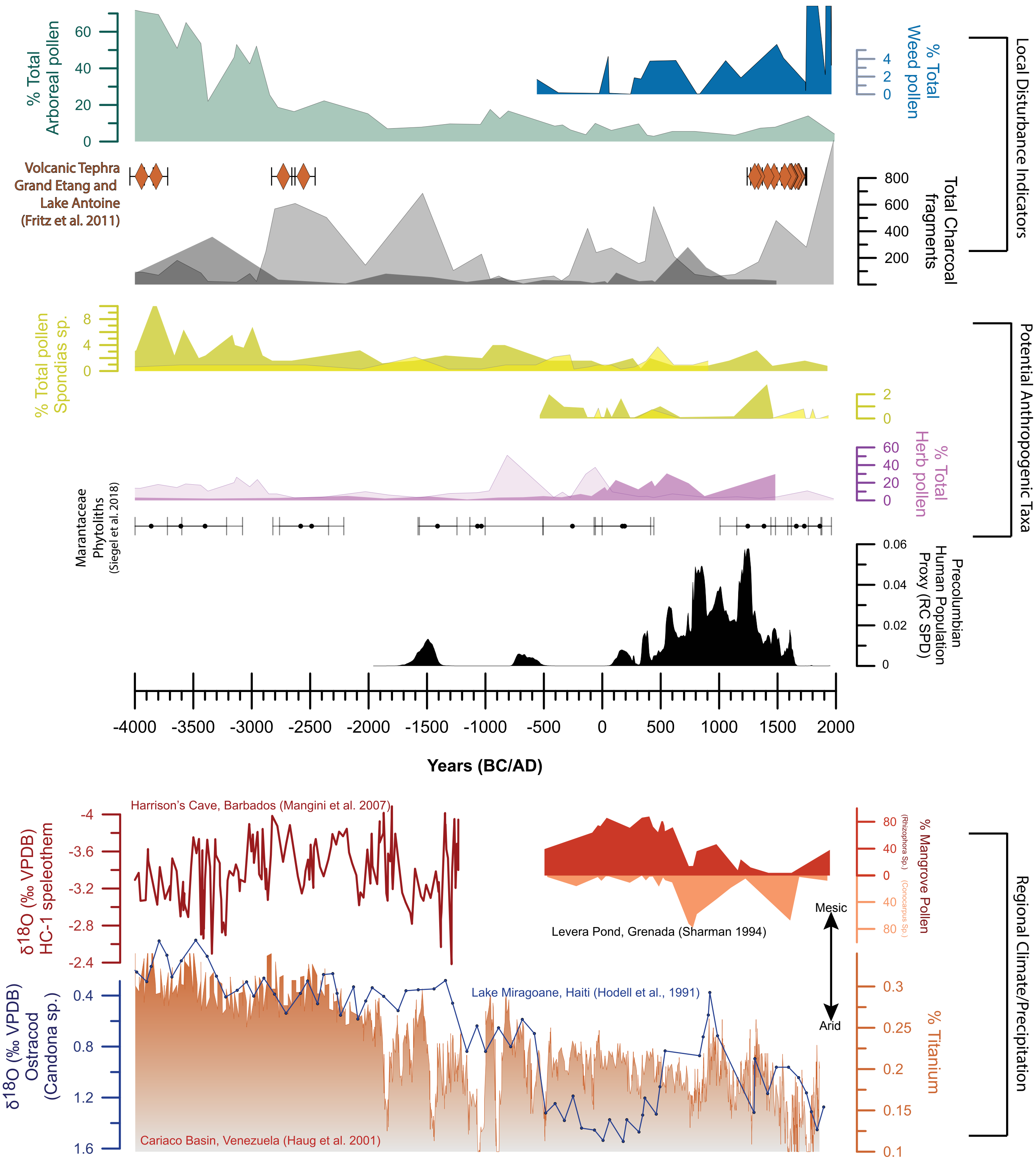


Figure 2.2. Paleoenvironmental Record of Precolumbian Grenada – comparison of regional precipitation and chronological records with local vegetation and archaeological records

correlated to the first arrival of humans (~3-5000 BC) and the arrival of Europeans (~AD 1500).

By the time of human arrival in the West Indies, the shock of Holocene warming was well past, and there is no evidence that earlier warming periods in the Quaternary caused mass extinctions. Meanwhile, the arrival dates for humans in the region correlate well to the last appearance of many species (Cooke *et al.*, 2017). However, there is limited archaeological evidence of non-marine faunal remains from the Archaic Age, so it is possible that 'collateral damage' from human disturbance and habitat loss (rather than direct hunting) contributed to their disappearance, perhaps coupled with some yet undetected (e.g. now underwater) hunting of larger animals with slow reproductive rates (Steadman *et al.*, 2005; MacPhee, 2009). The periods of burning and decline of arboreal pollen described above are examples of such anthropogenic disturbance in Grenada. But it is also likely that the post-LGM flooding of the Grenada Bank, as well as the volcanic events mentioned, contributed to the disappearance of megafaunal species like capybaras and sloths, perhaps well before humans arrived (McFarlane *et al.*, 1998). The gaps in the faunal record are simply too wide to tell.

The Archaic Age also saw the arrival of translocated/commensal species of plants and animals, some of which may have filled niches of extinct species. As hinted above from evidence of arrowroot (*Marantaceae*) cultigens 3-4000 BC in Lake Antoine and Meadow Beach (Jones *et al.*, 2018), Archaic peoples brought a suite of horticultural plants and tropical root crops, including avocado (*Persea american*a), arrowroot (*Marantacea*e sp.), wild fig (*Ficus* sp.), primrose (*Oenothera* sp.), yellow sapote (*Pouteria campechiana*), West Indian cherry (*Malpighia* sp.), and zamia *(Zamia* sp.) (Newsom and Wing, 2004). They also probably brought animals—agouti (*Dasyprocta* sp.), guinea pigs (*Cavia porcellus*), opossum (*Didelphimorphia* sp.), and dogs (*Canis familiaris*), but the earliest evidence comes from later, Ceramic Age sites (deFrance *et al.*, 1996; Giovas, 2017).

Beginning about 500 BC in the Leeward Islands (~AD 100 in the Windward Islands), a distinctive pottery assemblage (dubbed "Saladoid") arrived in the West Indies. Traced to the Orinoco watershed in modern Venezuela, its sudden appearance in the Caribbean—along with a similar agricultural repertoire, site planning, and architecture—is believed to reflect diasporic fissioning from lowland South America (Boomert, 2000, p.114; Keegan, 2000; Hanna, 2019). Little is understood about the interactions between the inflowing Saladoid horticultural groups and the Archaic forager-gardener peoples already present, but evidence in the northern Antilles has fueled ongoing debate (Davis, 2000; Callaghan, 2003; Lalueza-Fox *et al.*, 2003; Keegan, 2006).

Numerous plants and animals arrived in the Caribbean during this period. Plants included for example achiote (*Bixa orellana*), beans (*Phaseolus* spp.), chilis (*Capsicum* spp.), cotton (*Gossypium* sp.) and soursop (*Annona muricata*). Animals included agouti (*Dasyprocta* sp.), dogs (*Canis familiaris*), guinea pigs (Cavia porcellus) and muscovy ducks (*Cairina moschata*), among others (Newsom and Wing, 2004; Rick *et al.*, 2013).

Despite the pulse of new introductions and human population growth, the Ceramic Age did not see the same level of extinction events as the initial arrival of Archaic peoples. Archaeological evidence confirms many animals (including several native species such as armadillo, iguana, giant rice rats, and several bird species) were indeed hunted. Still, all appear to have survived until European arrival (Pregill *et al.*, 1994). However, there is also evidence of localised depressions and depletions of faunal (especially marine) species due to intermittent over-predation (Wing and Wing, 2001; Carlson and Keegan, 2004).

Prehistoric Caribbean peoples, directed by cultural adaptation and ideology, transformed their local environments and created ecosystem niches that entailed positive and negative feedback (Janzen, 1998; Terrell *et al.*, 2003; Balée and Erickson, 2006; Laland and O'Brien, 2010). One interesting ecological relationship that is not well understood is between Amerindian sites and wetlands. Research on ecological variables surrounding well-studied archaeological sites reveals a strong correlation with wetland environments (Hanna, 2018a). In fact, all 89 pre-Columbian sites currently recorded in Grenada are within 500m of a wetland (61% within 100m), including inland sites far from the coast (Figure 2.3 on page 85) (Buckmire *et al.*, 2022). The association could be due to wetland plants with economic value, whether for ritual/medicinal use or utilitarian applications like palm thatch and timber/firewood. Indeed, the coring studies described above show mangroves at Conference and Levera formed 2,500 and 5,000 years ago, respectively (Sharman, 1994; Siegel *et al.*, 2015), indicating they were preserved and managed during Amerindian times.

Finally, far from being extinct, many ancient practices persist in Grenadian culture today. As described above, many animals and plants are legacies of Amerindian introductions, and the way they are harvested retain those legacies as well. The way conch shells are cut, certain methods of fishing (including crayfishing and fish pots), methods of shifting cultivation (especially gardens far from one's homestead), hunting armadillo or opossum, drinking cocoa tea, eating farine in the morning or traditional pepper pots, as well as many herbal remedies ("bush medicines") are not Old World practices but based in indigenous ecological knowledge from the New World.

2.2.6. Climate in the Holocene

Climate likely influenced the behavior of humans after their arrival in the region 5-6 kya (see below). The aforementioned pollen and coring studies indicate increased moisture with warming of the Holocene, then drying in the Middle Holocene (~3000 BP) (Curtis *et al.*, 2001), with variations tied to fluctuations in the ITCZ (Cooper, 2013; Haug *et al.*, 2001). Overall, the available climate proxies suggest a generally wet/mesic period from 350 BC-AD 750 in the Caribbean Basin, followed by mostly dry conditions from AD 750-900, AD 1050-1200, and again from AD 1500-1700 (Cooper, 2013, p.53). This is corroborated by several lake core studies in Grenada, all of which confirm, in particular, a drying trend during the Late Ceramic Age, from ~AD 700–1300 (Sharman, 1994; McAndrews and Ramcharan, 2003; Siegel *et al.*, 2015). This also explains the various archaeological sites (especially petroglyphs and workstones) that are now buried in beach sand but were once much further from the sea (Hanna, 2018b).

Additionally, French settlement in AD 1649 occurred during a dry period, when sea levels were slightly lower than today (Mann, 2002). The French settled on a sand spit that once enclosed the St. George's Lagoon, but which became inundated and unlivable within the first few decades of the colony. Similarly, several sand bars and reefs that present hazards for ships today were once above water, such as the now inundated islands off Grenville Bay and Morne Rouge/BBC Beach depicted on the 1667 map by Blondel (Martin, 2013).

2.2.7. The Columbian Exchange: European invasion and its environmental impact

Undoubtedly, the greatest human impacts on Grenada's environment began with European colonization. While previous extinctions saw the decline of large-bodied animals (e.g. over 3kg), during the European period, many small-bodied animals also went extinct (Cooke *et al.*, 2017). However, like the previous extinction event, this was not from direct hunting (by humans) but rather predation, out-competing, and disruption by introduced species (e.g. cats, dogs, mongoose, black rats) as well as large-scale habitat loss from clear-cutting for plantation agriculture (Watts, 1987).

Ironically, however, it did not begin this way. Rather, the decline of Amerindian populations following European arrival in the region initially lessened anthropogenic pressure on the environment. In Grenada, "Island Carib" groups resisted various attempts at settlement until the French finally succeeded in 1649 (Martin, 2013). And even then, the French population remained low for the first few decades of the colony. But by the end of the 17th century, Grenada's population was growing and like everywhere in the New World, most newcomers were from Africa. Although bound and enslaved, a surprising amount of flora and fauna came with them (often unintentionally—in packaging, in textiles, and myriad other ways). Soon, the

Figure 2.3. Map of Grenada showing the association between Precolumbian sites, mangroves, and wetlands, with likely current or former wetlands based on low slopes and alluvial/accretive soils (see Appendix 1 for references and data sources)

Caribbean was filled with African rice, okra, yams, bananas, black-eyed peas, millets, melons, sorghum, sesame and coffee. Grenada's Mona monkeys (*Cercopithecus mona*) also arrived from the Guinea Coast (likely Sao Tome) in the 18th century (Martin, 2022).

And, of course, European staples were introduced: wheat, cauliflower, cabbage, onions, grapes, lettuce, radishes, and various livestock. While the Spanish famously deposited feral pigs across the globe, the sheep, goats, horses, and cattle wreaked the most havoc on vulnerable grasslands. In fact, they ate right through the native grasses, leading to the importation of Old World grasses (e.g. *Poa bulbosa*) (Crosby, 2003, p.73). The practice of burning fields for pasture and farmland also disadvantaged native species, pushing them to the margins and circumscribing their reduced habitats.

In Grenada, commercial plantations of indigo, cotton, and tobacco were eventually surpassed by sugarcane and a slave-dependent economy that intensified after the British annexation of 1763 (Williams, 1971). Massive deforestation and soil erosion increased during plantation agriculture resulting, for example, in the exponential increase of sedimentation rates at Levera (Sharman, 1994). Colonial maps show that much of the island was clear-cut and ploughed and also razed during the massive Fédon Rebellion of 1795-96 (Brizan, 1998; Steele, 2003). Cataclysmic fires, insect infestations (e.g. sugar ants in the 1770s), tropical storms (1731, 1768, 1817, 1831, 1832), and at least one major hurricane (1780) all contributed to severe environmental destruction during colonial times (Martin, 2022). Given all this devastation, it is unknown how much (if any) of the inland forests today are old growth. However, early maps do suggest that the burgeoning environmental movement (spurred partly by the disastrous deforestation of Barbados) led to loose protections of Grenada's forested central mountains, although no specific legislation appears to have been enacted (as it was in St. Vincent and Tobago, for example) (Grove, 1996). By 1882, some of these lands had been planted, especially in St. John and St. Mark (and even abutting the southern edge of Grand Etang). But in 1897 and 1906, formal forest reserves were created for Mt. St. Catherine and Grand Etang, respectively (Beard, 1949, p.148; Martin, 2022).

2.2.8. Post-emancipation ecology

Following the full emancipation of the enslaved population on August 1, 1838, West Indian sugarcane became unprofitable. However, even while the estates changed hands, they remained largely intact, and political control was retained within the elite, property-owning "plantocracy" (Steele, 2003). Other crops like coffee, nutmeg, banana, coconut and cocoa took over. By 1890, cocoa represented 80% of Grenada's exports but then collapsed in the 1920s, replaced by bananas and coconuts (Martin, 2022). During this time, too (circa 1860-1950), agricultural operations were attempted on many previously untouched offshore islands (e.g. Large/Laidlarge Island, Saline Island), as well as whaling industries (Coffey and Collier, 2021; Martin, 2022). In Carriacou, citrus operations began, whilst cattle overgrazing caused erosion and land slippage (Vernon *et al.*, 1959), a problem that continues today.

Meanwhile, many former enslaved opted out of the plantation economy altogether, focusing on subsistence gardening (Smith, 1974, p.285), remnants of previous slave gardens that now expanded both in space and diversity. The depressed labour force spurred many plantation owners to import indentured labourers, mostly from India (Steele, 1976). Like their predecessors, these new workers are credited with importing new crops like turmeric and chickpeas.

It was not until the Sky Red protests of 1951 that the plantocracy began to crumble (helped also by Hurricane Janet in 1955). By the 1960s and 1970s, many estates were confiscated or broken up, often into residential plots rather than smallholdings (Brierley, 1992; Griffith, 2015). This was the start of Grenada's economic modernisation, seeing more drastic changes in land use than any other time since European colonisation. However, a lack of infrastructure and support for small-scale, mixed agriculture, as well as severe corruption and mishandling of estate lands, ultimately destroyed Grenada's agricultural sector for a generation (Brierley, 1992; 1998). Reforms and investment during the People's Revolutionary Government and the post-Revolution Model Farms Corporation helped, but technology and infrastructure needs (e.g. access to roads, markets, fertilisers, seeds, etc.), particularly after Hurricane Ivan in 2004, continue to be a challenge for increasing food security and sustainability. In recent times, real estate has proved a more profitable use of land than agriculture, exacerbating Grenada's sustainability issues and further encouraging the destruction of valuable natural capital.

The massive transformation of Grenada's environment chronicled above is the ecological history of the landscape we have inherited today. As can be seen most acutely in island environments worldwide, the choices made in the past restrain the choices available for future generations (Amorosi *et al.*, 1997; Burney, 1997). However, a knowledge of the distinct formation history of Grenada's environment, allows for better management and protection of its diversity today and thus the country's capacity for resilience in the future.

2.3. Status of Grenada's flora and fauna resources

Much of Grenada's ecosystems, and their associated biological communities, have undergone much change in the past century. While data availability varies among ecosystems and biota, this chapter attempts to succinctly describe the status of Grenada's flora and fauna today and general trends in their availability and distribution.

2.3.1. Agriculture (and agrosystems)

As covered under Section 2.2 (Past environments), much of Grenada's landscape, following European colonisation, was modified to accommodate agriculture; and as well covered in Section 2.3.4 (Forests), much of the current forested areas were previously cultivated (Beard, 1949). Regardless, in this section, we provide an overview of agroforests, and poultry and livestock to highlight: 1) their use for food production; 2) the recent trends in their respective industries; and 3) how they may influence other ecosystems. A trend of note is that agriculture and agrosystems, though they are modified landscapes for human food production, provide habitat for native and domesticated fauna.

Agroforests and Croplands

Flora

Much of the forested areas in Grenada have been repurposed for agriculture as these offered ideal conditions for growing major export crops, including banana, nutmeg, and cocoa. However, the combined aftermath effect of natural disasters and abandonment of plantations gave way to natural vegetation regrowth (Dunn, 2005; 2009); estimates from the Land Use Division suggest that this abandoned cropland accounted for 6,238ha of land area (i.e. 20%).

According to Grenada's Annual Agriculture Review (2009), there was a steady increase in the production of forest tree species from the years (mainly from 2005 to 2009) preceding the passage of hurricanes Ivan and Emily (Grenada Ministry of Agriculture, Forestry and Fisheries, 2009). These species of trees would have included Mahogany, Blue Mahoe, Nutmeg, Cinnamon Spice, and other forest-related tree species that were propagated at the Forestry Nursery, accounting for 2,900ha in 2009 (Land Use Division, 2009). Also, through annual plant distribution programmes at the Mirabeau and Ashenden Stations farmers, the public has been able to incorporate trees (mainly fruit trees) into their farming practices. The trees are not only used as windbreaks for short-term crops (tomatoes, peppers) or environmental purposes but also for economic purposes harvesting fruits, seeds, or plant materials.

Fauna

Agricultural landscapes do provide a habitat for fauna in Grenada. In a survey of land birds in Grenada between 2016-2018, both Bergen (2020) and Williams (2020) reported that agricultural landscapes, particularly those that contained nutmeg and mixed-wood agriculture, supported higher densities, abundance and diversity of land birds. Surveys by De Ruyck between 2017 and 2019 may explain why these agricultural landscapes (particularly agroforests) are important for birds – they host a greater diversity of fruit, seed and flowers for foraging birds than dry and secondary forest (De Ruyck, 2023). Additionally, Grenada's land birds have morphological adaptations that allow them to persist in urban/agricultural habitats (Cyr *et al.*, 2020; Wetten, 2021). For instance, Cyr *et al.* (2020) reported that house wrens modified their songs in urban landscapes to communicate in these noisier environments. Agricultural landscapes, as posited by Williams (2020), could be important for some land birds, particularly species that are neither nectarivores or granivores. Though these agroforests may be valuable for other fauna, the only other published work on other taxa are mammals- specifically, the introduced mammal, Mona monkeys (*Cercopithecus mona*). Mona monkeys can persist in a variety of habitats because of their dietary flexibility (Glenn and Bensen, 2013); thus, agroforests with high dominance of fleshy fruit, the preferred food choice for Mona monkeys in Grenada (Glenn, 1997), may also provide foraging habitat for these mammals. Further evidence for the use of agricultural areas by Mona monkeys was reported by Glenn (1996) and Groome (1970), where these animals have been observed raiding crops along the forest edge.

Poultry and livestock

Given limitations in data availability, we conducted informal interviews with personnel in the Ministry of Agriculture and the Poultry Farmers Association to obtain information on the status of poultry and livestock in Grenada. Interviews revealed that egg production accounts for a larger percentage of revenue for this industry and is believed to nearly meet the demands of the local market. However, most of the poultry meat consumed in Grenada is imported. Consequently, it is unlikely that there is significant environmental impact of the poultry industry on Grenada's ecosystems, though livestock farming (e.g. pigs) may contribute to increased eutrophication in waterways (Nimrod, Franco and Andrews, 2013; Gaea Conservation Network, 2020).

Egg production

Based on estimates from the Ministry of Agriculture, we note that eggs are produced throughout the year, with chickens providing the largest proportion of eggs in the market (Table 2.1). These eggs are largely produced by one breed of chickens, the Rhode Island Red/Brown Layer, producing brown eggs. These layers are sourced externally, with chicks imported from an international distributor, then grown and used by the local farmers. There is no functional hatchery on the island, or breeders of laying hens.

Table 2.1. Egg production based on estimates from the Ministry of Agriculture personnel

Egg Production Chart			
Species/Type	Percentage of market	Scale of Production	Distribution of farms
Chicken	98%	Small and large	Island-wide
Quail	~2%	Niche	Set locations
Ducks	<1%	Niche	Sporadic

Chickens

Estimates from the Ministry of Agriculture suggest that approximately 95% of the locally-produced chicken eggs are brown and 5% are white. The color of the eggs is directly related to the company from which the chickens were sourced. Most laying hens are 4-way crosses, and the genetics are controlled by a parent company to the breeding and hatching companies.

Quails and ducks

According to the Poultry Farmers Association and the Ministry of Agriculture, the quail egg industry has gained popularity in recent years, with most of the demand coming from visitors. To meet this growing demand, there is one major farm doing quail eggs and a few smaller farms going into quail egg production. Duck eggs are less popular in the urban areas but appear to have pocket markets in rural areas of the island.

Meat, dairy and skinning

This section covers the meat production industry in Grenada, with brief considerations of dairy farming. It should be noted that there is no zoning for agricultural lands, thus livestock production is sporadic throughout the island.

Chickens, quail, turkey and ducks

While chicken is the main meat produced in Grenada, there are smaller markets for turkey, quails, and ducks. While medium (100-1000 birds slaughtered) and small-scale (12-100 birds slaughtered) chicken meat production are more common, there are plans to shift to large-scale poultry meat production (1000+ birds slaughtered). Turkey meat, however, is produced periodically on a small scale, with peak production around the Christmas season. Most turkey farmers are primarily chicken farmers. While the demand for quail in Grenada is small, there are producers of quail meat for local consumption. Finally, duck farmers are distributed island-wide, but this appears to be the meat source with the lowest demand, though they are harvested year-round.

Livestock farming

Sheep and goats are the only small ruminants that are farmed in Grenada. There are farmer cooperatives, small group partnerships, small-scale farmers (<50 head of stock) and large-scale farmers (>50 head of stock). Most of the small ruminants are restrained by tying a slip that is fastened to a tree or pole (tying), whilst the others are kept in stalls, and a small percentage are kept in open enclosures on a rotation system. On Carriacou and in rural areas, the stock may be left to roam free and/or released on uninhabited islands. The major product of the small ruminant industry in Grenada is meat production. Milk and cheese production is maintained on a small scale. The skins and wool are seldom harvested.

Cattle are also tied to a fixed object, with approximately 80% of the local stock being tied to a fixed object and rotated (Coffey and Collier, 2021), while 20% cent is kept on a pole. With the pole system, a cow or bull is left in one spot, and food is brought to it. Herds that are tied to a fixed object could be small (1-10) or medium-sized (10–100). There are not any significant cattle farms with 100+ heads of cattle. The fodder for cattle on pole is usually accumulated from agricultural by-products from corn and vegetable farming. Cut and carry are also used to feed the cattle. Traditional grasslands are seldom expanded, and cattle farmers do not advance into the interior, so the environmental impact for small ruminant and cattle farming is likely mild to moderate. The faecal by-product is usually recycled as fertilisers. There is no 'feedlot' high production system on the island nor a dairy industry. Hence, long-term air and waterbed pollution from cattle farming are nonexistent.

Traditionally, pigs were tied to a fixed object in an area and fed the food scraps from the kitchen. Households owned a small number of pigs (1-5). Modern advances in pig farming have seen changes such as concrete penned housing, facilitating large-scale pig farming (5-500). Health regulations are not heavily enforced, and pig farms can be found in residential areas near rivers. Runoff from many pig farms enters the rivers and streams directly. A small percentage of pig farmers recycle waste products for biogas production. The raw materials used in the production of pig ration are imported, so, there are no areas of land cleared for corn and grain production. The two main environmental concerns about pig farming in Grenada are air pollution and the runoff of waste products into watercourses.

2.3.2. Coastal ecosystems

Beaches

Grenada has numerous beaches around the island (Figure 2.4 on page 91). Grand Anse Beach, located within the Grand Anse Marine Protected Area on the southwestern coast, is regarded as the most popular on the island. Other notable beaches are

Morne Rouge, Magazine, Parc a Beouf and Pink Gin, La Sagesse, Bathway, Levera, Sauteurs and Grand Mal (Allen, Diller and Zabarauskas, 2017). Beaches on Carriacou include Harvey Vale Paradise, Lauriston, Bogles, Petit Carenage/L'Islet, Windward and Manchineel Bay. There is also Main Beach on Petite Martinique (Allen, Diller and Zabarauskas, 2017; Peters, 2000). Several of Grenada's offshore islands (e.g. Calivigny Island, Hog Island, Sandy Island, etc.) also have iconic beaches. Like many small islands in the Eastern Caribbean, the beaches on the windward side of Grenada are exposed to the Atlantic Ocean. They are generally unprotected, while those on the leeward side of the island border the Caribbean Sea and are more sheltered. Exceptions to this are Telescope and Marquis Beach, located on the eastern coast of Grenada which are protected by coral reefs (Peters, 2000). Beaches in Grenada are generally flat and lack a well-defined dune system, with beach sediments being derived from diverse sources such as volcanic parent material and coral from offshore reefs (Peters, 2000). Grenada's beaches are important sites for recreation, tourism and fish landing.

Associated flora and fauna

Sandy beaches (e.g. Levera, Bathway, Grand Anse, Pink Gin) in Grenada and Carriacou (Petit Carenage, Anse La Roche, Big Field, Sparrow Bay, Saline and Sandy Island, etc.) are important nesting sites for leatherback turtles (*Dermochelys coriacea*), green turtles (*Chelonia mydas*) and hawksbill turtles (*Eretmochelys imbricata*) (Grazette *et al.*, 2007; Horrocks *et al.*, 2011; Charles, 2017; KIDO, n.d.). Levera Beach, located along the northeastern coastline of Grenada, is the primary nesting beach for the endangered Northwest Atlantic leatherback turtles (Maison *et al.*, 2010; Charles, 2019; Eckert and Eckert, 2019) (Figure 2.5 on page 92). Under Article 17 of the 2001 Fisheries (Amendment) Regulations, 1) there is a closed fishery for all turtles (except leatherback turtles) between 1st April to 31st August, 2) leatherback turtles and their nests are protected throughout the year, 3) turtle eggs of all species are protected throughout the year and, 4) marine turtles harvested during the open season must meet the minimum size limit (25lb).

Native (several species of *Gracilaria*) and imported (*Eucheuma cottonii, Eucheuma isiforme*) seamoss (marine algae) are grown and harvested in the shallow waters of various beaches and sheltered bays (Grenville Bay-specifically Telescope and Soubise, Petit Bacaye, and Woburn) in Grenada (Société Française de Réalisation, d'Études et de Conseil [SOFRECO], 2012). Seamoss harvesting in Grenada is regulated under the *Grenada Fisheries Act* (1986) as seamoss is included within the broad definition of 'fish' (Government of Grenada, 1986; Gardner, 2006).

Sandy beaches also provide important nesting habitats for iguanas and simultaneously support several species of resident and migratory birds. Based on recent observations, there is evidence that the Grenadines' pink rhino iguana subspecies (*Iguana insularis insularis*) (Breuil *et al.*, 2018) nests on beaches in Anse la Roche, Carriacou and occurs elsewhere at offshore islands (J. Coffey, 2022, personal communication, 31 January; Charles *et al.*, 2021). These coastal ecosystems are also used by birds for foraging, roosting, and nesting (Appendix 2). As of November 2021, approximately 110 species of birds, some of which are categorised as resident endemic and breeding endemic to the Lesser Antilles and the West Indies, were sighted on or near beaches in Grenada and Carriacou (Appendix 3).

Several plant species aid in the stabilisation of beach sediments. These include buttonwood (*Conocarpus erectus*), white mangrove (*Laguncularia racemosa*), seagrape (*Coccoloba uvifera*), manchineel (*Hippomane mancinella*) and beach morning glory (*Ipomoea* sp.).

Mangroves

Mangroves are present in Grenada (181ha), Carriacou (101ha) and the Grenadine islands of Isle de Ronde, Isle de Caille, Saline Island, and White Island (11ha) (Moore, Gilmer and Schill, 2015) (Figure 2.4 on page 91). Mangrove habitat types recorded are basin (181ha), fringe (65ha), littoral/back (42ha), scrub (8ha) and riverine (1ha) (Moore, Gilmer and Schill, 2015). The majority of mangroves on the main island of Grenada are found along the southern and eastern coasts (Moore, Gilmer and Schill, 2015). On the

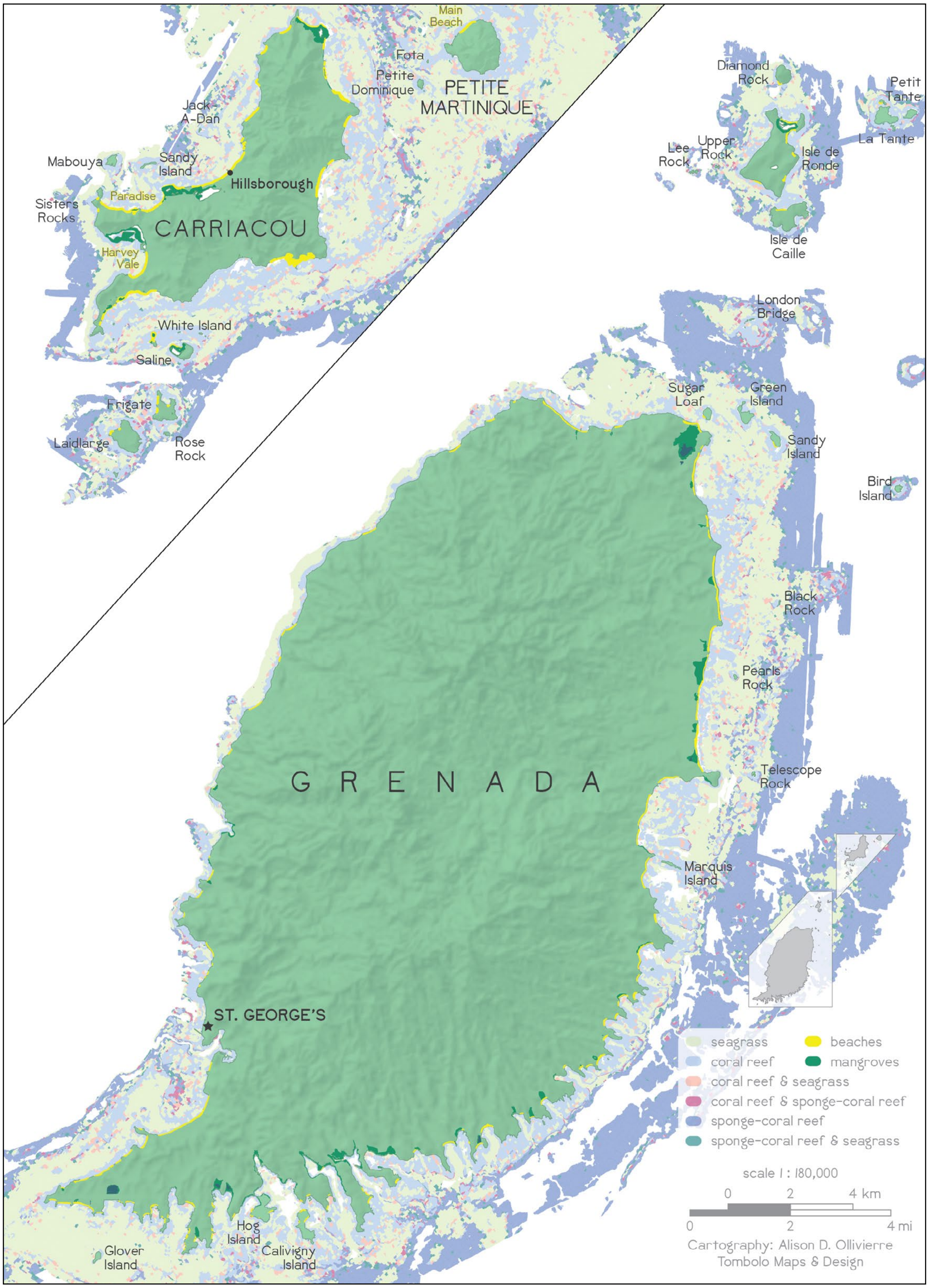


Figure 2.4. Coastal ecosystems in Grenada
(see Appendix 1 for references and data sources)

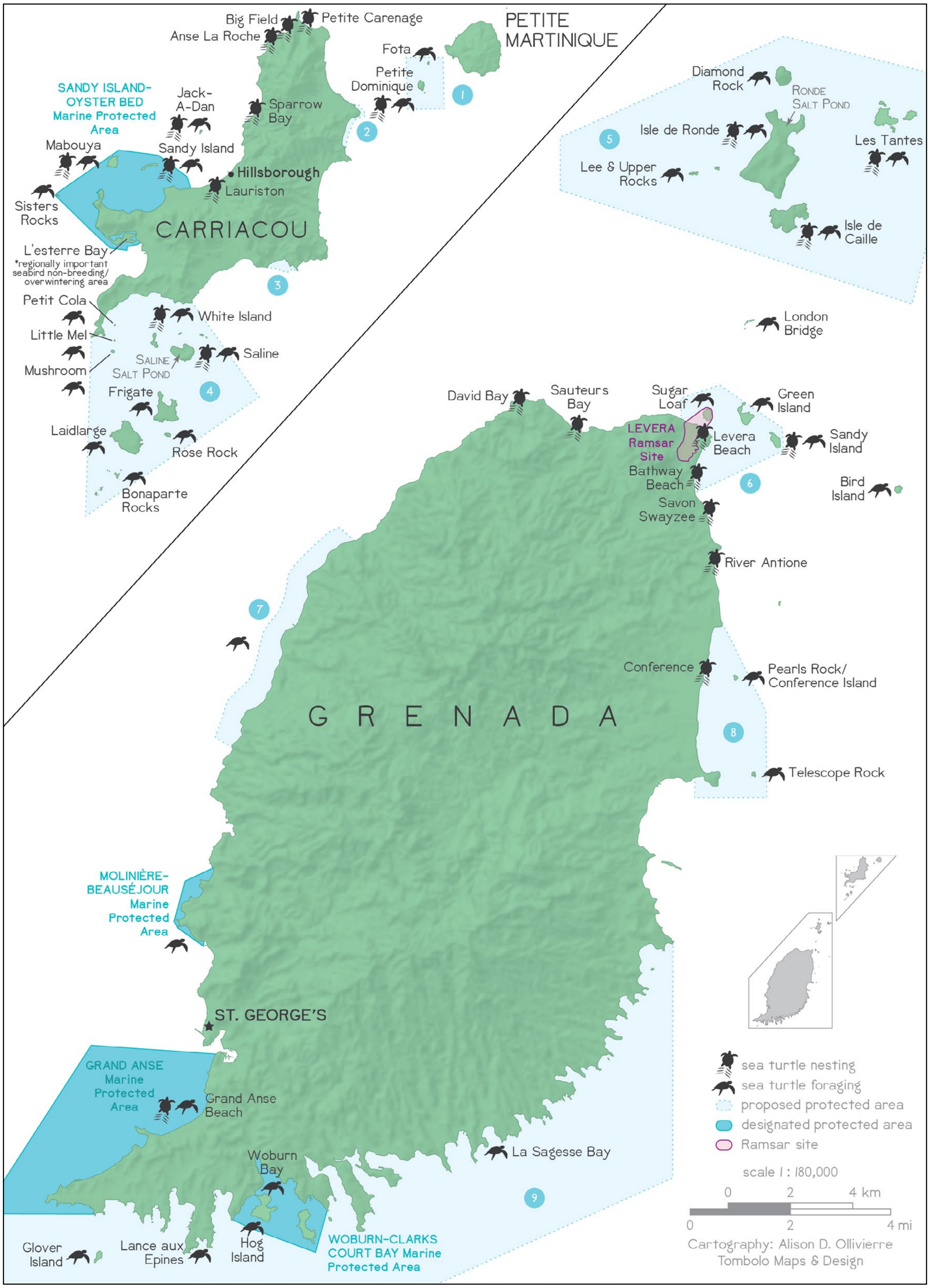


Figure 2.5. Areas in Grenada, Carriacou, and Petite Martinique where sea turtles are known to nest and forage
(see Appendix 1 for references and data sources)

eastern coastline, they can be found from Levera to Telescope and along the south-eastern coastline from Requin to True Blue (Figure 2.4). The largest areas are Levera, Conference, Upper Pearls, Westerhall and Calivigny (Figure 2.4). In Carriacou, there are three main areas of mangroves currently found — Tyrrel Bay (most ecologically significant, fringe and basin habitat), Petit Carenage (fringe habitat), and Lauriston (basin habitat) (Moore, 2003).

Associated flora

The true mangrove tree species and associates that have been recorded in Grenada and its offshore islands include red mangrove (*Rhizophora mangle),* black mangrove *(Avicennia germinans, Avicennia schaueriana)*, white mangrove *(Laguncularia racemosa)*, and buttonwood *(Conocarpus erectus)* (Spalding *et al.*, 2010; Government of Grenada, 2014). Other flora also typically associated with mangroves in Grenada include the mangrove fern (*Acrostichum aureum).*

Associated fauna

Mangrove vegetation and their associated mudflats are important roosting, nesting and foraging habitats for several species of birds, many of which utilise these areas as temporary stopovers during their long-term migrations (Moore, 2003; Moore, Gilmer and Schill, 2015; Coffey and Ollivierre, 2019). In the mangroves at Tyrrel Bay (Carriacou), some of the species that have been recorded include yellow-crowned night-herons (*Nyctanassa violacea*), green herons (*Butorides virescens*), little blue herons (*Egretta caerulea*), great egrets (Ardea alba), spotted sandpipers (*Actitis macularius*), ruddy turnstones (*Arenaria interpres*), greater yellowlegs (*Tringa melanoleuc*a) and lesser yellowlegs (*Tringa flavipes*) (Moore, 2003). Some terrestrial species also utilise mangroves for short-term foraging or as a longer-term habitat. As of November 2021, approximately 109 species of birds, some of which are categorised as resident and breeding endemic to the Lesser Antilles and the West Indies, were sighted in mangroves in Grenada and Carriacou (Appendix 2; Appendix 3).

The Grenada Bank tree boa (*Corallus grenadensis*), a nocturnal snake endemic to Grenada and the Grenadines, is a generalist species that has been documented in mangrove habitats, e.g. Mt. Hartman and Woburn in Grenada, Tyrrel Bay and Lauriston Point in Carriacou (Henderson, Sajdak and Winstel, 1997; Henderson and Berg, 2006; Ministry of Carriacou and Petite Martinique Affairs, 2015).

Certain mangrove-associated fauna are harvested for human consumption by Grenadians. Mangrove oysters (*Crassostrea rhizophorae*) and flat tree oysters (*Isognomon alatus*) are often found on the prop roots of red mangroves (*Rhizophora mangle*) (Moore, 2003; Blommestein *et al.*, 2012). Significant oyster beds, growing upon the roots of red mangroves, are found at Tyrrel Bay within the Sandy Island/Oyster Bed MPA (Ministry of Carriacou and Petite Martinique Affairs, 2015). Local boaters use the mangroves at Tyrell Bay to secure their boats during severe weather events (The Nature Conservancy and Grenada Fisheries Division, 2007). The harvesting of oysters is regulated by existing subsidiary legislation (Government of Grenada, 1996). Mangroves in Grenada also provide a habitat for several species of crabs, such as the mangrove root crab (*Goniopsis cruentata*), mangrove tree-climbing crab (*Aratus pisonii*), grapsid crab (*Sesarma rectum*) and other crab species such as *Uca* spp., *Cardisoma guanhumi*, and *Callinectes* spp. (Schubart, Horst and Diesel, 1998; Layman *et al.*, 2006; Peterson *et al.*, 2013).

Seagrasses

Seagrasses can be found along all coasts of the main island of Grenada and the islands of Carriacou and Petite Martinique (Figure 2.4 on page 91). Species recorded in nearshore waters include paddle grass (*Halophila decipiens*), shoal grass (*Halodule wrightii*), manatee grass (*Syringodium filiforme*), and turtle grass (*Thalassia testudinum*) (Aucoin, 2013; Kramer *et al.*, 2016). Monospecific stands of the transoceanic invasive halophila seagrass (*Halophila stipulacea*) were first reported at Flamingo Bay in Grenada in 2002, where it was suggested that these seagrasses were potentially introduced into Grenadian waters via the fouled anchors of pleasure yachts (Ruiz and Ballantine, 2004). Later, *Halophila stipulace*a was also recorded at other bays (Dragon Bay, Beausejour Bay) in the Moliniere-Beausejour Marine Park of

Grenada (Grenada Ministry of Agriculture, Forestry and Fisheries, 2010) as well as on the leeward coast of Carriacou (Scheibling, Patriquin and Filbee-Dexter, 2018).

Associated fauna

Seagrass beds function as an important habitat, nursery, and foraging ground for numerous marine organisms (Appendix 4). In Carriacou, it was highlighted that seagrasses provided an important habitat for a diverse array of filter-feeding macroinvertebrate fauna (sponges, ascidians, bivalves, ophiuroids) and echinoderm grazers such as sea urchins (*Tripneustes ventricosus*) and sea stars (*Oreaster reticulatus*) (Scheibling, Patriquin and Filbee-Dexter, 2018). Further, it was suggested that the endangered sea stars specifically utilise seagrass beds as a nursery for their juveniles (Scheibling, Patriquin and Filbee-Dexter, 2018). Green sea turtles (*Chelonia mydas*) and hawksbill turtles (*Eretmochelys imbricata*) are also associated with seagrass beds, and they are known to forage in nearshore Grenadian waters (Bräutigam and Eckert, 2006).

White sea urchins (*Tripneustes ventricosus*), commonly known as 'sea eggs', are important herbivores that feed mainly upon turtle grass (*Thalassia testudinum*) and algae. In Grenada and Carriacou, 'sea eggs' are often found in shallow nearshore waters in beds of *Gracilaria* sp., seagrass beds or reefs (Pena *et al.*, 2010). Sea egg harvesting started as a subsistence fishery and traditionally took place on the southern and eastern coasts of Grenada and the east and southwest coasts of Carriacou (Nayar *et al.*, 2009; Pena *et al.*, 2010). Although the fishery thrived in the 1980s and early 1990s, it collapsed in 1994 due to overharvesting. The fishery was subsequently closed in 1995 and then re-opened in 2015 (Nayar *et al.*, 2009; Harvey, 2019).

Throughout their ontogenetic development, queen conch (*Aliger gigas*) depends on a diverse array of habitats, including sandy or rubble seafloors, seagrass beds and coral reefs (Theile, 2001). While juvenile queen conch utilise seagrass beds as nurseries, adults often migrate into deeper waters (Theile, 2001). In Grenada, queen conch is an important coastal resource consumed by locals, marketed as a delicacy in the tourist industry, and exported to nearby countries such as Trinidad and Barbados (European Union, 2013). The main queen conch fishing grounds are on Grenada's northern, northeastern, and southern shelves (European Union, 2013). Subsidiary legislation in Grenada restricts the harvesting of 'immature conch' (size limits and weight limits) (SOFRECO, 2012), but there is currently no closed season for queen conch (Government of Grenada, 1996).

Coral reefs

The total reef area in Grenada is estimated to be approximately 150–160km^2 (Spalding, Ravilious and Green, 2001; Burke and Maidens, 2004). However, this is not inclusive of live coral cover as some reef areas on the southeast side of Grenada do not have any major reef structures (e.g. reef crests) but are carbonate formations covered by algae (Aucoin, 2013). Fringing and patch reefs are present along all coasts of Grenada, while bank barrier reefs are present along the eastern coasts of Carriacou and Petite Martinique (Spalding, Ravilious, and Green, 2001). On the east coast of Grenada, between Telescope Point and Marquis Island, there is one barrier-type reef (Organisation of Eastern Caribbean States [OECS], 2004). Several of Grenada's offshore islands also have coral reefs associated with them (Figure 2.4 "" on page 91). These reefs, which are adjacent to the numerous seabird colonies on the offshore islands, receive substantial nutrients circulated from land to sea by seabirds through guano and spillover effects (see Section 2.3.6) (Coffey and Collier, 2020).

Some estimates suggest that there are approximately 54 species of scleractinian corals (reef forming/ building corals) in Grenada (Aucoin, 2013). Of these, at least 11 species are on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (Aucoin, 2013). Two species are critically endangered: staghorn coral *(Acropora cervicornis*) and elkhorn coral (*Acropora palmata*); two species are endangered: boulder star coral (*Orbicella annularis*) and mountainous star coral (*Orbicella faveolata*); one species is near threatened: blue crust coral (*Porites branneri*); six species are vulnerable: lamarck's sheet coral (*Agaricia lamarcki*), boulder star coral (*Orbicella annularis*), elliptical star coral (*Dichocoenia stokesii*), pillar coral (*Dendrogyra cylindrus*), rough cactus coral (*Mycetophyllia ferox*), and large ivory coral (*Oculina varicosa*) (IUCN, 2021).

Associated fauna

The long-spined black sea urchin (*Diadema antillarum*), a keystone species and generalist herbivore, performs a critical role as a grazer of algae on coral reefs, making grazed substrate available for colonisation by crustose coralline algae, reef-building corals and other benthic organisms (Nimrod *et al.*, 2017) (Appendix 4). In the 1980s (1983–1984), the mass mortality of long-spined black sea urchin populations on coral reefs in the Caribbean resulted in a significant 'phase shift' whereby macroalgae increased and live hard coral cover decreased (Nimrod *et al.*, 2017). In Grenada, recent studies have recorded the long-spined black sea urchin on reefs in southwest Grenada (e.g. Grand Anse Bay), suggesting that there is some evidence of population recovery (Carpenter and Edmunds, 2006; Anderson *et al.*, 2012; Nimrod *et al.*, 2017).

The Caribbean spiny lobster (*Panulirus argus*), a commercially-important species harvested for human consumption in Grenada, utilises several coastal ecosystems (mangroves for spawning, seagrasses as nursery for juveniles, coral reefs for habitat, and foraging ground for adults) during its ontogenetic development (Cruz and Bertelsen, 2009) (Appendix 4). Adults specifically utilise coral reefs in Grenada for foraging as well as a primary habitat. Although the lobster fishery in Grenada accounts for only 1% of the total catch, it is a significant contributor in terms of value (SOFRECO, 2012). Throughout much of its range in the Western Central Atlantic, the Caribbean spiny lobster is reported as fully overexploited (Cruz and Bertelsen, 2009). Subsidiary legislation in Grenada 1) restricts the harvesting of undersized, moulting and egg-carrying lobsters, 2) specifies the methods (hand, loop, trap, pot) via which lobsters can be harvested, and 3) specifies a closed season (May 1st to August 31st) for the harvesting of lobsters (Government of Grenada, 1986).

Protected areas

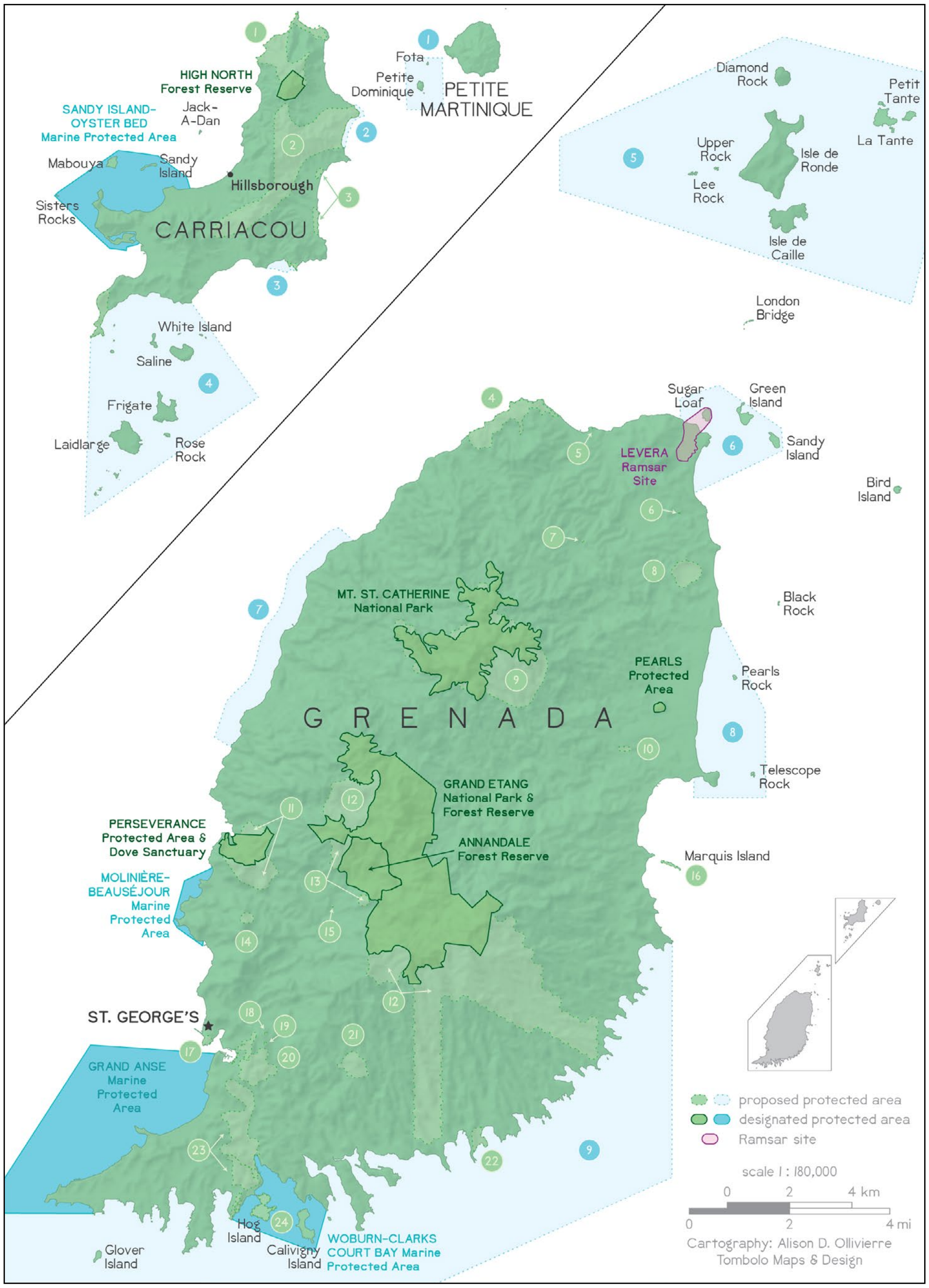
As part of the Caribbean Challenge, Grenada aims to protect as much as 20% of its natural resources and establishing new Protected Areas (Figure 2.6 on page 96) is one of the island's main tools to achieve this goal. To date, numerous Protected Areas are proposed, with some having draft management plans. As we show below, however, there are only four designated and gazetted Marine Protected Areas: 1) Sandy Island Oyster Bed; 2) Molinere-Beausejour; 3) Grand Anse; and 4) Woburn.

2.3.3. Deep ocean

Although Grenada's open ocean and deep ocean occupy a large proportion of its exclusive economic zone (EEZ), it is largely understudied. Grenada's open and deep ocean areas are home to many species, including those that are commercially important and highly valuable. These open and deep ocean species, such as bigeye tuna (*Thunnus obesus*) and yellowfin tuna (*T. albacares*), tuna-like fishes, Atlantic sailfish (*Istiophorus albicans*) and swordfish (*Xiphias gladius*), account for ~70% of the reported landings (FAO, 2018), although, several of these species are considered overfished globally (IUCN, 2021).

The vast majority of Grenada's deep ocean remains unexplored and uncharacterised as there have only been a handful of biological research expeditions, especially of the water column. The little exploration that has occurred indicates that Grenada's deep ocean abounds with habitats that could be considered Vulnerable Marine Ecosystems (VMEs) or Ecologically or Biologically Significant Marine Areas (EBSAs) (i.e. coral and sponge gardens, methane seeps).

The most well-known area of Grenada's deep ocean is around the active submarine volcano, Kick-'em-Jenny, which has had both the crater at the summit and the deep slope explored by a Remotely Operated Vehicle (ROV) (Carey *et al.*, 2014a; Carey *et al.*, 2014b; Carey, *et al.*, 2015a; 2015b). At the summit (190-260m), high temperatures of fluid and gas venting (up to 250°C) have been detected, especially along the steep walls of the inner crater, as well as white bacterial mats amongst red-orange iron oxides and iron-oxyhydroxide spires/chimneys (Graff, Blake and



Map Disclaimer: The Grenada NEA Team has dedicated significant effort towards researching and producing the most up-to-date map of Protected Areas in Grenada. However, this has been a complex and conflicting process, due to factors such as: a) Lack of clarity on whether the sites were actually designated or putative b) Multiple spatial data sets with significantly conflicting boundaries, for both designated and proposed protected areas c) Different names/naming conventions used in data attributes from published documentation d) Lack of clarity on official names versus commonly used local names e) Separation in ministerial/departmental authority over Marine Areas and Terrestrial Areas. This lack of clarity regarding Protected Areas has been highlighted as a key knowledge gap within the NEA, including a strong recommendation for this to be addressed by the Government of Grenada to improve natural resources management in the country. Given the above constraints, the team ultimately chose to use the online spatial data from the Protected Planet: The World Database on Protected Areas (United Nations Environment Programme World Conservation Monitoring Centre [UNEP-WCMC] and IUCN, 2020) to produce Figure 2.6. However, it should be noted the names of Protected Areas in the map were finalised using OECS (2009) which the Grenada NEA Team determined to be a more authoritative source for site names

Figure 2.6. Marine and Terrestrial Protected Areas in Grenada
(see Appendix 1 for references and data sources)

Wishner, 2008; Carey *et al.*, 2014a; Carey *et al.*, 2016). Kick-'em-Jenny appears to be unique, in that it is a single volcanic system that exhibits the spectrum of chemosynthetic environments, from hot vents to cold seeps (Carey *et al.*, 2014a).

Associated fauna

Invertebrates

There are 473 deep-sea records for Grenada on the Ocean Biodiversity Information System (OBIS), of which 156 species are from nine phyla that were collected between 1879 and 2014 (Ocean Biodiversity Information System [OBIS], 2021). Several of these collected species are deep-sea stony corals, black corals (e.g. *Leiopathes glaberrima*, *Stylopathes columnaris*, *Stichopathes pourtalesi*, *Tanacetipathes hirta*, *Tanacetipathes tanacetum*), and octocorals, which enhance benthic biodiversity as they form essential habitat (OBIS, 2021). There are also many species of sponges, including *Chondrocladia* (*Chondrocladia*) *concrescens* (a carnivorous sponge), *Characella agassizi* and *Calthropella (Pachataxa) lithistina* (OBIS, 2021; Dias, Santos and Pinheiro, 2019; Soest, Beglinger and De Voogd, 2010; Hestetun, Pomponi and Rapp, 2016), as well as several species of foraminifera (OBIS, 2021). Off the coast of Carriacou, the first starfish bed (a channel-filled deposit laid down in >150-200m) was found in the Antilles region and had significant implications for the understanding of the taphonomy and evolution of Antillean echinoderms (Jagt *et al.*, 2014).

Kick-'em-Jenny fauna

There are numerous biological communities associated with Kick-'em-Jenny. The fauna inhabiting the summit included a vent-specific spionid worm, *Malacoceros jennicus*, and cf. *Alvinocaris* shrimp, as well as sipunculids, urchins, cerianthid anemones, moray eels, snowy groupers, torpedo rays and greater amberjacks (Carey *et al.*, 2014a; Graff, Blake and Wishner, 2008). In the deeper areas of the volcano, ten active cold seeps with a downward flow were discovered on the debris avalanche in 2013 and 2014 (Carey *et al.*, 2014a; 2014b; Carey *et al.*, 2015a; 2015b). Their origin in this unusual geologic setting was attributed to the over-pressuring of subsurface fluids caused by the catastrophic collapse of the volcano and subsequent fluid movement downslope (Carey *et al.*, 2015a; 2015b). Chemosynthetic communities were found at all seeps (1800-2100m), including clams, tubeworms, other polychaete species, gastropods, brittle stars, anemones, shrimp, octopods, crabs, *Chiridota cf. heheva* sea cucumbers, and fishes (Carey *et al.*, 2014a; 2014b; Carey *et al.*, 2015a; 2015b). Very large *Bathymodiolus boomerang* mussels with commensal polychaete scale worms (*Branchipolynoe* sp.) were also observed, including the largest specimen of this species ever recovered (36.6cm) (Carey *et al.*, 2014a; 2014b; Carey *et al.*, 2015a; 2015b). The exceptional gigantism and presumed longevity of this species are related to the abundance of nutrients via symbiotic bacteria and the adaptation to fluid flow variability (Cosel and Olu, 1998; Carey *et al.*, 2015a; 2015b). These seep communities show overlap with seeps off Venezuela, Trinidad and Tobago, and Barbados, in the Gulf of Mexico, and the eastern equatorial Atlantic (Olu *et al.*, 1996; Sibuet and Olu, 1998; Amon *et al.*, 2017). Additionally, the large volcanic blocks and sedimented slopes of the volcano were also inhabited by cf. *Anthomastus* corals (Carey *et al.*, 2015). Exploration of the other submarine volcanoes adjacent to Kick-'em-Jenny revealed spectacular underwater lava flow formations (resulting from eruption of highly viscous magma) that were inhabited by a variety of deep-sea corals (Carey *et al.*, 2014). A full biological characterisation of the deepwater ROV imagery collected in 2013 and 2014 is expected soon.

Seabirds

Over 30 species of seabirds have been recorded in Grenadian waters. Flocks of seabirds such as boobies (*Sula* spp.) numbering in the thousands can be observed feeding on zooplankton, squid, and forage fish (e.g. flying fish, sprat) and larger fish year-round in waters surrounding Grenada and the Grenadines. Between April-September, seabird diversity and abundance increase with the return of several breeding species (e.g. brown noddy, laughing gull, bridled/sooty tern). At sea, Sargassum concentrations act as a 'hanging reef', where seabirds (e.g. brown noddies) actively forage for fish concealed underneath. Local ecological knowledge collected from fisherfolk from Grenada and the Grenadines revealed that seabirds are useful indicators for locating schools of bait, subsistence, and commercial fish species (Coffey and Ollivierre, 2019).

Marine mammals

Not much is known in general about cetaceans, their local population status, migration patterns, and ecology within the water of Grenada and in the Caribbean region in general (Romero and Hayford, 2000; Romero *et al.*, 2002a; Bolaños-Jiménez *et al.*, 2014; Gero and Whitehead, 2016; Fielding, 2018; Fielding and Kiszka, 2021;). However, the species of whales that presently inhabit, visit, or migrate through Grenada's waters are showcased in Appendix 5 (Romero *et al.*, 2002b).

From a historical perspective, during pre-colonial times, the indigenous communities that inhabited the region were known to rely heavily on marine resources (Figure 2.7 on page 98). However, most experts agree that as it relates to marine mammals, they largely targeted the Antillean manatee (*Trichechus manatus manatus*) and not cetaceans (Fielding and Kiszka, 2021). There was a small whaling industry at the beginning of the 20th century (Romero and Hayford, 2000) however this had collapsed by 1927.

2.3.4. Forests

Grenada's forest vegetation, not inclusive of Carriacou and Petite Martinique or other offshore islands, covers approximately 58% of its surface (Caribbean Handbook on Risk Information Management [CHARIM], 2016), belonging to four broad classes, based on a system first described by Beard (1949) (Figure 2.8 on page 100). These plant communities span varying geographic conditions, ranging from cool temperatures in high mountainous areas with constant rainfall (20°C, 4,000mm) to warm temperatures with less rainfall (27°C, 1,000mm) towards the coast. Using the classification of Caribbean vegetation from the US Federal Geographic Data Committee (Federal Geographic Data Committee [FGDC], 1997), which is widely used in the classification of forests within the Caribbean and builds on Beard's initial work (Beard, 1949), Grenada's four broad classes include: 1) Dry Scrub Woodlands (i.e. Drought Deciduous and Semi-Deciduous Forest, Forest/Shrub, Shrubland or Woodland, Lowland or Submontane) (7,386ha in 2014) (CHARIM, 2016); 2) Rainforests (i.e. Seasonal Evergreen and Evergreen Forest or Forest/Shrub, Lowland or Submontane) (5,696ha in 2014) (CHARIM,

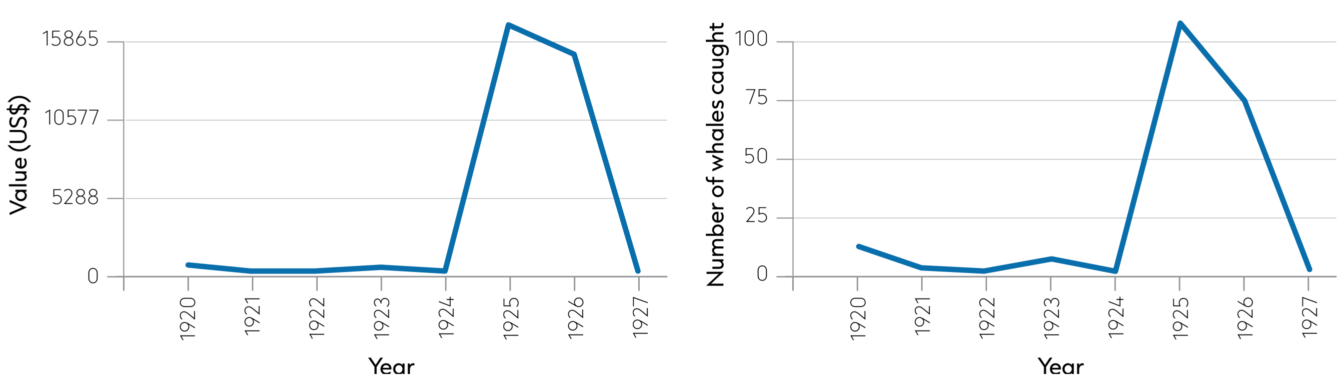


Figure 2.7. Capture rates of historic whaling industry in Grenada

2016); 3) Mountain Thicket, Elfin Woodland and Palm Break (i.e. Evergreen Forest—Cloud Forest and Lower Montane) (8,631ha in 2014) (CHARIM, 2016); and 4) Forested Wetlands (Figure 2.8 on page 100). Though these forest classes can be further delineated, we will focus on these broad categories to discuss the dominant flora and fauna within these forest classes and, further delineate the associated forest sub-classes. Because mangrove forests have been covered under Section 2.3.2, we will only discuss three of the four broad forest classes in this section and their associated native fauna (see Appendix 7 for a list of exotic and invasive terrestrial species).

Forest classes by dominant flora

Earlier work by Beard, which was a departure from Stehlé's approach (Stehlé, 1945) to forest classification using climatic zones exclusively, marked the (Caribbean) region's first shift to using floristics to classify terrestrial vegetation (Beard, 1949). Under Stehlé's forest classification system, there were five forest classes: 1) mangrove; 2) xerophytic forests; 3) mesophytic forests; 4) hydrophytic forests; and 5) altitudinal forests (Stehlé, 1945). Both Beard and Stehlé's forest classifications are based on the understanding that climate, and to a lesser extent soil, determine what plant community would occur along the altitudinal gradient. However, Beard's focus on the composition of plant communities allowed a clearer zonation of forests in the Caribbean, which are determined by specific tree species (i.e. plants that are woody and grow taller than 5 meters). The forest zonation under Beard's classification, from coastline to mountain top, included: 1) Dry Scrub Woodlands; 2) Rainforests; and 3) Mountain Thicket, Elfin Woodland and Palm Break. While zones 1-2 were seasonally dry and had lower rainfall amounts, the third zone was defined by abundant rainfall, lower temperature, and greater exposure to trade winds (Beard, 1949).

Later, in 2008, Helmer relied on the US Federal Geographic Data Committee's standards in his mapping of land cover class in Grenada (Helmer, 2008). The FGDC standards, with respect to the leeward islands, build on Beard's work, subdividing the three non-wetland broad groups into several others (FGDC, 1997; Areces-Mallea, 1999). These subclasses are no different from Beard's broad classes but differ in name, mostly. Below, we use the naming conventions from both Beard and FGDC classifications to describe the three major non-wetland forest classes in Grenada. However, we rely on Beard's work, though dated, to discuss the composition and structure of these forest classes in the sections below [note that for updated common and scientific names, we rely on the classifications from Hawthorne *et al.* (2004)].

Dry Scrub Woodlands (Drought Deciduous and Semi-Deciduous)

As defined by Beard's original 1949 work, this broad forest class is inclusive of coastal vegetation and extends to the interior of the island up until the annual drought is no longer effective in structuring plant communities. Starting from the coast is the littoral woodland (i.e. deciduous, evergreen coastal and mixed forest or shrublands), where plant communities are exposed to sea winds that are ladened with salt, causing much damage to the leaf tissues. While the seaward plants are usually stunted, wind-swept bushes (e.g. paradise plum: *Chrysobalanus icaco*; *Erithalis fruticosa*; frangipani/caterpillar tree: *Plumeria alba*), those behind are taller and evergreen, sheltered from the wind (e.g. white cedar: *Tabebuia pallida*). The dry evergreen forest, which follows behind the littoral woodland, is believed, by Beard's observations, to be heavily modified because of human activity; and in the case of Grenada, much had been cleared for agriculture, leaving little climax forest remaining in the 1940s (apart from in Morne Delice). Thus, much of Beard's inferences come from studying relatively intact forests in Saint Lucia. This forest class is very dense, mostly due to the growth of young saplings or small trees/shrubs in the understory. Though grasses, ferns, mosses, and herbs are absent, bigger trees are buttressed and may be thorny. From Beard's studies of Grenada's dry evergreen forests, he stated that the naked Indian (*Bursera simaruba*) dominates, though other species can be common [e.g. West Indian bay (*Pimenta racemosa*)]. While a transition to the mesic forest, the topography is hillier or generally sloping, contrary to the littoral woodland, which is often flat.

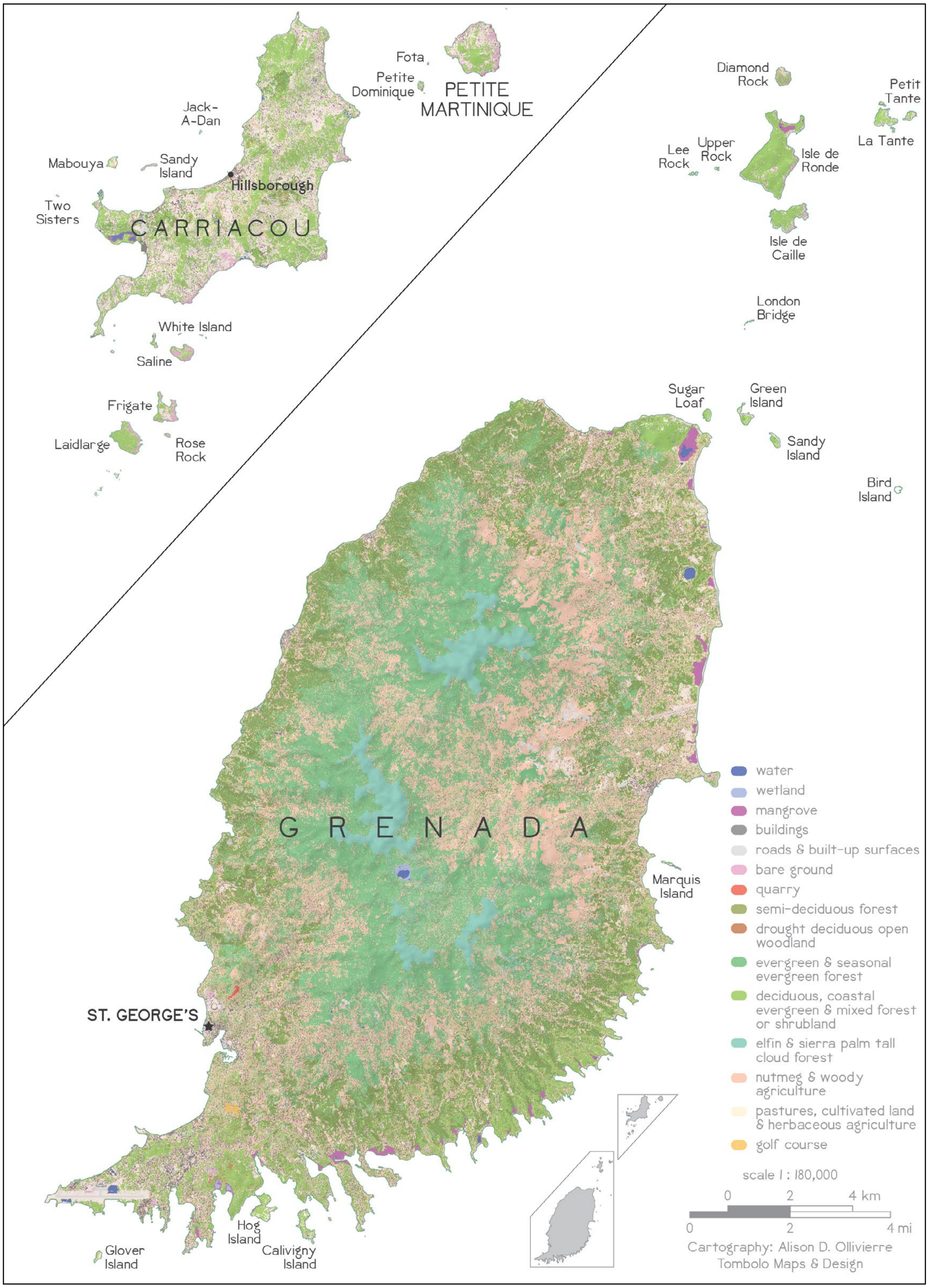


Figure 2.8. Terrestrial land use/cover in Grenada in 2014
(see Appendix 1 for references and data sources)

Rainforest (Seasonal Evergreen and Evergreen Forest or Forest/Shrub)

At altitudes where the annual drought is no longer influential, Beard proports a transition to the rainforests typical of the tropics. On most Caribbean islands, there are two subclasses, but Beard reports that in Grenada, the true rainforest and lower montane rainforest are nearly indistinguishable. Contrary to the lower elevation forests, which have disproportionately undergone damage to accommodate an expanding agriculture sector, there is wider availability of rainforests in a climax state, even in Grenada. The wet conditions allow for more forest complexity, with epiphytes, ferns, mosses, and small plants being more common. Across the Lesser Antilles, because of a relatively similar relative proportion of dominant species, there is an association of plant communities called the Dacryodes-Sloanea association in the true rainforest subclass. When Beard conducted his surveys in Grenada, he reported that there were 23 species that are part of this association, with *Dacryodes excelsa* (gromier/candlewood) being the dominant native species. From surveys in Grand Etang, Beard reported that the Grenadian gouti tree (*Maytenus grenadensis*) was another tall tree species (30-35m) in the true rainforest class, with breaknail (*Licania ternatensis*), which are usually shorter (5-20m), also being common. In the lower montane subclass, in Grenada and elsewhere, there is a plant association called Micropholis-Richereia-Podcarpus, though Grenada's association is largely dominated by wild balata (*Micropholis guyanensis*). Another key difference between these two subclasses is that trees in the true rainforests are much taller and are at lower altitudes.

Though not in a climax state, Grenada, in the 1940s, had a large expanse of Secondary Tropical Forest. These are areas that were formerly Lower Montane but were cleared for cultivation. Early evidence of these forests was along the Mount Sinai ridge during Beard's surveys. Then, Beard reported that there was a dense crop of balisier (*Heliconia bihai*). Though one would expect extensive tree ferns and bois cendre (*Miconia andersonii*) in these areas, the brown and loamy state of the soil due to prior cultivation, suggested conditions were not optimal for these species as yet. There were other numerous pioneer species, and these included laurier (*Ocotea martinicensis*) and bois rouge (*Guarea macrophylla*), among others.

Mountain Thicket, Elfin Woodland and Palm Break (Evergreen Forest—Cloud Forest)

Farthest inland is the final forest class- Elfin Woodland - dominated by plants that are shorter in stature as they are more readily exposed to trade winds. Closer to the Lower Montane Forest subclass is Montane Thicket, which, in Grenada, was likely modified by fellings for timber/cultivation. Covering the summit of the main watershed from Morne Quaqua south to Mount Sinai, this forest subclass, like Lower Montane Forest, is dominated by wild balata (*Micropholis guyanensis*) (40%), based on Beard's surveys in the 1940s. Also common were species in the genus *Myrtaceae* (goyavier), taking up as much as 19% of the surveyed area, and breaknail (*Licania ternatensis*), mountain cabbage (*Euterpe dominicana*) and *Dacyrodes excelsa*, mountain almond (*Richeria grandis*) also common but occupying less area (11, 9, 5, 4% respectively). Beard also reported nearly no shrub layer, and epiphytes were mostly small orchids and ferns, with a few climbers. Ground vegetation, however, consisted of typically Montane Thicket plants- seedlings, ferns, and razor grass. Even further inland, there is a transition to the final subclass- Elfin Woodland and Palm Break. The vegetation typically on the slopes of Mt. St. Catherine and Fedon's Camp are quite representative of this forest class. Here, we see bare earth because of recent slides, while areas covered in moss are indicative of locations that would have undergone slides less recently. The next stage is the thicket of small tree ferns or baliser. The final stage is that of a Palm Break colonised by *Euterpe globosa* (Palm Break), often measuring no taller than 3m. Also common are irregular clumps/groves of other *Euterpe* spp. (16-18m).

Associated fauna

Grenada, and the Grenada Bank, is home to hundreds of birds, mammals, amphibians, and reptiles. While insects are also part of these terrestrial ecosystems, the lack of extensive studies on insects make it

difficult to adequately inventory what is present on the island. As such this section focuses on native/naturalised taxa for which data are more readily available, namely birds, mammals, amphibians, and reptiles (Appendix 2, Appendix 3, Appendix 6). For a list of exotic and invasive species on the island, see Appendix 7.

Birds

Though Grenada's bird diversity is generally low when compared to other Caribbean islands (Heathcote *et al.*, 2021a), land birds in Grenada do show evidence of adaptations that allow them to persist in a more diverse habitat (Heathcote *et al.*, 2021a; 2021b). Based on their analyses of data from Lepage (2018), Heathcote *et al.* (2021a) report that apart from Montserrat, which has 122 species, Grenada had the lowest bird diversity among 23 Caribbean islands and Venezuela (i.e. having 177 species of residents and migrants across all guilds). Earlier work by Wunderle (1994) suggested a land bird richness of 34 species in Grenada. After measuring the morphological traits of four land birds on Grenada- bananaquits (*Coereba flaveola*), black-faced grassquits (*Melanospiza bicolor*), Lesser Antillean bullfinches (*Loxigilla noctis*), and common ground doves (*Columbina passerina*), Heathcote *et al.* (2021b) reported that Grenada's land birds had morphological adaptations that allowed more generalist foraging. For instance, they reported that Lesser Antillean bullfinches and bananaquits had longer tarsi, while Lesser Antillean bullfinches had larger wings. The authors concluded that these differences in morphological traits with Grenada land birds could be explained by increased predator pressure by mongoose, introduced in the last 200 years (Groom, 1970) and a warmer climate. Simply, having longer tarsi/legs can allow a greater take off acceleration (Lind *et al.*, 2010), and longer/larger wings assist in faster escape speed (Provini *et al.*, 2012) – both helpful in evading predators like mongoose. A smaller body size, however, allows these birds a greater ability to dissipate heat (Clegg and Owens, 2010).

Even with low bird diversity, Grenada does support regional and island endemics – some of which are low in abundance. Grenada's only endemic land bird species – the Grenada dove (*Leptotila wellsi*) – is critically endangered and is largely limited to two subpopulations in the south of the island in dry and moist forests: Mt. Hartman and Perseverance (Rusk, 2017). Based on the territorial mapping between 1987-2007, Rusk (2017) reports between 136 and 182 individuals, while a population census by Rivera-Milán *et al.* (2015) in 2013 suggests a population size of fewer than 250 individuals. Also rare, but an endemic subspecies, is the Grenada hook-billed kite (*Chondrohierax uncinatus mirus*), which is believed to be isolated to areas with a vast array of older growth forests (i.e. taller, larger trees) (Campbell, 2019), where tree snails are more widely available (Smith, 1988). Earlier surveys by Thorstrom and McQueen (2008) between 2000 and 2006 suggest that there are fewer than 75 individuals are on the island, while a more recent survey Campbell (2019) using both point count and road-transects, suggests that kites are increasingly rare. The Antillean broad-winged hawk is a regional endemic subspecies and is widely abundant, though with a possible preference for treed agricultural and urban habitats (Campbell *et al.*, 2022). The Grenada flycatcher (*Myiarchus nugator*), bananaquit, and Lesser Antillean tanager (*Stilpnia cucullata*) are regional endemics species, and are quite ubiquitous on the island (Bergen, 2020; Williams, 2020); though the Lesser Antillean tanager, along with other nectroeirs and gaveonrious species, seem to prefer forested habitat (Williams, 2020) at higher elevations (Devenish-Nelson and Nelson, 2021). Bird diversity and abundance does generally appear to increase at higher elevations and closed canopy habitat in the dry season (De Ruyck, 2023). Both the Grenada flycatcher and bananaquit also show habitat preferences; the Grenada flycatcher (Devenish-Nelson and Nelson, 2021) and yellow morph of the bananaquit (Wunderle, 1981) are more common in drier, lowland habitat. A more recently identified endemic subspecies is the house wren (*Troglodytes aedon grenadensis*) which is widely abundant with adaptations occurring in both urban and forested habitats (Cyr *et al.*, 2020; Wetten, 2021). For a full list of land birds in Grenada, based on eBird data from 2013 to 2022, see Appendix 3. Appendix 2 shows how community composition varies by habitat type.

Mammals

Published reports from the National Biodiversity Reports (Government of Grenada, 2014) show that 15 known native mammalian species found in the State of Grenada, including four terrestrial species and 11 bats; however, recent population data on these taxa are lacking. Groome's work in the 1970s is the main (recent) historical reference of native mammals, which detailed accounts of native mammals occurring during that period.

Each of Grenada's non-flying terrestrial mammals are game species, and these include the Mona monkey (*Cercopithicus mona* ssp.), common opossum (*Didelphis marsupialis* ssp.), nine-banded armadillo (*Dasypus novemcinctus* ssp.) and Robinson's mouse opossum (*Marmosa robinsoni*). There was a fifth species, but it is now extirpated – agouti (Dasyprocta sp.). Of these four mammal species, much of the published work has been on the Mona monkey – a charismatic megafauna for which Grenada's tourism industry capitalises on viewings within its natural habitat. Glenn and Bensen (2013) argue that the Mona monkey's preference for interior, mesic forests, where habitat loss and fragmentation was minimal when they were introduced, allowed the population to grow unperturbed soon after they were introduced in the mid 1700s. Though population estimates by Glenn from 1994 to 1995 suggest that there were thousands of individuals in Grenada (Glenn, 1996; 1998), more recent work by Gunst in 2014 suggests that the population has declined due to natural disasters (i.e. Hurricane Ivan) and further illegal hunting practices (Leca *et al.*, 2015; Gunst *et al.*, 2016).

Unlike the well studied Mona monkey population trends, the nine-banded armadillo and Robinson's mouse opossum have not been as well studied. For the common opossum, however, a pilot survey by Forestry Division personnel using distance sampling along transects in 2012 suggests a population density of 29.7 (±5.26SE) individuals/km^2 (Nelson, 2013). The Forestry Division does regulate hunting activity on these non-flying terrestrial mammals relying on open (October to December) and closed seasons (throughout the rest of the year); however, the efficacy of this system is disputable without continuous, standardised monitoring.

Among Grenada's terrestrial mammalian species are bats. Hoffman *et al.* (2019) found that elevated species richness among bats was linked to habitat diversity and climate, thus a likely indicator of habitat quality. Despite Groome's (1970) recorded 11 native species of bats, Genoways *et al.* (1998) suggest upwards of 13 species found from 1967 to 1989 on the mainland of Grenada. More recently published is the increasing study of one species' connection with the rabies virus. In a study done with the Jamaican fruit bat (*Artibeus jamaicensis*), results suggested that these were reservoirs for the virus and found in four of Grenada's six parishes (Price and Everard, 1977; Zieger *et al.*, 2017). The resulting disease affects the brain and nervous system and is spread through bite or scratch. Bats are a known vector of the virus, which can be potentially lethal to humans directly or indirectly through infected livestock and/or domesticated animals.

Amphibians

Published works document the presence of four terrestrial amphibian species inhabiting the island of Grenada. Overall, these are limited to accounts of their presence and origin (Groome, 1970) in addition to some information of their local distribution and population trends. Of these, the Grenada frog (*Pristamantis euphronides*) is endemic to the island and is one of two species endemic to the West Indies region. Harrison *et al.* (2011) describe the reclassification of its former genus, *Eleutherodactylus* – Leptodactylodae family, now reassigned to the distinct Strabomantidae family. The other whistling frog on Grenada is Johnstone's whistling frog (*Eleuthrodactylus johnstonei*). It has its geographic origin in the southern Lesser Antilles, though not Grenada (Kaiser, 1997) and is considered invasive and is widespread across most habitat types that vary in elevation, quality, and human disturbance. A popular train of thought is that this species competes with the Grenada frog, which was also once widespread, now restricted to undisturbed rainforests (Germano *et al.*, 2003).

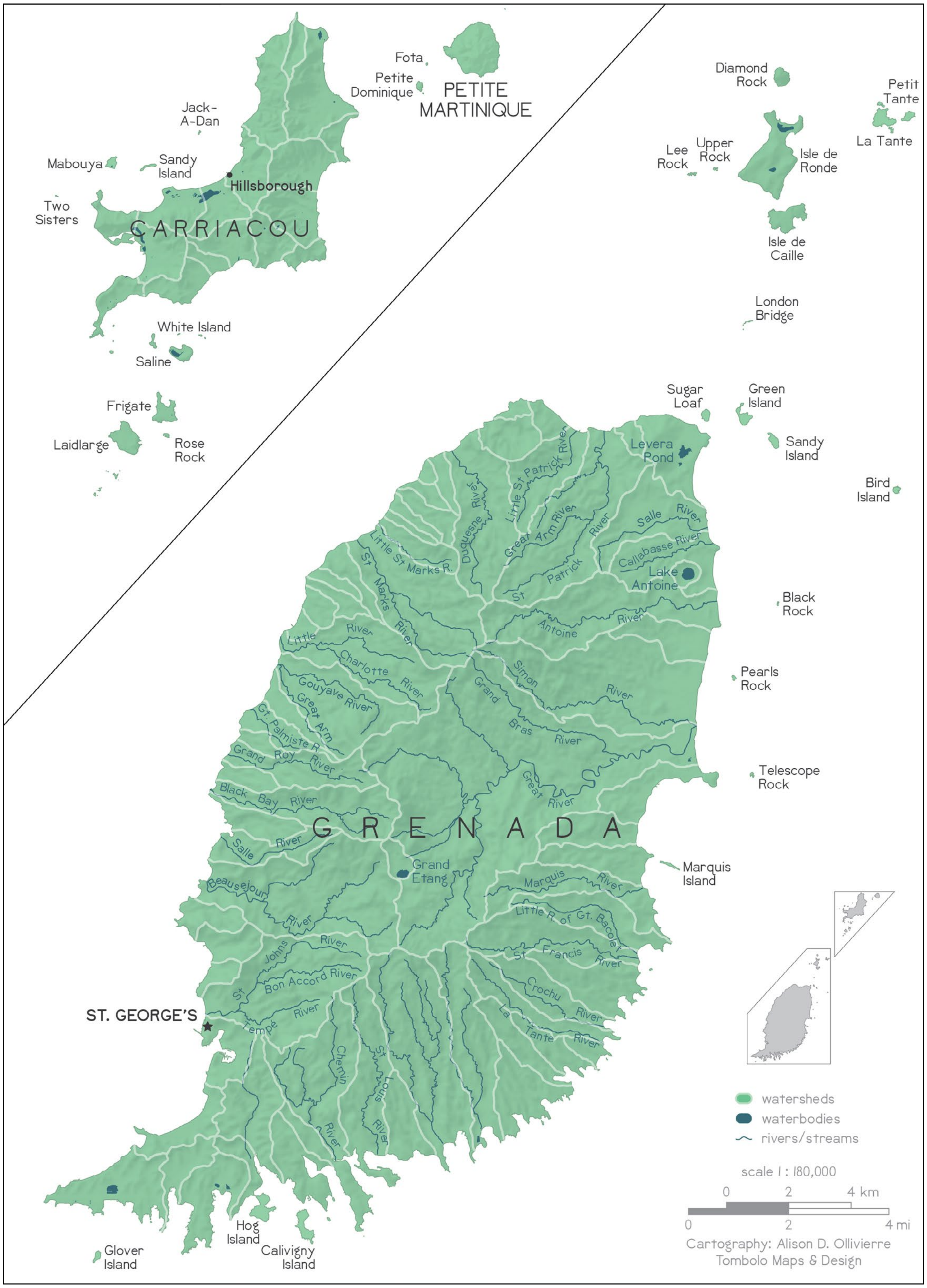


Figure 2.9. Watershed extents, and location of rivers/streams, in Grenada
(see Appendix 1 for references and data sources)

Harrison's study (2011) described the Grenada frog population showing a declining trend while noting the prevalence of chytrid fungus (Chytridiomycosis) among surveyed species – a fatal disease to amphibians and known to cause extinctions. With the cumulative effects of habitat loss and competition by the invasive whistling frog, the Grenada frog has deemed an endangered species (Henderson *et al.*, 2006; Powel *et al.*, 2012). Other amphibians documented include the insular populations of Windward ditch frog (*Leptodactylus validus*)- another regional endemic- and the introduced cane toad (*Rhinella marina*). Both these species' status is currently of the least concern.

Reptiles

Past accounts of terrestrial reptiles document two distinct groups found in Grenada, namely lizards (Lacertilia) and non-venomous snakes (Ophidia) – both described in Groome (1970) and Malhorta *et al.* (1999) (see the complete list in Appendix 6). Among these include two snake species and one lizard species that are endemic to the island of Grenada and the region of Grenada, St. Vincent and the Grenadines respectively.

The Grenada tree boa (*Corallus grenadensis*) and the Grenada bank blind snake (*Amerotyphlops tasymicris*) are two endemic snake species found on the island of Grenada. The Grenada tree boa is found throughout the island's forested areas with a population density that decreases with elevation. Henderson (2011) estimated that the Grenada tree boa is in decline from habitat loss due to development and with an estimated 7500 ± 500 individuals. This nocturnal species also preys on small rodents (*Rattus* sp.), and likely plays a functional role in ecological pest control (Sajdak, 2016). Insular populations of Typhlopidae are documented throughout the Caribbean with origins traced likely from Northern South America. The *Amerotyphlops* sp. are seen to be endemic wherever they are found; however, some distinct species show similar characteristics. Wilson *et al.* (2020) demonstrates this when comparing morphological features of *Amerotyphlops* sp. found in both Grenada and the St. Vincent Grenadines. The blind snake was recently reassessed for its status, which is now endangered (Henderson, 2011). With the paucity of Grenada blind snakes and continued degradation in areas where they occur, Henderson (2021) believes that this species should be reassessed and changed to critically endangered status.

Protected Areas

Just like Marine Protected Areas, Terrestrial Protected Areas are one of Grenada's tools to increase the 20% of its natural resources that are protected under the Caribbean Challenge (Caribbean Challenge Initiative, 2022). Under Section 2.2.2, we provided a map of both Marine and Terrestrial Protected Areas (Figure 2.6 on page 96 Here, we refer to this map and focus on gazetted Protected Areas: 1) Grand Etang Forest Reserve; 2) Annandale Forest Reserve; 3) Grand Bras Forest Reserve; 4) Levera Ramsar Area; 5) High North Forest Reserve (Carriacou); 6) Mt. Moritz Forest Reserve; 7) Mt. Gazo Forest Reserve; 8) Mt. St. Catherine Forest Reserve; 9) Mt. Hartman National Park and Dove Sanctuary.

2.3.5. Freshwater

Grenada is divided into 71 watersheds (Ravndal, 2019) (Figure 2.9). There are no permanent streams on Carriacou, Petite Martinique or any of the offshore islands (Paterson, n.d.). The freshwater habitats are dominated by lotic habitats originating as small streams in upper elevations. Typical substrata consist of boulders, rocks, and cobbles (Bass, 2004). Some streams remain narrow all the way to the sea, while others merge to form larger rivers as they approach the coast (Bass, 2004). Streams have considerable riparian input (leaves etc.), especially at the upper elevations, where they run primarily through forested areas. The most significant lentic habitat is Grand Etang Lake, a crater lake which empties into the Great River (OECS, 2007). There are several small ponds at low elevations (Bass, 2004; Charles, 2018), and Grenada also has several geothermal springs (Aucoin, 2018).

Associated fauna

Grenada's freshwater habitats support 19 native fish species. Some of these species are primarily marine or estuarine, though spending at least some time in freshwater areas (see Appendix 8). In addition to these native species, there are 6-7 known exotics. The distribution and abundance of the native freshwater fish populations are unclear, and data are lacking; it cannot be ruled out that overharvesting and other factors have led to a concerning decline in several species, including *Sicydium plumieri* (tritri) (Groome, 1970).

More than ten species of native decapod crustaceans can be found in Grenada's rivers and streams, and several of these are harvested for food (see Appendix 8). At least 10 species of freshwater snails have been documented, including the exotic species *Melanoides tuberculata*, which is described as "abundant and widespread" in Grenada (Bass, 2004) (see Appendix 9).

In terms of amphibians, only one native species is known – the endemic frog *Pristimantis euphronides* (Kaiser, 1994). This species is found in Grenada's Forest Reserves but does not spend any part of its life cycle in streams. Exotic amphibians include *Eleutherodactylus johnstonei* (also on Carriacou), *Leptodactylus validus* and *Rhinella* marina. Recently, the exotic Cuban treefrog, *Osteopilus septentrionalis*, has been recorded – although not yet established (Somma and Graham, 2015).

2.3.6. Offshore and uninhabited islands

Proportionally, island ecosystems support more biodiversity than their respective mainland; as such, they are the focus of global biodiversity preservation (Rendell *et al.*, 2014). There are approximately 60 uninhabited islands, islets, cays and rocks in Grenada. Satellites of mainland Grenada and the offshore Grenadine islands range in size from <1-265ha with a cumulative surface area of ~600ha. Each of these islands is found on the relatively shallow Grenada Bank, the majority of which are considered part of the transboundary Grenadines archipelago shared between Grenada and St. Vincent and the Grenadines and recognised as a biodiversity hotspot (Coffey and Collier, 2020). While many of these offshore islands feature habitats previously discussed, they have additional ecologically unique characteristics.

Habitat features/classes

Most of these islands are of volcanic origin with wave-cut cliffs and rocky outcrops (Howard, 1952). Beaches are typically shell sand, coral sand or black volcanic sand. Some of the islands are former volcanic plugs and feature unique formations, such as the striking polygonal columnar basalt formations characteristic of White and Mushroom/Cola Island. Terrestrial areas of these islands have shallow soils dominated by dry forest, scrub, cacti, shrubs, grasses, and xerophytic vegetation, with several also having coastal mangrove forests (e.g. Saline, White, Frigate and Isle de Ronde; see Mangroves, Section 2.3.2) (Beard, 1949; Howard, 1952; Moore, Gilmer and Schill, 2015). Woody vegetation in the Grenadines is typically deciduous, and almost all forests are considered secondary due to being extensively cultivated or altered in the past (Howard, 1952). Rainfall throughout the entire Grenadines, including the offshore islands, is very low in comparison to mainland Grenada.

Unlike the inhabited Grenadines, vegetative communities on most of the offshore islands appear less disturbed, with inaccessible islands being the most intact. Nevertheless, many species of flora have been introduced to islands, especially those that were previously cultivated. Sandy and coral sand beaches exist on several islands, such as Sandy Island (Carriacou), Jack Adan, Saline, Frigate, Mabouya and Sandy Island (Grenada) (see Section 2.3.2), and large boulders are common on many islands. Some of the most spectacular and productive coral reefs in the nation surround the offshore islands, receiving little influence from sewage, pesticides, and marine pollution (e.g. bilge water) originating from and near main islands. Two islands (Isle de Ronde and Saline) have seasonal salt ponds that provide important habitat, e.g. for the resident ruddy duck and migratory birds e.g. great egret and green-winged teal (Coffey and Ollivierre, 2019). The ponds are also sites for 'salt picking' by residents of nearby islands. Rocky intertidal zones of offshore islands are frequent sites for collecting whelks (*Cittarium pica*).

Associated flora

Terrestrial vegetation types at the offshore islands include the following communities: beach, rock pavement, grassland, marsh, mangrove, coastal scrub, cactus thorn scrub and dry/coastal forest (Coffey, 2022; S. Carrington, 2022, personal communication). Stands of *Croton* thickets, *Cordia* thickets, *Leucaena* thickets and *Logwood-Acacia* thickets are common (Howard, 1952). While there have been no recent assessments of vegetation at offshore islands, see Beard (1949) or Howard (1952) for details on floral species at offshore islands. Marine vegetation includes a variety of species, such as seagrass beds (e.g. at Saline Island), providing essential inshore feeding habitat for sea turtles.

Associated fauna

More than 120 species of breeding, non-breeding resident, migratory, restricted-range and regionally endemic birds have been recorded at offshore islands (Coffey and Ollivierre, 2019) (Appendix 2; Appendix 3; Appendix 9), as well as five bat species (Genoways *et al.*, 2010), and a variety of regionally endemic reptile species (Powell and Henderson, 2012). The recently described Grenadines pink rhino iguana (*Iguana iguana insularis*) (Breuil *et al.*, 2019) subspecies has been confirmed present on Mabouya Island (Charles *et al.*, 2021) but is likely present on other offshore islands. Information on invertebrate (e.g. insects) diversity at offshore islands is scant. Many islands have not been inventoried for their biodiversity. Recent discoveries of endemics on other Grenadine islands (e.g. *Gonatodes daudini*) highlight the potential for the discovery of additional endemic, regionally endemic species and/or relict populations formerly more widespread on main islands than on Grenada's offshore islands.

The offshore, uninhabited islands support breeding colonies of at least nine species of breeding seabirds at colonies meeting global and regional BirdLife International Important Bird Area (IBA) criteria, hosting at least 1% of the global or regional breeding population for a particular species (Figure 2.10; Table 2.2) (Lowrie, Lowrie and Collier, 2012).

Table 2.2. Global/Regional important seabird colonies in the Grenada Grenadines (Lowrie, Lowrie and Collier, 2012)

Name of Island	Seabird Colony Meets Important Bird Area (IBA) Criteria	Species triggering IBA Qualification
Petit Tante	Global	Red-footed booby
Diamond Rock	Regional	Red-billed tropicbird, brown booby, red-footed booby, laughing gull
Frigate Island	Regional	Audubon's shearwater, red-billed tropicbird, laughing gull
La Tante	Regional	Red-footed booby
Diamond Rock + Les Tantes	Global	Red-billed tropicbird, brown booby
Les Tantes + Brothers/Sisters (Upper and Lee Rock)	Regional	Red-billed tropicbird, brown booby

Petite Tante for example, has a globally important population of red-footed boobies (*Sula sula*). Diamond Rock has four regionally important colonies (brown booby, red-billed tropicbird, red-footed booby and laughing gull). Frigate Island is thought to host the largest colony of laughing gulls in the Lesser Antilles, with additional regionally important populations of Audubon's shearwater (*Puffinus lherminieri*) and red-billed tropicbird (*Phaethon aethereus*) (Lowrie, Lowrie and Collier, 2012). Sisters Rocks, Rose Rock,

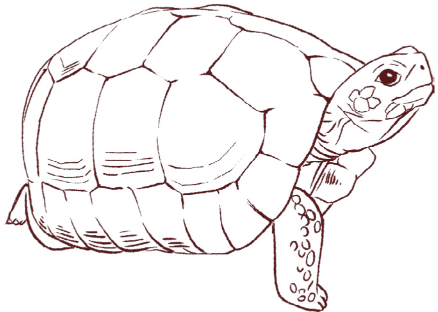
Figure 2.10. Seabird colonies on offshore islands in Grenada
(see Appendix 1 for references and data sources)

Mushroom/Cola, Petit Cola, and The Sisters (Upper/Lee Rock) host important colonies of several species given their inaccessibility, while Jack Adan is an important site for the roseate tern (United States Fish and Wildlife Service [USFWS] Threatened). The demise of such colonies could therefore have consequences for global and regional populations of seabird species (Coffey and Collier, 2020). Of the nine breeding species present, four are listed as Caribbean At-Risk Species (roseate tern, brown booby, Audubon's shearwater and sooty tern) (Bradley and Norton, 2009).

Several additional species were previously known to breed in the Grenada Grenadines but have not been recorded nesting in recent years (e.g. magnificent frigatebird and masked booby). While gulls, terns and noddies nest primarily between May-August annually, other species such as boobies and tropicbirds nest year-round with species-specific peak timing or with no apparent peak. Threats to seabirds therefore (e.g. disturbance, visitation, burning of vegetation) can pose a much greater threat to nesting populations during specific times of the year. The offshore islands additionally provide important nesting habitat for other species such as the scaly-naped pigeon (*Patagioenas squamosa*), carib grackle (*Quiscalus lugubris*), American oystercatcher (*Haematopus palliatus*), little blue heron (*Egretta caerulea*), and yellow-crowned night-heron (*Nyctanassa violacea*) as well as foraging and resting areas for migrating shorebirds (e.g. spotted sandpiper, Wilson's plover, ruddy turnstones, semipalmated plover), land birds (e.g. peregrine falcon, barn owl) and waterbirds (e.g. green-winged teal, ruddy duck) (Coffey and Ollivierre, 2019; Charles *et al.*, 2021). The highest annual counts of brown pelicans in Grenada occur in November in the Sandy Island Oyster Bed Marine Protected Area (Sisters Rocks, Mabouya and Sandy Island) and at Jack Adan, highlighting these sites as a highly important non-breeding, feeding and roosting area for this species.

Many seabird species exhibit high nest-site philopatry, returning to the same islands annually for nesting and raising chicks. The offshore islands provide ideal habitats for seabirds that nest in colonies on remote uninhabited islands. These species nest sympatrically, each utilising different terrestrial habitats such as trees and shrubs, cliffs and crevices, open grassy areas and between cacti, amongst boulders and in burrows, which allow them to overlap on islands with limited interspecific competition for nesting habitat. Where competition can occur, this is often alleviated by differences in species-specific timing. Seabirds circulate nutrients between terrestrial and coastal/marine ecosystems, contributing to surrounding intertidal and coral reef health, enhancing fisheries productivity (Bosman and Hockey, 1986), and influencing terrestrial floral and faunal communities. For example, coral reefs immediately adjacent to seabird colonies have been shown to be healthier and more productive than in areas without the influence of nutrients facilitated by seabirds (Graham *et al.*, 2018).

The offshore islands, in addition to mainland Grenada and Carriacou, provide critical nesting and foraging habitats for hawksbill, loggerhead, and green sea turtles, with the surrounding waters supporting leatherback turtles during their inter-nesting phases (Eckert and Eckert, 2019; Charles, 2019). The leatherback turtle (*Dermochelys coriacea*) is the dominant nesting species in Grenada, followed by the hawksbill turtle (*Eretmochelys imbricata*). Green turtle (*Chelonia mydas*) nesting appears to be rare, and there is no documented nesting by loggerhead (*Caretta caretta*) or olive ridley turtles (*Lepidochelys olivacea*) (Eckert and Eckert, 2019; Charles, 2019). Species differ in their nesting habitat preferences, with leatherback turtles nesting on wider sandy bays (e.g. Isle de Ronde) and hawksbills preferring narrow beaches with foliage bordering the high-water mark (e.g. Isle Caille, White Island and Sandy Island). Green and hawksbill turtles of all ages are present in nearshore waters foraging around seagrass meadows and coral reef habitats (Charles, 2019).



2.4. Trends

Though data on trends in Grenada's ecosystems over the past half century are limited, we rely on spatial data from 1982 to 2014 to quantify recent trajectories in these ecosystems in this section. Assessments are limited to whichever land cover classes are designated in each period; as such, these estimates may not be comprehensive or fully accurate. Trend analyses are grouped by the main method to gather the data- manual digitisation of satellite imagery/aerial photos versus image classification of satellite imagery. The former is the result of manual digitisation of aerial photos by the Land Use Division from 1982 and 2000, and the latter from machine learning classification of satellite imagery by the Nature Conservancy from 2000 (Helmer *et al.*, 2008) and CHARINODE project from 2014 (CHARIM, 2016). By comparing land cover change among these datasets (i.e. 1984, 2000, 2009 and 2014), general trends in the percentage cover of Grenada's ecosystems over the past 40 years are suggested below.

2.4.1. Land Use Division data (manual digitisation)

1982

Agriculture was the dominant land cover class on Grenada in the 1980s (Figure 2.11). As we reported under Section 2.2, with larger estates broken down to smaller residential plots (Griffith, 2015), we would expect a higher dominance of non-tree planting. Beard's surveys in Grenada in the 1940s, confirm that much of the prior true rainforests were in a secondary stage, as they were once used for agriculture, and this dominance of agriculture is common in the 1980s. As we show in Figure 2.11, consequently, cultivated lands were the dominant land cover class, amounting to much as 60% of overall cover. The Aggregate Land Use in 2009 data from the Land Use Division were generated using manual digitisation of satellite

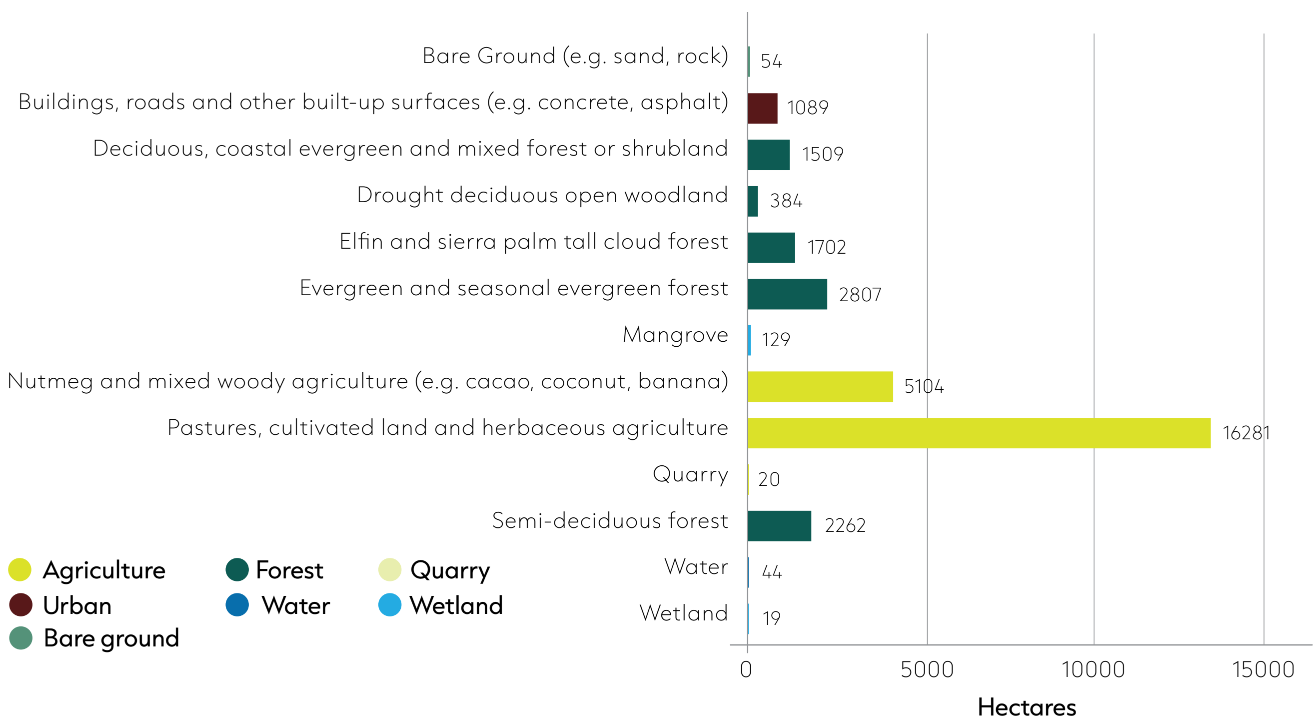


Figure 2.11. Aggregate land use in the 1980s from the Land Use Division

imagery with follow-up ground truthing. These data only include mainland Grenada.

2009

By 2009 following Hurricane Ivan, pastures and cultivated land were the largest land cover class (Figure 2.12; Appendix 10). These data were generated using manual digitisation of satellite imagery with follow-up ground truthing. These data only include mainland Grenada. Semi-deciduous forests were the most prevalent forest class; however, evergreen forests and nutmeg and mixed wood agriculture had nearly equal land cover area. Wetlands (inclusive of mangroves) were one of the least prevalent land cover classes.

2.4.2. Helmer and CHARINODE (Image Classification)

2000

Forests account for the largest proportion of land area, based on image classification by the Nature Conservancy in 2000 (Figure 2.13; Appendix 11). These data were generated using Cloud-free image mosaics from Landsat 7 Enhanced Thematic Mapper (ETM+). These data only include mainland Grenada**.** Of the forest classes, there is nearly equal land area of semi-deciduous and evergreen/seasonal forests, suggesting that rainforests account for the largest proportion of forests overall. The second most common of forest types are dry scrub forests (e.g. deciduous forests), and least common is the montane thicket. Wooded agriculture occupies the largest

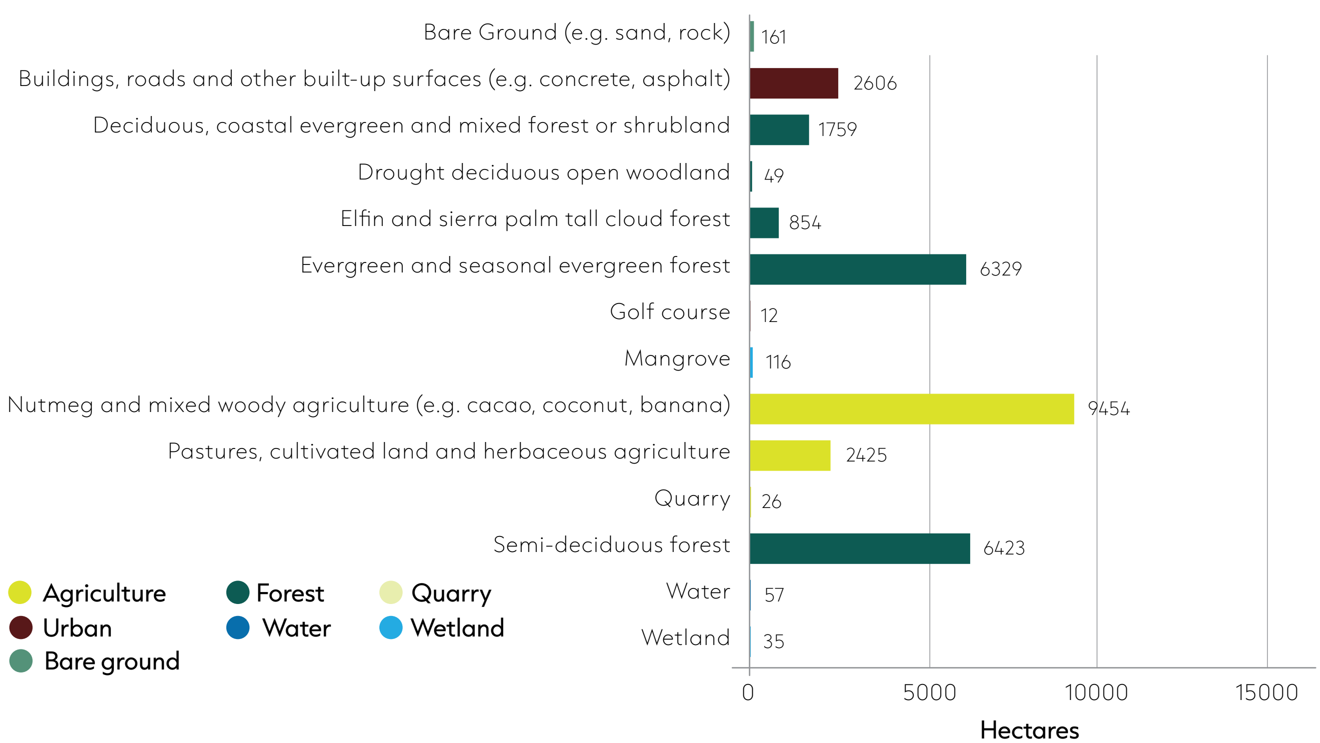


Figure 2.12. Aggregate land use in 2009 from the Land Use Division

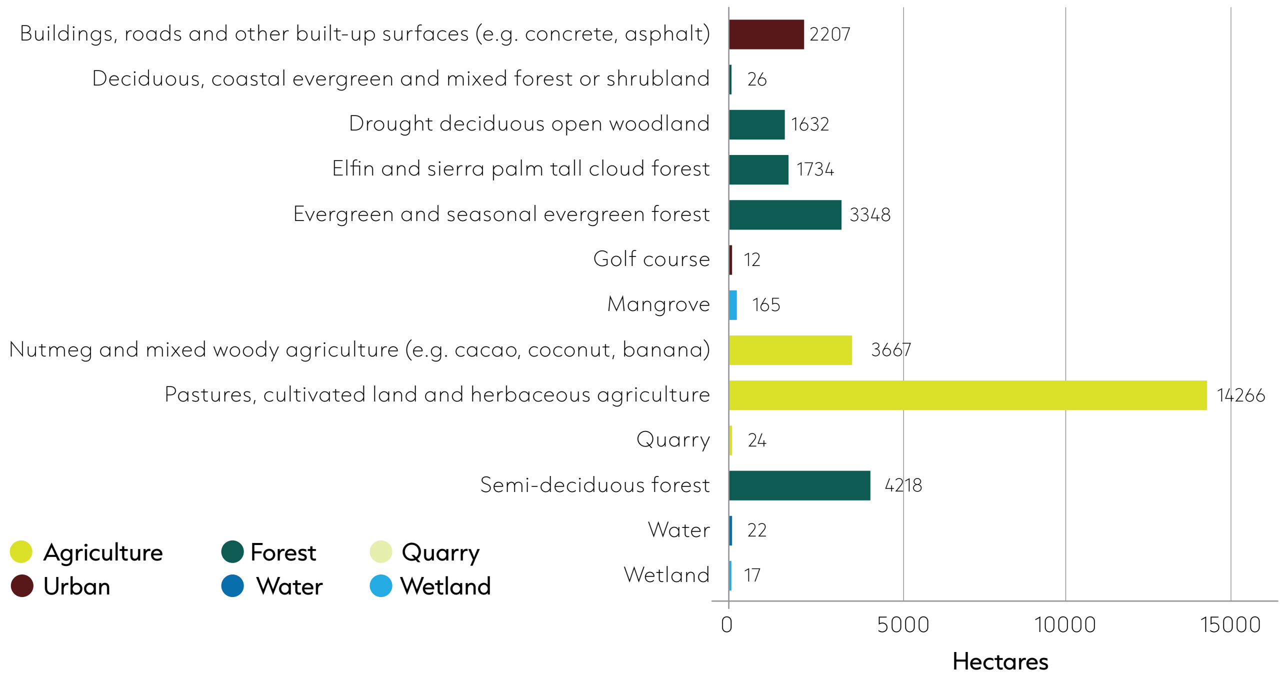


Figure 2.13. Aggregate land use in 2000 from Helmer et al. (2008)

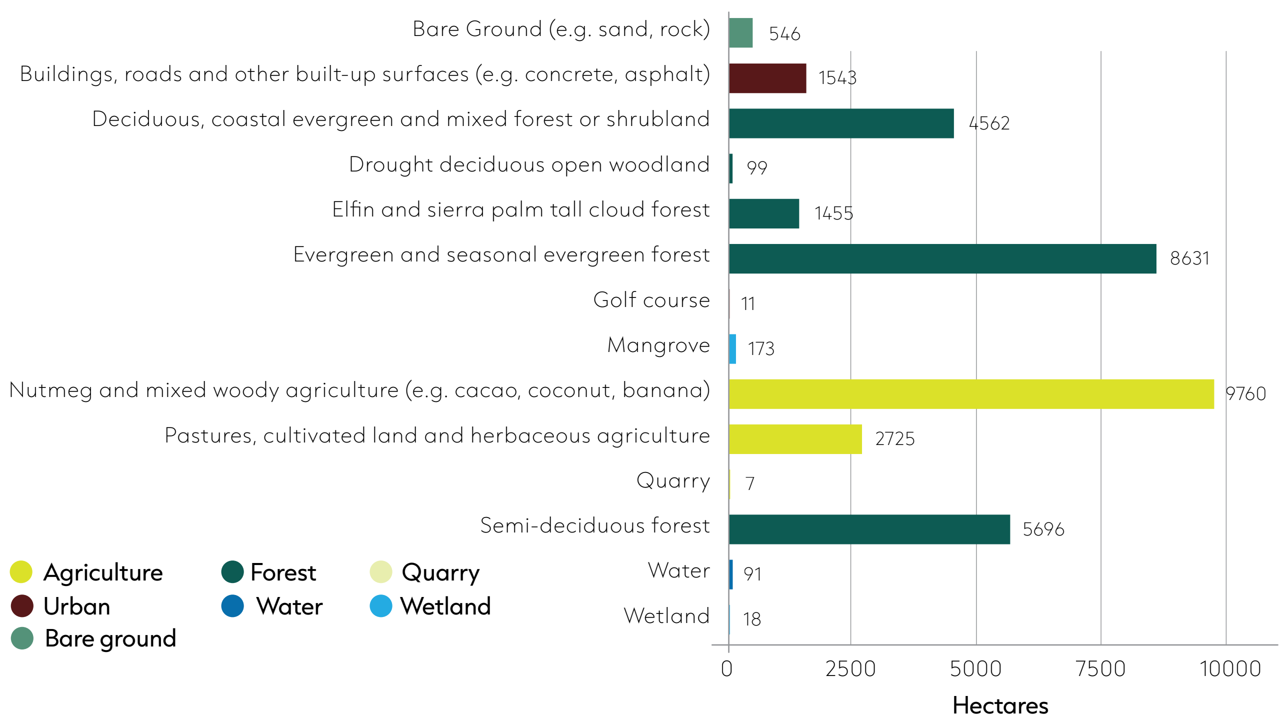


Figure 2.14. Aggregate Land Use in 2014 from the British Geological Survey (CHARIM, 2014). The data were created using Earth Observation satellite data for 2014. These data only include mainland Grenada

percentage of land area, while wetlands and golf courses account for the lowest land area.

2014

Of all land cover groups classified by the British Geologic Survey (CHARIM, 2014), nutmeg and other woody agriculture account for the largest land area class, while forests are the dominant land cover class. Also dominant are deciduous forests and seasonal and evergreen forests (i.e. rainforests) (Figure 2.14; Appendix 12). As with prior years, wetland and mangrove cover are minimal along with urban cover. Quarries and golf courses account for the lowest land area.

2.4.3. Summary of ecosystem trajectories

This section focuses on the change in land cover/land use based on the method used to gather the data- manual digitisation (1982-2009) versus image classification (2000-2014). We thought this was necessary as the absolute changes in land cover from 1982 to 2000 may be more related to the method used to classify the land cover; simply, manual digitisation would result in aggregation of neighbouring land cover classes into the dominant class versus having mixed-use areas reflect the diverse land use activities in those areas with image classification. Simply, with manual digitisation, an area that contains both rainforests and wooded agriculture would be assigned the land cover class that is most dominant in that area. Conversely, image classification would assign the proportion of each land cover class in each area. Consequently, we may overestimate some land cover classes and underestimate others with manual digitisation.

In most cases, the trajectories of these land cover classes are congruent between methods, with a few exceptions (Figure 2.15). Trajectories of land cover classes in Grenada are based on manual digitisation of aerial photos from Grenada's Land Use Division

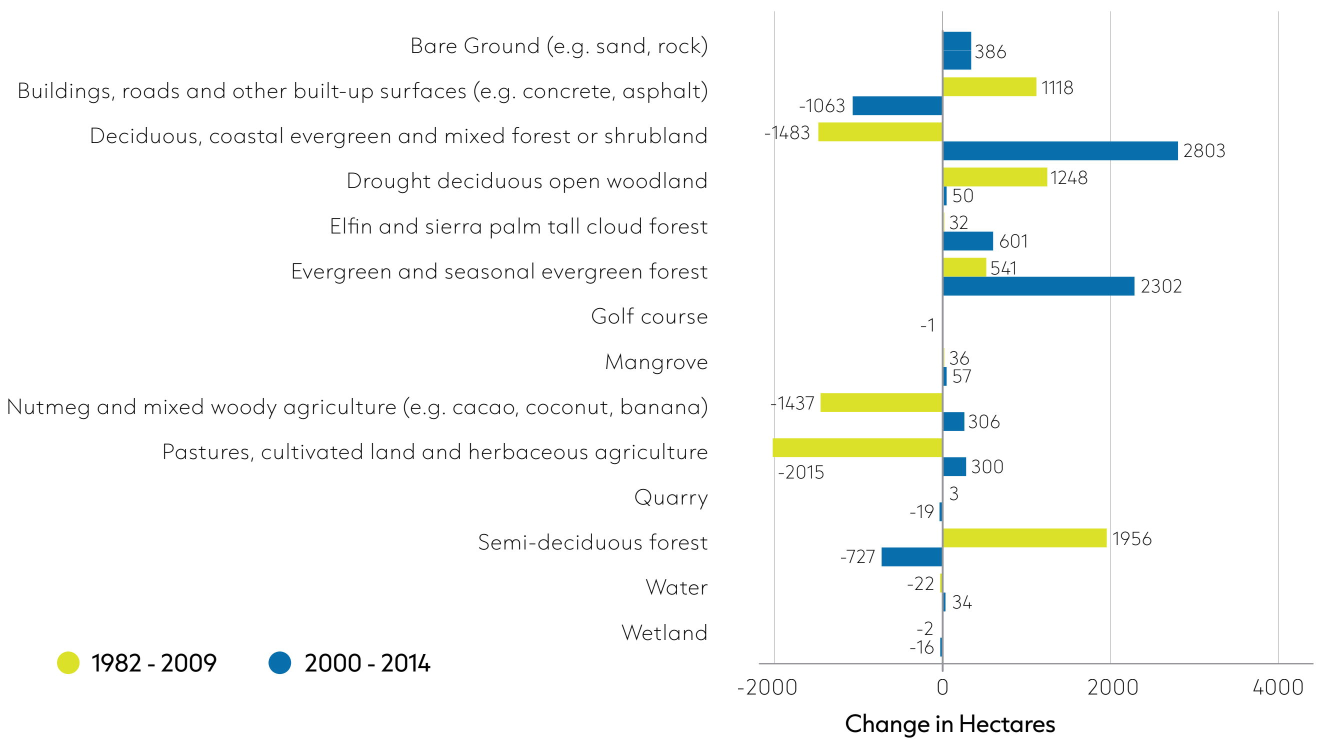


Figure 2.15. Trajectories of land cover classes in Grenada based on manual digitisation of aerial photos from Grenada's Land Use Division from 1982 and 2009, and machine learning image classification of satellite imagery in 2000 and 2014

from 1982 to 2009 and machine-learning image classification of satellite imagery in 2000 and 2014. Both methods suggest that while the wetland area declined, there were increases in mangrove cover, though quite marginal. We caution, however, recent losses in mangrove cover to accommodate coastal development in 2020 would suggest a declining trend in mangrove cover and not an increase (BirdsCaribbean, 2020; Buckmire *et al.*, 2022), even with small-scale restoration projects around Grenada (Grenada Fund for Conservation, 2019; Beck *et al.*, 2020). Also congruent are increases in all forest classes, apart from semi-deciduous and deciduous forests. There were contradictory results for agricultural lands- with one method suggesting broad declines and the suggesting increases- this may be explained by a difference in time periods that these layers cover. We suspect that following the breaking up of the "plantocracy" in the 1980s, there were shifts to nutmeg and mixed wood agriculture into the 2000s. However, by the 2000s, any increases in agriculture were likely marginal.

2.5. Threats to Ecosystems

While there are both anthropogenic and natural threats to Grenada's ecosystems, we focus on threats in five major groups: 1) diseases; 2) habitat loss and degradation; 3) invasive species; 4) pollution; and 5) overexploitation. Each section below succinctly describes how these various threats affect ecosystems. We note, however, that these threats, while expansive, do not include all threats; and that they do not exist in isolation. Synergies between threats are important and may result in increased impact compared to individual threats.

2.5.1. Diseases

Within the past few decades, numerous epizootic events and disease outbreaks have been reported in coral reefs within the Caribbean Region. Recent studies conducted in both shallow water (Valleys, Flamingo Bay) and deep water (>15m, Valleys) habitats in Grenada have reported incidences of 1) White Plague Type II (WP-II) in *Diploria* colonies, 2) Black Band Disease (BBD) in *Diploria* colonies, 3) Black Band Disease (BBD) in *Siderastrea* and *Montastraea* colonies, 4) Aspergillosis (ASP) in *Gorgonia ventalina*, 5) Dark Spot Disease (DSD), 6) White Band- White Spot Syndrome (WBS) in crustose algae, 7) Purple band in colonies of *Siderastrea siderea* and *Siderastrea intersept*a and, 8) Other Syndromes (Weil, 2004; Cróquer and Weil, 2009). Apart from anthropogenic stressors, the hatch success of leatherback turtle nests in Grenada was also shown to be impacted by pathogens (Zieger *et al.*, 2009; Choi *et al.*, 2020).

For terrestrial ecosystems, the prevalence of diseases is less well known, apart for a few taxa. Rabies, which is endemic and likely introduced from Europe, spread from the northeast to southeast of the island between 2011 and 2014 and was detected in mice, dogs, cats, and goats (Zieger *et al.*, 2014). Zieger *et al.* (2014) also posits that the small Indian mongoose (*Urva auropunctata*) is a reservoir for rabies in Grenada [but also Leptospirosis as reported by Everard *et al.* (1976)] (Choudhary *et al.*, 2013; Miller *et al.*, 2015; Jaffe *et al.*, 2018). Rabies was also detected in Grenadian bats in a later study (Zieger *et al.*, 2017), and Hantavirus in rats (Sharma *et al.*, 2019). Both domesticated and wild birds also showed evidence of diseases; in a 2011 study, authors detected evidence of Infectious Bronchitis in 31% of the individuals they sampled (Kumthekar *et al.*, 2011), and authors in another study reported a 47% prevalence of haemo protozoans among wild and domestic birds (Ricklefs *et al.*, 2011; Tiwari *et al.*, 2012). Yet another taxon affected by diseases is frogs – chytrid fungus has been detected in Grenada's cane toads (Drake *et al.*, 2014), and it is not yet clear its prevalence among other frog species.

2.5.2. Habitat loss and degradation

The loss and degradation of habitat is, arguably, the largest threat to Grenada's ecosystems. Both anthropogenic activities and natural events can lead to habitat loss and degradation, which we cover in this section: climate change, deforestation, physical development, sand mining, storms and hurricanes, rainfall events, resources extraction, maritime vessels, and recreational activities.

Climate change

Like other Small Island Developing States, Grenada's ecosystems are threatened by a warmer climate coupled with changing precipitation trends and sea level rise – both attributed to climate change. These climate change-associated threats are interlinked – warmer temperatures quicken sea level rise. However, the direct effects of warmer temperatures on Grenada's ecosystems do differ from the direct effects of sea level rise; consequently, we discuss these impacts separately below.

Warmer temperatures and precipitation trends

Warmer air temperatures will have clear impacts on Grenada's marine, aquatic and terrestrial ecosystems, and depending on the magnitude of change in precipitation, we may observe more disastrous impacts on these ecosystems. Based on the Intergovernmental Panel on Climate Change (IPCC) 2022 report, we could expect at minimum, a 1.5°C increase in global surface air temperatures in the near term, even under scenarios with reduced greenhouse gas emissions (IPCC, 2022). Compared to the 1980-1999 baseline, climate forecasts suggest an increase in surface air temperatures in the Caribbean Sea to between 1.8°C- 2.3°C by 2100 under the intermediate scenario (Nurse *et al.*, 2014). Similarly, all climate scenarios for both the 2014 and 2007 forecasts for the Caribbean suggest increases in surface air temperatures (Nurse *et al.*, 2014), which is consistent with recent Regional Climate Models (Climate Studies Group Mona, 2020).

While global climate models suggest high uncertainty precipitation for the tropics (Long *et al.*, 2016), Regional Climate Models for the southern Caribbean suggests there will be a decline (Climate Studies Group Mona, 2020). Under the IPCC reports for the Caribbean, the earlier evaluation, some models suggested a 10% increase in precipitation and others a 10% decline (Mimura *et al.*, 2007). In the 2014 assessment for the Caribbean, only one scenario showed strong consistency in a decline in annual precipitation (i.e. RCP 8.5) as none of the ensemble models forecasted increases (Nurse *et al.*, 2014). Interestingly, more recent Regional Climate Models suggest up to a 25% decline in precipitation by the end of the century in the Caribbean, most pronounced between November to January and in the southern islands (i.e. inclusive of Grenada) (Climate Studies Group Mona, 2020). Regardless, past precipitation trends do suggest: 1) a net decline between June-August (wet season); 2) a decline in the consecutive number of dry days; and 3) an increase in the number of heavy rainfall events (Mimura *et al.*, 2007), which can impact Grenada's ecosystems as detailed below.

Coral reefs and deep ocean ecosystems

Slower warming in the deep ocean encourages a perception that its biodiversity is less exposed to climate change than that of surface waters, but this is not the case (Brito-Morales *et al.*, 2020). Contemporary (1955–2005) climate velocities are faster in the deep ocean than at the surface, suggesting that while mitigation could limit climate change threats for surface biodiversity, deep-ocean biodiversity faces an unavoidable escalation in climate velocities, most prominently in the mesopelagic (200–1,000m) (Brito-Morales *et al.*, 2020). To optimise opportunities for climate adaptation among deep-ocean communities, future open-ocean protected areas must be designed to retain species moving at different speeds at different depths under climate change (Brito-Morales *et al.*, 2020).

Freshwater ecosystems

Climate change is affecting the supply and quality of freshwater in Grenada through saltwater intrusion, extreme floods and droughts, and intense storms. During the October 2009 to January 2010 drought, Grenada recorded its lowest rainfall averages for the past 25 years. As a result, soil moisture decreased, leading to a 150% increase in reported bush fires. Within the agricultural sector, there are reports of saltwater intrusion into groundwater (Center for Responsible Travel, n.d.).

Forest ecosystems

Given that Regional Climate Models for the southern Caribbean suggest a decline in rainfall in the early rainy season (Climate Studies Group Mona, 2020), we may observe a change in forest composition in Grenada. Plants are cued to produce fruit and leaves by the first rains at the end of the dry season (Frankie *et al.*, 1974) and a delay or decline in these rainfall events will result in a delay in these productive periods (Morellato *et al.*, 2016). A delay in these productive periods can result in more arid conditions in areas that previously supported evergreen tree species. Consequently, in Grenada, we may observe an increase in the percentage cover of forest classes dominated by deciduous and semi-deciduous trees, which are cued by rainfall events for leaf production (Tomlinson *et al.*, 2013). This hypothesis is supported by work by Nelson *et al.* (2015), who forecasted that more than 50% of Grenada's land area will become suitable for Dry Scrub and Woodlands due to changes in precipitation timing, intensity and duration.

A decline in rainfall events can have cascading impacts on biota within Grenada's forests. Research in Peru suggests that biomass of arthropods is highest at intermediate levels of rainfall – under drought and extremely wet conditions, biomass is substantially lower (Newell, Ausprey and Robin, 2023). Arthropod abundances in Grenada are at its highest when rainfall levels peak, which initiates moult-breeding among forest birds, even for species considered to be nectarivores, frugivorous, or granivorous (De Ruyck, 2023). Given the importance of arthropod for Grenada's forest birds, a decline in rainfall due to climate change could negatively affect bird diversity and abundance in Grenada.

Offshore islands

Terrestrial habitats could be considerably altered due to changes in vegetation due to climate change (Nelson *et al.*, 2015), which will affect nesting seabirds on offshore islands. Seabirds may experience reduced nesting success and lower survival rates with warmer sea surface temperatures due to a change in the availability of their prey species (Cruz-Flores *et al.*, 2022). With lower survival in previously productive areas, seabirds may undergo change in their distributions, which is likely to affect terrestrial plants and coral reefs with reduced nutrient spillover provided to these ecosystems by major seabird colonies (Caut *et al.*, 2012). Other bird species that use specific vegetation types on offshore islands for nesting may experience a lowered availability of suitable nesting habitat (e.g. scaly-napped pigeon, yellow-crowned night-heron and little blue heron) with the loss of nutrient provided by the relocated seabirds.

Sea level rise

As with other regions, the Caribbean has undergone increases in sea levels in the past century. In the 20th century alone, sea level rise in the Caribbean was 1mm per year. However, this increase was variable in some regions, affected by El Niño and volcanic/tectonic crustal movement in the Caribbean basin (Mimura *et al.*, 2007). Forecasts suggest, however, that an increase in sea level is expected, as much as 1.8 ± 0.5mm per year (Mimura *et al.*, 2007). In another study, Grenada and other islands in the southern Caribbean are expected to undergo an increase of at least 1m (Climate Studies Group Mona, 2020). While the increase expected for Grenada is uncertain, as islands can differ in the tectonic setting and sea surface temperatures (Mimura *et al.*, 2007) the increase in sea level can impact coastal areas as previously-settled/occupied areas are eroded.

Coastal ecosystems

Rising sea levels can have negative impacts on coral reefs, seagrass beds and mangroves. In a study of coral reefs in the Caribbean and Indian Oceans, authors reported that the vertical growth rate in coral reefs is not sufficient to counteract sea level rise (Perry *et al.*, 2018). Under the intermediate climate scenario, reefs are unlikely to grow vertically at sufficient rates in the absence of ecological recovery (Perry *et al.*, 2018). Because coral reefs are necessary to ensure that the hydrodynamics of an area are suitable for seagrass beds, their inability to grow at rates to counteract sea level rise will result in the loss of seagrasses in most areas undergoing sea level rise (Keyzer *et al.*, 2020). Although mangroves are quite resilient, increases in sea level could result in the death of seaward mangroves as there are abrupt changes in the cycle of inundation frequency and duration, exposing some species to salinities and sedimentation rates that they cannot tolerate (Friess *et al.*, 2012; Sasmito *et al.*, 2016; Ward *et al.*, 2016). Thus, increases in sea level rise in Grenada could result in mangrove die-offs along the coast with simultaneous changes in species composition inland, assuming sea level rise inland is not as heightened. Similar trends in coral reefs (die-offs) in the absence of lowered anthropogenic stressors (e.g. water quality) can be also expected.

Low-lying areas, sandy beaches and cays are susceptible to reduction in size due to sea level rise, resulting in loss of sea turtle and seabird nesting habitat, and intertidal foraging opportunities for numerous bird species, such as waterbirds and shorebirds (Coffey and Collier, 2020).

Deforestation

Between 2000 and 2012, Grenada ranked in the top 10 countries for deforestation rates in the world, with an average annual rate of 0.29%. Interestingly, four of the top ten countries were in the Caribbean region. Researchers studying land-based sources of pollution in Carriacou also noted deforestation of some areas as a source of erosion and sedimentation (Williams, 2007; Moore, Gilmer and Schill, 2015). Another study noted clear-cutting by farmers near the Beausejour River, often a greater area than eventually utilised, leading to erosion and sediment runoff. The study also found increased nutrient levels in the Beausejour River after rainfall, suggesting that agricultural chemicals such as fertilisers were also present in the surface runoff (Nimrod, Franco and Andrews, 2013).

Clearing and cultivation of areas near rivers for agriculture can exacerbate the erosion of soils into the rivers and lakes, especially on steep slopes, sometimes even causing landslides. This is an issue for the quality of domestic water supply, and the quantity, as sedimentation of reservoirs reduces their capacity (Paterson, n.d.; OECS, 2007). Grand Etang Lake, for example, is shrinking despite dams, partly due to sedimentation (Cooper *et al.*, 2011). Sites such as Grand Etang Lake and Annandale waterfall are visited by cruise ship passengers among other tourists (Blommestein *et al.*, 2012). Thus, climate change may indirectly impact on the tourism experience.

Physical development

Physical development (e.g. resorts, hotels, marinas, etc.) within the coastal zone of Grenada, Carriacou, Petite Martinique and their offshore islands has resulted in the loss of coastal vegetation. In Carriacou, the construction of a marina at Tyrrell Bay resulted in the loss of 20% of the mangrove vegetation (Moore, Gilmer and Schill, 2015). More recently, the construction of a new resort and luxury hotel resulted in the loss of white mangroves and buttonwood at La Sagesse, Grenada (BirdsCaribbean, 2020). It is projected that mangrove vegetation will also be lost at 1) Mt. Hartman Estate, private property adjacent to the Woburn Clarks Court Bay Marine Park, due to the proposed construction of a resort and marina and, 2) Levera Ramsar wetland due to the proposed construction of a mega-resort (BirdsCaribbean, 2020; Buckmire *et al.*, 2022). Any natural or anthropogenic factors that result in a loss of mangrove vegetation will subsequently impact mangrove-associated fauna due to habitat loss.

Human activities such as the removal of beach vegetation to facilitate coastal development have threatened the ecological well-being of Grenada's beaches (Huber and Meganck, 1990). Coastal vegetation helps with the stabilisation of sediments and when removed, beaches become more vulnerable to erosion during natural events such as storms and hurricanes. One example of the removal of vegetation was at Grand Anse Beach, where mangrove, manchineel and seagrape vegetation were removed to facilitate coastal development (Huber and Meganck, 1990). Within the past decade, Maison *et al.* (2010) highlighted that the construction of an 18-hole golf course adjacent to Levera Beach in 2004 resulted in the removal of coastal vegetation, sediment run-off from the site and deposition of fine-grained sediments onto the beach. Temporal changes in beach profiles as well as beach sediments can influence the spatial distribution of turtle nests and impact the hatching success of nests (Maison *et al.*, 2010).

Freshwater biota is also under threat from development. Several of Grenada's freshwater species have life cycles that involve migrating between the sea and freshwater streams. These include the endangered American eel (*Anguilla rostrata*), the goby *Sicydium plumeiri*, and several freshwater shrimp (crayfish) species (see Appendix 9). These species are extremely vulnerable to any developments that obstruct their passage up or downstream, preventing the completion of their life cycle.

The persistent threat of development is one of the most pressing threats to offshore island ecosystems. Many are privately owned and listed on the international real estate market. Development proposals are often incompatible with the local environment and can cause irreversible change to island ecosystems and extirpations of native flora and fauna. For example, the Levera hotel development plan proposes increased visitation to Sandy Island (Grenada) which would disturb the seasonal colonies of nesting seabirds, likely leading to their abandonment of the colony. Currently, given their remote, relatively inaccessible settings and lack of freshwater, these islands are typically only visited by island caretakers, fisherfolk, hunters and recreationists from nearby islands (e.g. picnic and BBQ) and visitors. Proposed increased visitation to the islands can negatively impact on the flora, fauna and ecosystems on the islands.

Sand mining

Beach sand mining has been occurring in Grenada for a long time; up until 1996, beach sand mining was the sole source of sand for construction in Grenada. On the main island of Grenada, sand has been mined from the following beaches: Grand Anse, Beausejour, Palmiste, Duquesne, Telescope and Content, while on Carriacou, sand has been mined from Harvey Vale, Hillsborough, Lauriston, Jew Bay, and Mt. Pleasant/Grandbay (Huber and Meganck, 1990; Peters, 2000). Sand removal at beaches in the tri-island state has led to beach erosion as well as the destruction of habitats for birds and turtles (Cambers, 1997; Fitzpatrick, Kappers and Kaye, 2013; Reguero *et al.*, 2018). A 1995 estimate put beach sand extraction at 40,000-50,000 m^3/year. (Isaac, 1996). Legal sand mining continued, due to a lack of alternatives, and insufficient application of existing regulations to limit the activity.

Beach sand mining was banned in 2009, due to negative ecological and other effects and sand was imported from Guyana to fill the gap. As of January 2013, beach sand mining was again made legal, but only in three areas (Galby and Grand Bacolet Bay, St. David and the Canals of Mt. Rodney, St. Patrick), and only by the Grenada Gravel, Concrete & Emulsion Production Corporation, a statutory body established by an Act of Parliament (Act 43 of 1986) (Gravel Concrete and Emulsion Production Corporation, 2013; Grenada Government Information Service, 2013). The ban may have had limited success, as there continue to be media reports highlighting concerns about illegal sand mining, as well as notices from the Royal Grenada Police Force reminding persons about the legal consequences of this activity. As recently as 2018, illegal sand mining was identified as an issue in the Gouave, Levera and Bathway areas (Grenada Coral Reef Foundation, 2018). Many in the society recognise that beach sand mining is a risk to both mined beaches and premier tourist beaches like Grand Anse. However, there is a disconnect between the understanding of the problem, and the cessation of the negative activity.

Storms and hurricanes

The tri-island state of Grenada is located within the 'Hurricane Alley' of the eastern Caribbean and the country has experienced several storms and hurricanes of which the most notable are Hurricane Janet (1955), Hurricane Lenny (1999), Hurricane Ivan (2004) and Hurricane Emily (2005). Storm surges generated during such events have resulted in the loss of sediments from beaches (Fitzpatrick, Kappers and Kaye, 2013). Following Hurricane Ivan in 2004, it was estimated that 50% of the beaches in Grenada sustained major damage (OECS, 2004).

Storms and hurricanes have also caused physical damage to coral reefs in Grenada. One such area that has experienced this damage is the reef at Red Rock on the northwestern coast of Grenada (OECS, 2004). Other coastal resources such as seamoss may also be negatively impacted by extreme weather events.

Storms and hurricanes have resulted in defoliation, blowdowns, and in some cases, complete levelling of vegetation in Grenada and its offshore islands (Moore, Gilmer and Schill, 2015). Following the passage of Hurricane Ivan in 2004, 70% of mangrove vegetation in the country sustained damage (OECS, 2004). In Woburn Bay, there was a 50% reduction in mangroves (Moore, Gilmer and Schill, 2015). Seagrass, forests, and watersheds were also impacted by Hurricane Ivan. The relatively small sizes of the offshore islands combined with their exposure to the elements result in coastal and terrestrial habitats and associated flora and fauna being highly vulnerable to extreme weather events.

Rainfall events

Erosion and siltation can also occur from natural sources, and much of this impact is seen in freshwater ecosystems (Williams, 2007). Grenada is a mountainous country, and so it is expected that erosion and sediment runoff could be a problem, even if there was no human interference. This is noted in the Annandale watershed, where it is estimated that up to 80% of the existing Annandale Dam is filled with silt. The slopes of the mountains in this area range from 20 to 30 degrees, and so are at risk of erosion (Springer, 2018). Because Grenada is prone to heavy rainfall, especially in the mountainous areas, general declines in the quality of domestic water supply are often observed, as interior water sources are polluted from surface runoff (Paterson, n.d.). Land-based runoff that contains sediments, as well as nutrients, can also pose a threat to seagrasses, as the former reduces the availability of sunlight and subsequently disrupts photosynthesis while the latter can result in eutrophication.

Resource extraction

There are few current activities resulting in habitat destruction in Grenada's open ocean and deep ocean. However, in 2017, natural gas was discovered in ~180m water depth, indicating that Grenada could explore further and eventually exploit its oil and gas reserves as it has already leased several offshore and deepwater blocks (GEOExPro., 2017). Oil and gas exploration and extraction is known to have several negative impacts on ocean environments, including on very unique and fragile deep-sea habitats such as methane seeps and coral gardens that can be associated with reserves (Etnoyer *et al.*, 2011; Cordes *et al.*, 2016; Amon *et al.*, 2017; Schwing *et al.*, 2020).

Maritime vessels

In the Moliniere-Beausejour Marine Park, the use of beach seine nets and the anchoring of vessels have been highlighted as activities which inflict physical damage to seagrasses, in particular, yachts (Grenada Ministry of Agriculture, Forestry and Fisheries, 2010). There are also associated risks from these vessels due to bilge water pumping, accidental oil spills, and the release of sewage/greywater, each with the potential to change the water chemistry in the affected areas (Lloret *et al.*, 2008; Carreño and Lloret, 2021).

Recreation and tourism

Several freshwater sites, e.g. the Annandale waterfall, are regularly visited by cruise ship passengers among other tourists (Blommestein *et al.*, 2012). This can lead to habitat modification at these sites including small-scale deforestation, flow modification, pollution and other local disturbances.

2.5.3. Invasive species

Freshwater ecosystems

Many of the known invasive species in Grenada occur in aquatic and marine habitats. In freshwater ecosystems, there are six known invasive fishes. Of these koi, guppy and swordtail are reported from Grand Etang Lake and are suspected to have negative effects on the native community (Ravndal, 2019). Two species of tilapia (*Oreochromis* spp.) and the mosquitofish (*Gambusia* sp.) are reported from Levera Pond (Charles, 2018) (Appendix 8). Also in freshwater ecosystems, there is the exotic plant, mocu mocu reed (Ravndal, 2019). The amphibian assemblage of Grenada is dominated by introduced species (Appendix 8) and it seems likely that the introduced frog *E. Johnstonei* may replace the critically endangered Grenada frog in human-altered areas (Kaiser, 1997). Further, the Cuban treefrog, *Osteopilus* *septentrionalis*, has been recorded – although not yet established (Somma and Graham, 2015). The exotic snail *Melanoides tuberculata* is described as "abundant and widespread" in Grenada (Bass, 2004).

Coastal ecosystems

Coastal ecosystems are also plagued with invasive species. The transoceanic Mediterranean seagrass (*Halophila stipulacea*) and the Indo-Pacific lionfish *(Pterois volitans, Pterois miles*) pose specific threats to coral reef ecosystems. Because *Halophila stipulacea* can occupy hard substrate, it has been suggested that this invasive seagrass potentially poses a threat to the settlement of corals (Grenada Ministry of Agriculture, Forestry and Fisheries, 2010). Invasive seagrass species (e.g. *Halophila stipulacea*) which have been reported at various locations in Grenada and Carriacou also pose a threat as they play a role in displacing native seagrasses, altering habitat structure and trophic interactions in seagrass meadows (Ruiz and Ballantine, 2004; Grenada Ministry of Agriculture, Forestry and Fisheries, 2010; Scheibling, Patriquin and Filbee-Dexter, 2018;). Some of the traits of *Halophila stipulacea* that confer a competitive advantage over native species are its ability to 1) survive in waters of depths up to 50m, 2) inhabit diverse substratum types and, 3) rapidly expand its vegetative growth (Ruiz and Ballantine, 2004; Scheibling, Patriquin, and Filbee-Dexter, 2018).

Lionfish

One major threat to fish in Grenada is the Indo-Pacific lionfish (*Pterois volitans*), generalist carnivores that have been recorded in nearshore waters of Grenada since 2012 (Fisheries Division- Ministry of Agriculture, Lands, Forestry, Fisheries, and the Environment, 2015; Horricks *et al.*, 2019). As a marine invasive species in Caribbean coral reefs, lionfish may reduce biodiversity on reefs by disrupting native fish communities which have both ecological and economic implications (Gómez Lozano *et al.*, 2013).

Sargassum

Within the past decade, there has been an abnormal influx of Sargassum into the Caribbean's Large Marine Ecosystem. Some of the negative impacts of stranded Sargassum on beaches are 1) the physical challenge it presents to nesting turtles as well as to new hatchlings, 2) the disruption of seamoss production in shallow waters, 3) the inaccessibility of fish landing sites (primary landing sites affected were Grenville, secondary sites affected were Soubise Beach, Woborn, Petit Baycye, Menere, Conference Bay and Sauters), 4) the disruption of recreational/ tourism activities due to the noxious gases (hydrogen sulphide) produced by decaying Sargassum as well as the impairment of the aesthetic quality of beaches, 5) the disruption of fishing activities due to fish kill events and the entanglement of Sargassum in fishing gear, 6) the potential introduction of invasive species and, 7) the loss of beach sediment arising during Sargassum removal efforts (Japan International Cooperation Agency [JICA], 2019). The recent abnormal influx of Sargassum in eastern Caribbean islands such as Grenada poses a threat to seagrasses as well as their associated fauna as Sargassum may cause physical smothering, disrupt light availability, and cause seagrass die-offs (JICA, 2019). Sargassum also poses a threat to nearshore ecosystems such as coral reefs in Grenada. When Sargassum begins to decompose, the subsequent eutrophication, depletion of oxygen in coastal waters and release of hydrogen sulphide may result in unfavourable environmental conditions and cause coral die-offs (JICA, 2019). Sargassum influxes to Grenada may result in an introduction of invasive species to coral reefs and the disruption of recruitment of certain species, especially those that utilise coral reefs as nurseries e.g. shrimp, lobster, conch, snappers, etc. (JICA, 2019). Species of birds (e.g. shorebirds and seabirds) however, have been observed availing of enhanced foraging opportunities facilitated by Sargassum influxes both at sea and in coastal areas.

Forest ecosystems

The majority of Grenada's introduced species are plants (Appendix 7). Kairo *et al.*, (2003) recorded 32 exotic plants in Grenada, some of which are used for agricultural purposes (e.g. mango and papaya) but show little evidence of outcompeting local forest tree species.

In terms of exotic and invasive fauna, the small Indian mongoose, Johnstone's whistling frog and Mona monkey are believed to have the greatest impact on other fauna and flora. The small Indian mongoose is widely abundant in Grenada and is believed to be one of the main predators of the critically endangered and endemic Grenada dove, possibly a main threat to this bird's survival (Bolton *et al.*, 2016). The Johnstone's whistling frog, as we reported in Section 2.3.4, has invaded the habitat once dominated by the endemic whistling frog and this is expected to worsen with a warming climate (Harrison, 2021). Though not typically considered invasive, as some believe them to be naturalised, the Mona monkey can be quite destructive to birds and agricultural habitat (Groome, 1970). Also impacting agricultural habitat (crop predation) and prevalent is the introduced orange-winged parrot (Devenish-Nelson and Nelson, 2021). While Groome (1970) mentions cane toads and rats as widely abundant, their impacts may be limited to urban and agricultural areas. Groome posited that tree rats may cause vast damage in agroforests, foraging on ripening bananas, cocoa, coconuts and orchids (Groome, 1970).

Offshore island ecosystems

Native flora and fauna on the offshore islands are highly vulnerable to and threatened by invasive species, especially introduced non-native mammals (Coffey and Collier, 2021). Eradication of invasive species is a core objective of many island restoration initiatives worldwide, however, no such eradication or management programmes have occurred on any Grenadian offshore islands. There are a minimum of nine species of introduced mammals present at offshore islands, found throughout all established Marine Protected Areas (MPAs), all proposed MPAs and all islands with seabird colonies meeting global and regional importance (Coffey and Collier, 2021). Rats are present on Sugarloaf, Lee Rock, White Island, Sandy Island (Carriacou) and Jack Adan, with mice (*Mus musculus*), recorded on Sandy Island (Grenada) (Charles *et al.*, 2021; Coffey and Collier, 2021; Smart *et al.*, 2021). Two species of rat, black (*Rattus rattus*) and brown (*Rattus norvegicus*), have been detected with both being excellent swimmers capable of swimming between islands. It is likely therefore that they exist on other offshore islands undetected. Eradication of rats on islands with seabird colonies elsewhere have been linked to improved terrestrial and adjacent coral reef health, through the recovery of seabird populations. Cats were released by locals on Isle de Caille and Isle de Ronde to reduce rodent populations (Lowrie, Lowrie and Collier, 2012), while dogs have been recorded on several offshore islands such as Sandy Island (Carriacou), Sandy Island (Grenada), White Island, Saline Island and Jack Adan (Coffey and Collier, 2021). Rodents and cats are known to be significant predators of native species such as seabirds, sea turtles, reptiles and insects, and have driven extirpations and extinctions of island fauna worldwide. Dogs at offshore islands are typically linked to the fishing camps, and recreational picnic/BBQ and camping sites, brought to these islands temporarily by residents of nearby-inhabited islands and visitors. Although the frequency of these events is difficult to track, dogs have been known to depredate native fauna and can be especially destructive on islands with seabird colonies during nesting season.

Livestock (e.g. goats, and sheep) exist on offshore islands in both domestic and feral populations (Figure 2.16). Large herbivores can eliminate critical seabird nesting habitats, trample nests, and expose chicks and eggs to predators and inclement weather (Campbell and Donlan, 2005). This can result in increased nest-site competition, failed-nesting attempts, reduced-breeding success and abandonment of entire islands (Coffey and Collier, 2020). Goats are the most observed non-native mammal on offshore islandsand are present on at least 9 islands, including those with globally and regionally important seabird populations. Goats can withstand the extremely arid conditions at offshore islands during the dry season and rapidly reproduce, which allows them to persist on offshore islands in feral populations (Parkes, 1993; Coffey and Collier, 2021). Lowrie, Lowrie and Collier (2012) noted evidence of overgrazing on numerous islands, including Les Tantes, Isle de Ronde, Diamond Rock, Frigate Island and even Mushroom/Cola Island which is less than 1ha. The extent of overgrazing on Frigate Island is visible even from satellite imagery, where a large population of feral goats has caused

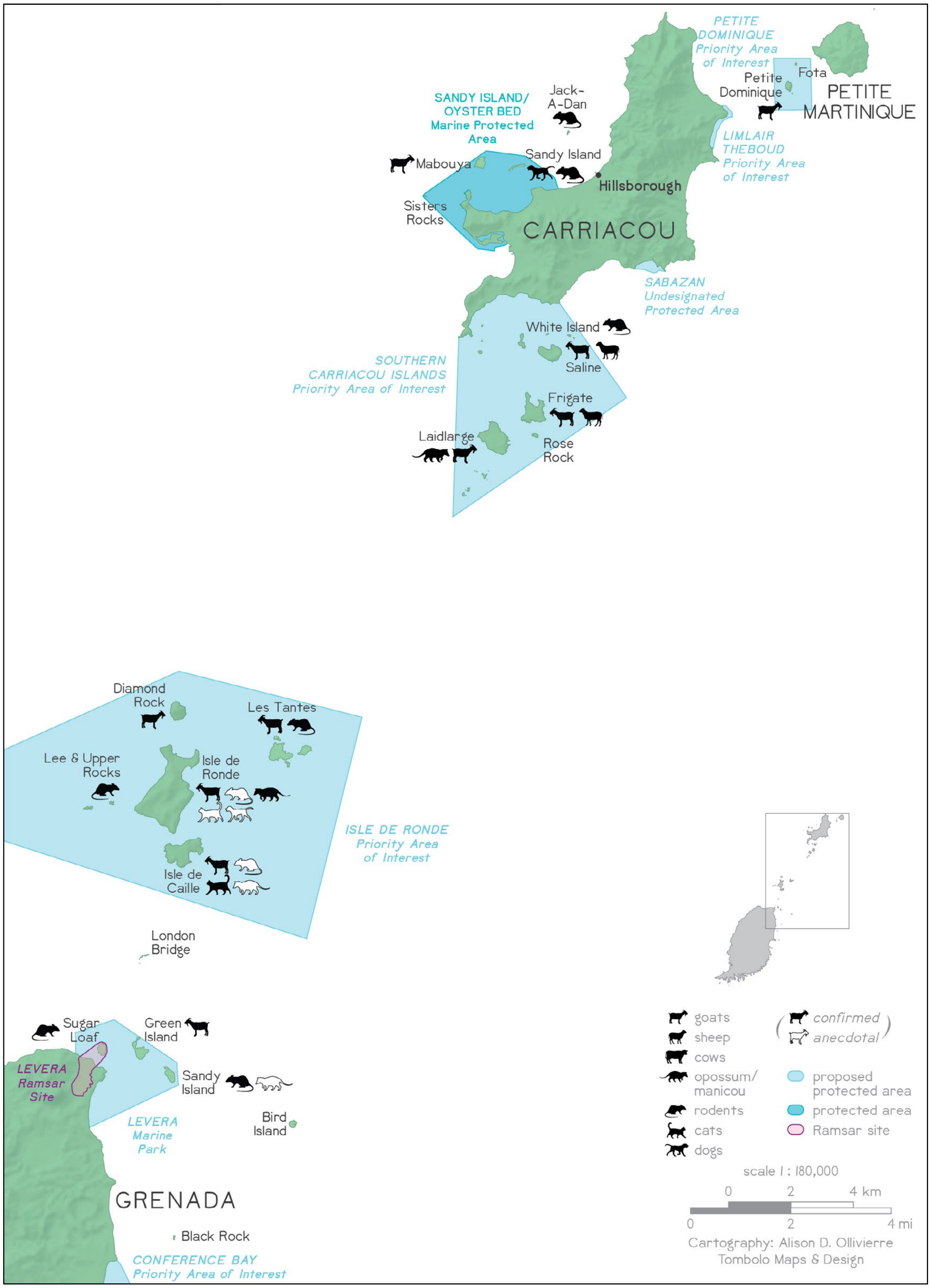


Figure 2.16. Invasive species on offshore islands
(see Appendix 1 for references and data sources)

severe depletion of vegetative cover and erosion. In 2020 to 2021, sheep were established on Saline and Frigate islands, where goat populations were already present. In 2019, four goats were released illegally on Mabouya Island in the Sandy Island/Oyster Bay Marine Protected Area where the population continues to expand. In some cases, goat hunting at offshore islands occurs in tandem with illegal seabird egg collecting and chick harvest and causes disturbance to nesting seabirds during the breeding season (Coffey and Collier, 2020). While other islands (e.g. Laidlarge, Isle de Ronde) formerly had cattle and donkeys (Howard, 1952), there are no recent records.

Opossums are thought to have ben introduced to Grenada prior to the arrival of Europeans (Giovas *et al.*, 2011; Masetti, 2011). While known to be present on two offshore islands (Laidlarge and Isle de Ronde) they are suspected at additional sites (Borroto-Paez and Woods, 2012; Sustainable Grenadines Inc., 2014; Smart, 2019; Coffey and Collier, 2021). They subsist on a highly-diverse diet including items such as plants, insects, turtle hatchlings, birds and eggs and rapidly reproduce without any natural predators (United States Agency for International Development [USAID], 2010; Coffey and Collier, 2021). Reduced vegetation and bird species richness on several Grenadines islands are thought to be linked to opossum presence (USAID, 2010). Fisherfolk attributed the disappearance of nesting seabirds on Isle de Ronde to both opossums and cats (Lowrie, Lowrie and Collier, 2012; Coffey and Collier, 2021). Nesting seabirds on Laidlarge are restricted to the inaccessible southeast cliffs.

There have not been any recorded sightings of mongoose in the Grenadines. Preventing their introduction to offshore islands remains a high priority to avoid devastating effects on native fauna, as evidenced on the Grenada mainland and elsewhere in the Caribbean. There is limited literature in terms of invasive flora on Grenada's offshore islands however, *Panicum maximum* is present on Isle de Ronde (Howard, 1952).

2.5.4. Pollution

The main sources of marine pollution around Grenada are sewage, hydrocarbons, sediments, nutrients, pesticides and other toxic chemicals, solid waste and marine debris (including plastics and microplastics) but there is little knowledge of the impacts (if any) in Grenada's open and deep ocean. The deep ocean is known to be a sink for pollution, however beyond observations of debris in Grenada's deep sea, little is known about the extent of pollution and the impact it is having on the communities (Woodall *et al.*, 2014; Jamieson *et al.*, 2017; D. Amon, 2022, personal communication, 31 January).

Pollution both on land and at sea can come from a wide variety of sources. In the Caribbean, 80% of the pollution in the Caribbean Sea is due to land-based sources, primarily untreated wastewater (sewage), agricultural runoff and litter (Diez *et al.*, 2019). A study done in 2007 in the Grenadine islands found that litter, greywater, and sediment were the mainland-based pollutants, and that the number of pollution source points increased with population density (Williams, 2007). Petroleum hydrocarbons on Grenadian beaches pose a threat to the aesthetic quality of the environment, and associated beach fauna, as well as disrupt activities associated with recreation, tourism and fisheries. Petroleum hydrocarbons, in the form of tar balls, were reported at moderate levels (range: 4.3 – 96.9g/m, average ± standard deviation: 30.1 ± 25.4) on one east coast beach in Grenada (Corbin, Singh and Ibiebele, 1993). Within the Wider Caribbean Region, petroleum pollution has primarily been attributed to marine-based activities such as petroleum tanker ballast washings, petroleum drilling, production operations and natural seeps (Corbin, Singh and Ibiebele, 1993).

Nutrients

Nutrient pollution is the contamination, usually of surface water, with excessive amounts of nutrients, specifically nitrogen and phosphorus in the aquatic environment. When in excessive amounts in surface water, these nutrients may lead to eutrophication and anoxic zones in both freshwater and marine environments. One such impact is the increasing growth of macroalgae on coral reefs throughout the Caribbean (Jagt *et al.*, 2014). Studies in the Moliniere-Beausejour Marine Protected Area (MBMPA) observed an increase in macroalgae overgrowth on the coral reef, and this is attributed to nutrient pollution from land-based sources. Implementation of fishing restrictions in the MBMPA has resulted in an increase in fish biomass, even with this nutrient-induced overgrowth of macroalgae (Nimrod, Franco and Andrews, 2013; Anderson *et al.*, 2014;). Monitoring at the mouths of three rivers that discharge near the MBMPA found elevated levels of ammonia and phosphate, levels that were several orders of magnitude above the recommended levels from the Caribbean Environmental Health Institute (Nimrod, Franco and Andrews, 2013).

Agricultural pollution

Farmed land, even in upland areas, is treated with pesticides, herbicides and fertilisers which leach into rivers during heavy rainfall (Paterson, n.d.). This has implications for all habitats from source to sea and can even impact reefs. Fertiliser application is often excessive (Gaea Conservation Network, 2018) and can lead to eutrophication in riparian areas. A study by Nimrod, Franco and Andrews (2013) found that the nutrient levels in the Beausejour River increased going downstream and were higher after a rainfall event. This was attributed to agricultural activity close to riverbanks, poor use of fertiliser and inappropriate livestock practices that led to the washing of nutrients into the nearby rivers (Nimrod, Franco and Andrews, 2013; Herman, 2015). Other sources of agricultural pollution include bacterial pollution from pig farms (Gaea Conservation Network, 2018; Forteau, 2019). Surveys in 2014 and 2017 in the Beausejour watershed found that most sites had levels of Enterococci and *E. coli* at higher than acceptable levels (according to the Land Base Source of Pollution Protocol/LBS) (Gaea Conservation Network, 2018).

Domestic pollution

Pollutants from household activities are widespread. Work by Forteau (2019) and Gaea Conservation Network (2018) has identified numerous pollutants in freshwater ecosystems in Grenada. These include detergents and soaps from laundry and car washing directly in the rivers and engine oil from cars that have runoff during heavy rainfall. In an earlier study, there was initial evidence of the use of detergents for laundry purposes along the banks of the Beausejour River- adding to the phosphate loading in both freshwater and coastal ecosystems (Nimrod, Franco and Andrews, 2013). A more large-scale point source pollutant is suspected to be Grenada's sole landfill in Perseverance. Rusk (2010) hypothesised that much of the material is being leached into the river.

Sewage

Pollution due to the release of poorly-treated sewage has an impact on both environmental and public health. Sewage contains high levels of nutrients, and when released into surface waters, can have similar impacts as the release of fertilisers in agriculture. Sewage also contains pathogenic microorganisms, which may impact the health of persons using polluted water for recreational, agricultural, or domestic purposes. The 2011 Grenada census indicates that 60.6% of the households are equipped with indoor toilets, however, only 4% of households were connected to a sewer. The remainder were either using septic systems (57.8%) or pit latrines (30.3%) (Central Statistics Office, 2011). There is some tertiary treatment of sewage, primarily individual/private package plants, but the majority is collected and discharged via ocean outfall. Studies in a variety of Grenadian bays were found to have faecal coliform levels higher than the United States Environment Protection Agency limits for marine water (Farmer-Diaz *et al.*, 2017). Limited marine water testing for the then proposed Levera Marine Protected Area (LMPA) found there were very low faecal enterococci but very high total coliform at six marine sites throughout the proposed LMPA. This suggested that there was no recent (<48 hours) sewage impact, but a high likelihood for longer-term chronic sewage impact, which would need to be addressed (Grenada Coral Reef Foundation, 2018).

Industrial wastes

The manufacturing industry in Grenada is mostly small-scale, with a focus on food and beverage and agricultural processing, although this sector has increased in size in recent years (Nexus Commonwealth Network, 2020). The food, beverage and agroprocessing industries also produce nutrient-containing waste, which can result in similar problems as found in agriculture. An unpublished study conducted in and around Woburn Bay found ammonia and phosphate levels in a river to be highest just downstream of the Clarke's Court Rum Distillery, (McCain *et al.*, 2018) which is described on its website as the largest in Grenada (Clarke's Court Rum, 2021). The study also found that the levels of nutrients in Woburn Bay correlated well with that at the distillery site. While the study concluded that the distillery was the main source of nutrient pollution in Woburn Bay, it should be noted that there are other potential sources of nutrient pollution in the area, including a hotel and a marina.

Solid waste in Grenada is disposed of at the sole sanitary landfill at Perseverance. Landfills are a noted source of hazardous chemicals; the components of the waste are leached by rain and organic acids are produced by landfill microorganisms. The current landfill at Perseverance replaced an open dump there in 2001; however, it is unclear how effective the new landfill is at retaining leachate. A study on nutrients in three Grenada rivers found extremely high nutrient levels at the mouth of the Salle River (490–534µg/L phosphate and 6,590–8,131µg/L ammonia) (Nimrod, Franco and Andrews, 2013). The ammonia levels in the Salle River were much higher than in either the Beausejour or Dragon Bay Rivers, the other two rivers in the study. The Salle River runs through the Perseverance area, and the authors suggest that the leachate from the landfill are impacting the river. This may also speak to the high likelihood of other chemicals coming from the landfill impacting the Salle River, and the nearby marine environment.

Not all chemical waste found in Grenada is local; the presence of tar balls on Grenada's coastal areas speaks to the presence of hydrocarbon pollution that is external. Tar balls were assessed in several small eastern Caribbean islands, and Grenada had a range of 4.3-96.9g/m, one of the higher ranges in the study (Corbin, Singh and Ibiebele, 1993). The reason suggested was Grenada's relative proximity to Trinidad and Tobago and pollution from the petroleum industry there. The sea currents and major winds can bring tar to Grenada from a variety of sources. This is of concern as the tar can impact tourism and the local fishing industry.

Anthropogenic litter

Marine debris/litter has been reported in the Caribbean Large Marine Ecosystem (CLME) between 1980 and to the present (Ivar do Sul and Costa, 2007; Diez *et al.*, 2019; Kanhai *et al.*, 2022). Surveys on Caribbean islands by Schmuck *et al.* (2017) found that approximately 90% of beach litter consisted of plastics, with the highest densities at sites with minimal to no human disturbance. In Grenada, the offshore islands are highly contaminated with marine litter (Lowrie, Lowrie and Collier 2012; Schmuck *et al.*, 2017; Coffey and Collier, 2020; Coffey, 2022). Clean-up efforts had not targeted the offshore islands before 2020 (Charles *et al.*, 2021). Between 1992 and 2019, marine debris was reported on Grenada's beaches via the citizen science International Coastal Clean-ups (ICC) of Ocean Conservancy (Ocean Conservancy and International Coastal Cleanup, 2020; Kanhai *et al.,* 2022), as well as through a regional study (Schmuck *et al.*, 2017). Data from 2019 indicate that single-use plastics such as plastic beverage bottles, plastic grocery bags, other plastic bags and food wrappers were among the most common items (Ocean Conservancy and International Coastal Cleanup, 2020), while items associated with fishing activity (e.g. rope, line, buoys) are additionally common on offshore islands (Schmuck *et al.*, 2017).

Seabird and sea turtle species in Grenada, the Grenadines and surrounding waters have been observed nesting amongst, entangled in, and killed through interactions with marine anthropogenic litter encountered at sea and on land (Coffey, 2022). Both types of animals are known to ingest marine litter leading to starvation, poor body condition, exposure to contaminants and mortality (Lavers *et al.*, 2014; Lavers *et al.*, 2019, Roman *et al.*, 2019). In addition, there is recent evidence in the Grenadines of seabirds intentionally incorporating marine litter into nest construction (Coffey, 2022). The prevention of marine litter in Grenada is complex as items may be sourced locally, arrive from foreign sources via oceanic currents, and/or from marine vessels (Barnett, 1997; Coe *et al.*, 1997; Wade, 1997; Schmuck *et al.*, 2017; Diez *et al.*, 2019). No data on the daily accumulation of marine litter on beaches exists for Grenada or the Grenadines, nor have there been any at-sea investigations. Some trash is discarded directly on beaches and offshore islands, such as during picnics, BBQs and day trips, both from domestic and tourism-related activities.

While microplastics are a growing environmental concern worldwide, investigations in Grenada are limited to a single study that found more than 97% of commercial fish sampled contained microplastics in stomach contents (Taylor and Morrall, 2018). Effects on human health through the consumption of species ingesting macro and microplastics (e.g. fish, sea turtles and seabirds) are unknown.

Solid municipal waste collection is up to 98% in Grenada, but there are still some concerns. In 2014, it was estimated that the per capita production of solid waste was 1.08kg/day, with waste composition (2009) indicating a high proportion of recyclable materials (62.6% plastic, paper, cardboard, glass, metal, and organic waste). Household waste made up the bulk of the collected material, and plastics were the third largest component of municipal waste (Zettl and Roberts, 2015). There is no integrated waste management, and a lot of litter (15% of municipal waste, and up to 30% of plastic bottles) still ends up in the environment. Ingrained cultural habits were listed as the main reason for this (Zettl and Roberts, 2015).

2.5.5. Overexploitation

Overharvesting, whether regulated or unregulated, can have vast impacts on Grenada's ecosystems. Apart from the fisheries sector, there is a paucity of information on the extent of overharvesting of marine wildlife. Regardless, it is suspected that fauna occupying Grenada's beaches and forests may be under threat from unsustainable harvesting practices.

Coastal and marine ecosystems

Although there has been unsustainable harvesting of marine resources (e.g. coastal fisheries) in the Caribbean, there is little evidence of this in Grenada's pelagic and deepwater fisheries: large and small pelagics (tunas, bigeye scad [jacks], sailfish and swordfish), and deepwater snappers. Overall production is stable, but the recent introduction of Fish Aggregating Devices (FADs) has led to a huge increase in yellowfin landings on the east coast, yet to be recorded by official statistics. Conversely a large drop in bigeye scad landings has been observed in recent years (FAO, 2018).

Deepwater fisheries

Of particular concern is the potential impact of FADs on growth overfishing. In the 1990s FADs were introduced to Grenada (FAO, n.d.) and since then particularly fishers in Grenville have galvanised this method into an important component of the longline fishing industry. FADs are also being used in Carriacou and Petite Martinique (Gentner, Arocha and Anderson, 2017). The Grenville FAD Fishers Organisation is a model for FAD management, collecting levies of US$1.85 for every 23kg landed for maintenance and enforcing use requirements (only licensed fishers and organization members can have access to the FADs) (Gentner, Arocha and Anderson, 2017). However, the government has yet to use this information to model the potential biological and ecological implications of FAD fishing. As a result, there are concerns about the effects of reduced Catch Per Unit Effort (CPUE) and growth overfishing (fish catch smaller than optimum sizes) around this technology.

These unknown effects are somewhat addressed (managed) by the minimum size recommendations from the International Commission for the Conservation of Atlantic Tunas (ICCAT) for species such as swordfish (*Xiphias gladius*), blue marlin (*Makaira nigicans*), and white marlin (*Kajikia albida*). However, this output control can only be enforced for exports and has little impact on the local market as there are no laws that direct size requirements for most commercially important species, though it should be noted that the local market is considerably smaller as compared with the export market. Additionally, input and output controls such as minimum hook size and limiting catch and/or effect are not required by law for any pelagic species. This can have dire consequences on the fishing industry, as new investors or further expansion into longline fishing (particularly around FAD technology) may already be saturated. Some fishers have expressed concerns over this issue; recommending FAD limits (the number of FADs deployed) and access limits (managing the number of fishers that can enter the fishery) (Patrick *et al.*, 2021). Additionally, financiers like the Small Business Development Fund, through the Grenada Development Bank, have expressed similar apprehensions as it relates to the rate at which loans default, suggesting that this may be due to the fishing industries saturation, and more information is needed to inform their decisions to approve loans in this sector (K. Haywood, 2021, personal communication).

Coastal fisheries

Non-fish species occupying Grenada's marine ecosystems may also be under threat of overharvesting e.g. Caribbean spiny lobster (*Panulirus argus*), queen conch (*Aliger gigas*) and white sea urchins (*Tripneustes ventricosus*). Other threats to these species include habitat loss, hurricane activity, rising sea temperatures and ocean acidification (Government of Grenada, 2014).

Coastal resources such as sea turtles are currently being threatened by anthropogenic activities such as illegal egg harvesting, illegal harvesting of nesting turtles, and illegal harvesting of turtles during the closed season (Bräutigam and Eckert, 2006; Maison *et al.*, 2010). Hardshell sea turtle species are legally hunted (mainly using nets and spearguns) during a seven-month open season operating from September 1st – March 31st and are killed illegally at other times of the year. Loggerhead turtles are infrequently encountered offshore, but on occasion are gaffed and brought ashore. At-sea capture of adult leatherback turtles are rare, and the killing of gravid females whilst nesting had been reduced considerably at the index nesting beach (Levera Beach) thanks to volunteer-based community conservation efforts in the 1990s and all-night beach patrols by Ocean Spirits since 2000. The presence of researchers has seen a decline in illegal sea turtle egg harvest drop from a 95% take to a <5% annual illegal sea harvest with the presence of researchers (Charles, 2017). Islands where researchers are not regularly patrolling experience much higher levels of illegal sea turtle and egg harvest such as Isle Caille, Isle de Ronde, Les Tantes and Sandy Island (Grenada) (Charles, 2017), while individuals have even been observed checking for turtle nests on Mabouya in the Sandy Island Oyster Bed MPA (Coffey, 2022). Mangroves in Grenada are also under threat due to the unsustainable harvesting of mangroves to produce charcoal (Layman *et al.*, 2006).

Freshwater ecosystems

There is evidence of unsustainable harvesting of fauna in freshwater ecosystems. Both recreational and subsistence fishing takes place in various rivers, in Grand Etang Lake (OECS, 2007) and within Levera Pond (Charles, 2018). This likely focuses on exotic tilapia and native crayfish. However, information on freshwater fisheries (which species and to what extent it occurs) is lacking. The goby, *Sicydium plumeiri* (tritri) was historically harvested in large quantities as juveniles attempted to migrate upstream in their thousands (Groome, 1970). This practice continues today as described in detail in Chapter 4.

Forest ecosystems

Based on reports from Grenada's Forestry Division, there are little to no data on population trends in game species (i.e. Mona monkeys, iguanas, nine-banded armadillos, common opossum), which makes it difficult in determining if these species are overharvested (A. Jeremiah, 2022, personal communication, 12 May). Apart from a 4-year moratorium on these game species between 2004-2008, following Hurricane Ivan, and a restriction of hunting to September to February each year, no additional measures have been implemented to lower hunting pressure (A. Jeremiah, 2022, personal communication, 12 May). Importantly, because of the lack of a population census (yearly), it is difficult to ascertain if these species are overexploited. Regardless, with the continual loss of their habitat, hunting may place additional stressors on these game species populations.

Offshore island ecosystems

Illegal harvesting of seabirds, their chicks and eggs is extensive and is regarded as the primary threat to breeding seabirds in Grenada, with all nesting species known to be targeted (Table 2.3) (Lowrie, Lowrie and Collier, 2012; Sustainable Grenadines Inc., 2014; Coffey and Ollivierre, 2019; Smart, 2019; Coffey and Collier, 2020). Surveys by Environmental Protection in the Caribbean (EPIC) in fishing communities through the Grenadines in 2019 revealed that over 50% of respondents had previously harvested seabirds, their chicks and/or eggs at offshore islands, while 60% were not aware that the practice is legally prohibited (Coffey and Collier, 2020). Harvesting of seabirds is reported to occur at every accessible island in the Grenadines that hosts breeding seabirds and is conducted opportunistically at sea with birds caught on baited hooks (Coffey and Ollivierre, 2019; Coffey and Collier, 2020). Seabird harvesting is conducted seasonally to coincide with nesting activities, with the majority of eggs reportedly collected in early May (gulls, terns and noddies), while chicks of other species can be collected year-round (e.g. booby spp.). In some cases, seabirds are purposefully harmed during interactions with fisheries, such as through competition for fish and/or for attempting to take fishing bait. Lowrie, Lowrie and Collier (2012) noted traps set in trees on Diamond Rock and Upper/Lee Rock assumed for entangling seabirds. There have been numerous reports of incidental poisoning of laughing gulls in Harvey Vale/Tyrrel Bay (EPIC, n.d.; unpublished data). Despite being fully protected through the *Birds and Other Wildlife Act* (Government of Grenada, 1957), enforcement of protective legislation has not been applied directly to discourage unsustainable harvest of seabirds in Grenada and the Grenadines. Seabird populations are rapidly declining globally (Paleczny *et al.*, 2015), including throughout the Caribbean where they were formerly widespread (Schreiber and Lee, 2000), and they are considered one of the most threatened types of birds worldwide. Although there is no data on population trends of seabirds in the Grenada Grenadines, they are considered to be in decline, with breeding colonies now restricted to remote, uninhabited islands and the extirpation of several formerly-nesting species. Harvesting activities at colonies additionally cause mortality to seabird eggs and chicks that are exposed to extreme temperatures and predators because of disturbance to incubating and attending adults (Coffey and Collier, 2020).

Table 2.3. Seabird species reported to be illegally harvested in the Grenadines (Coffey and Ollivierre, 2015)

Seabird Eggs	Seabird Chicks/Adults
Laughing gull	Audubon's shearwater
Booby species (red-footed, brown and masked)	Magnificent frigatebird
Brown noddy	Booby species (red-footed, brown and masked)
Bridled tern	Brown pelican
Sooty tern	Red-billed tropicbird

While there is a season (1st October – 31st December) for hunting iguanas and other wildlife (e.g. scaly-naped pigeon (*Patagioenas squamosa*), opossum (*Didelphis insularis*), the extent to which this activity occurs outside of the established season is unknown. Photos submitted to EPIC in 2020 of legally hunted iguanas by a resident of Carriacou appeared to be the Grenadines pink rhino iguana subspecies (*Iguana insularis insularis*) (EPIC, n.d.; unpublished data). Further surveys are needed to determine the distribution of this subspecies at offshore islands, particularly given their potential to hybridise with the introduced green iguana (*Iguana iguana*). A resident of Carriacou previously reported eating iguana eggs collected at Anse la Roche (Carriacou) where the subspecies is known to nest (EPIC, n.d.; unpublished data). Red-footed tortoise (*Chelonoidis carbonarius*), although believed to be an introduced species, is thought to be extirpated in Grenada due in part to harvesting but exists in substantial populations at some offshore islands.

2.6. Gaps

A list of gaps on the knowledge of Grenada's ecosystems in provided in Table 2.4. These gaps reflect what is unknown in the grey and scientific literature; thus, they do not speak to anecdotal data or information. Much of the gaps are due to the absence of continual monitoring of biotas in the ecosystems in Grenada. The absence of these monitoring programmes makes it difficult to identify which species are experiencing declines or increases or have stable populations. In instances when species are monitored, the absence of a publicly-available database, for example, eBird, makes it difficult to identify when there are data available on species or environmental conditions.

Table 2.4. List of knowledge gaps, based on a review of the grey and scientific literature, on the status, threats, and trends in Grenada's ecosystems

Gap	Agriculture	Coastal	Deep Ocean	Freshwater	Terrestrial	Uninhabited Offshore Islands
Trends in precipitation and temperature	These data are monitored across several weather stations in Grenada, but information on annual trends around Grenada are not publicly available. The range of native biotas may become restricted to changes in water availability due to a decline in precipitation.					
Population trends in biotas (native)	Agrosystems may provide habitat for native species, but apart from birds and Mona monkeys, little is known about their value for other taxa	Apart from fisheries yield, no consistent monitoring of biotas in mangroves/ seagrasses/coral reefs. Limited data available on birds in some wetlands. Little to no data available on non-fisheries species (e.g. sharks)	Apart from fisheries catch, no monitoring of pelagic or deep-sea biotas. Absence of monitoring makes it difficult to assess the true impacts of FADs.	Anecdotal evidence on declining bio-indicator species (e.g. crayfish), but not confirmed as there is no consistent monitoring. The status of the *Sicydium* sp. fishery is unknown with no known population monitoring.	Absence of consistent monitoring of native biotas, even endemics. This makes it difficult to identify which species are undergoing declines.	Data on the abundance and trends of biotas are limited.
Water quality	Activities around croplands/farms may impact water quality in freshwater areas, but is not consistently monitored	Absence of periodic monitoring of coastal water quality, which is impacted by in-land activities		No periodic monitoring of freshwater systems (apart from drinking water), which limits understanding of whether pollutant levels are outside of recommended limits	Biotas in these ecosystems may forage in and around freshwater ecosystems, which make knowledge of their water quality important	
Disease prevalence	Some information available (qualitative) on diseases affecting some crops from the Agriculture Division	Limited to no data on disease prevalence in coastal ecosystems, apart from the past disease affecting black sea urchins (qualitative)	No known data is available	No known data is available	Limited data on rabies prevalence in some mammals, and prevalence of other diseases are data limited	No known data is available
Invasive species impacts on native biota	Qualitative data available from the pest control department in the Agricultural Division.	Lionfish, among other invasive species, likely impact the abundance/ diversity of native fish, but there are no long-term monitoring programmes to assess if their populations are stable or increasing	No known data is available		Mongoose and other mammalian predators known to predate endemic birds (e.g. Grenada dove), but their population trends are not quantified	Invasive mammalian predators likely lead to declines in seabird nesting success, native reptile and invertebrate populations, but the true impact is not quantified

Gap	Agriculture	Coastal	Deep Ocean	Freshwater	Terrestrial	Uninhabited Offshore Islands
Cumulative impacts	No known data available					
Recreational use of ecosystems	No known data available	Some evidence of damage to coral reefs and seagrass beds from boat/yachts, though qualitative	No known data is available	No known data is available	Possible impacts of noise on biota, but no official data available to quantify impacts	Long-term impacts on native biodiversity through unregulated visitation to offshore islands is unknown
Climate change	Apart from inferences of climate change impacts in other better-studied regions, which are used to make inferences on ecosystems in Grenada, projected climate change impacts are poorly understood across all ecosystems.					

2.7. Local knowledge on the status, trends and threats to Grenada's ecosystems

The Grenada NEA has been a highly participatory process, with strong stakeholder engagement through mechanisms described in the introductory section of this assessment. This section documents the local knowledge contributed by stakeholders, specific to the focus of this chapter, namely on the status, trends and threats to Grenada's ecosystems. This information was captured through various feedback mechanisms including a workshop in September 2022, where civil society, private sector and youth shared information they had on the knowledge gaps the chapter's authors were trying to fill. Priority stakeholder concerns regarding Grenada's ecosystems were also captured as documented in Table 2.5 below.

Table 2.5. Local knowledge of status, trends and threats to Grenada's ecosystems as shared by stakeholders

Topic	Local knowledge shared by stakeholders.
Specific plants or animals under threat of extinction or extirpation (may cease to exist in a particular area)	Every species is in danger; but there are certain species that require immediate protection due to the unsustainable hunting and consumption of wild game. Species of concern are the nine-banded armadillo, the opossum or manicou, iguanas, and the Mona monkey. There has also been a major decline in the population of marine animals such as lobsters and conchs. Locals resort to killing some animals because they had a fear of or a distaste for specific species. These include snakes and bats. Species like the Grenada dove and the piping frog, are in danger of becoming endangered or being wiped out entirely.
Threats of major concern for above species	Grenada's ecosystems are under pressure from a wide variety of threats, including, but not limited to, the destruction of habitat, excessive hunting, the use of artificial fertilisers and pesticides, as well as the spread of infectious diseases and parasites to both marine and terrestrial species.
Geographic areas/ locations of concern in Grenada, Carriacou and Petite Martinique and recommendations to address concerns or general recommendations for species and ecosystem conservation and management.	Construction of hotels on or near protected lands is a threat causing damage to important ecosystem types, such as the mangrove forests on Grenada and Carriacou and the oyster beds on Carriacou. The implementation and enforcement of reserves and protected areas is needed. There is lack of data on local species and pollution. Baseline data is needed. White cedar trees (*Tababeuia* sp.) in High North Forest of Carriacou are under threat due to boat building. Iguanas are under threat from hunting, Butterflies and dragonflies are threated by habitat loss. Tracking land use changes over time is recommended.
Invasive species – locations where lionfish are more prevalent	There is a high population density of lionfish (*Pterois* sp.) in and surrounding marine zones, including protected areas and popular fishing places. More specific information on their exact position can be obtained from the Fisheries Division of the Government of Grenada and from diving shops in the surrounding area.

Topic	Local knowledge shared by stakeholders.
Invasive species- specific areas around Grenada that are more impacted by Sargassum	Sargassum is most dominant along the eastern coast of Grenada, most prominent in Sauteurs and Grenville with a north – south pattern of movement. From February-August, however, Sargassam is also prominent in Victoria; from July-September, prevalence in St John's seems to increase.
Presence and harvesting of *Sicydium* gobies (Titiree)	Titiree are found at the mouth of Grenada's main rivers and tributaries, such as the Charlotte's River in Gouyave St. John's and the Paradise River in St. Andrew's. This species is often used as a protein source by many locals and often being sold as a meal in major festivals such as Fish Friday at Gouyave, St. John's and Food Fest at Victoria, St. Mark's. However, due to a lack of interest on the part of younger generations, there has been a major drop in the amount of *Sicydium* gobies (Titiree) that have been harvested for consumption.
Data gaps	Lack of primary data for use in the Grenada NEA Lack of water quality data especially pertaining to sewage contamination.

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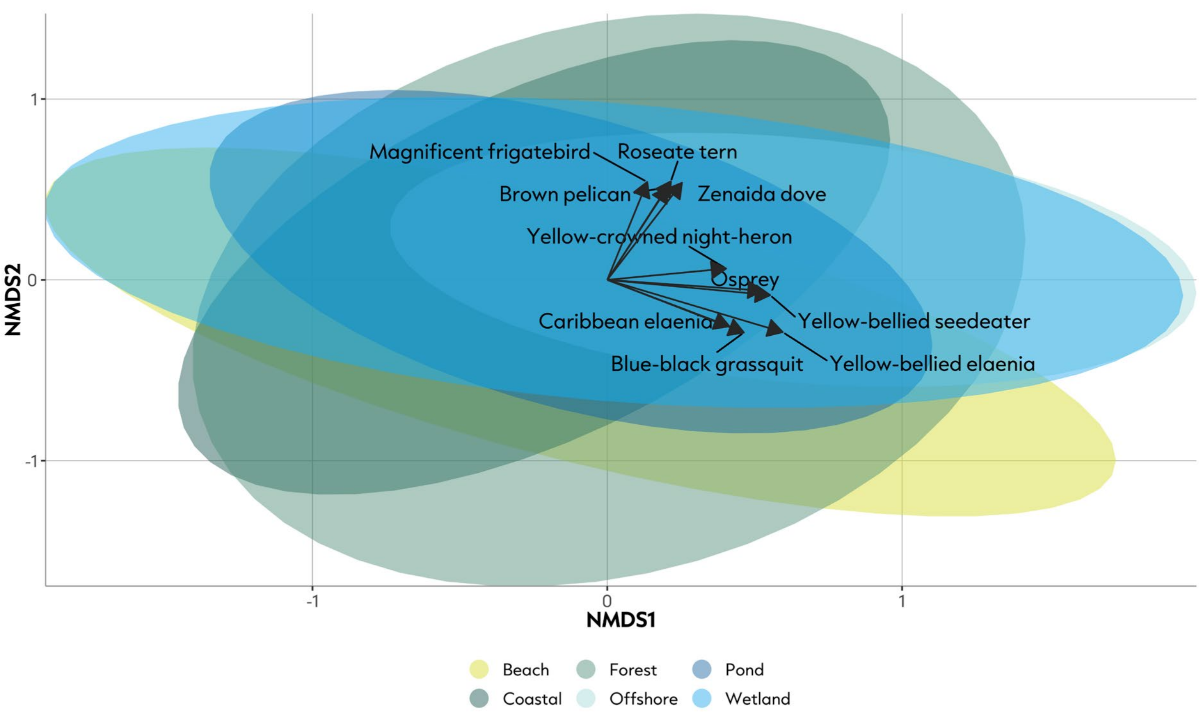
Appendices

Appendix 1. *Map references and data sources*

Map	References	Additional information on datasets and/or shapefiles used
Figure 2.1 Geological map of Grenada showing geological features and associated time period	Brinden *et al.* (1979); Speed *et al.* (1993); MacPhee *et al.* (2000); White *et al.* (2017); Rojas-Agramonte *et al.* (2017); Donovan *et al.* (2003)	Geology_2022; Carriacou_Geology_area; VolcanicPeaks
Figure 2.3 Map of Grenada showing the association between Precolumbian sites, mangroves, and wetlands, with likely current or former wetlands based on low slopes and alluvial/accretive soils	Vernon *et al.* (1959); Moore *et al.* (2015); Hanna and Giovas (2022)	n/a
Figure 2.4 Coastal ecosystems in Grenada	n/a	TNC Coral Reef Maps 2020 dataset; Centre for Environment Fisheries and Aquaculture Science (CEFAS) and Commonwealth Marine Economies Programme (CMEP) dataset (n.d.)
Figure 2.5 Areas in Grenada, Carriacou, and Petite Martinique where sea turtles are known to nest and forage	Eckert and Eckert (2019); Ocean Spirits Inc., unpublished data (n.d.); KIDO Foundation (n.d.); UNEP-WCMC and IUCN (2020)	Charles and Coffey, offshore islands turtle dataset; KIDO turtle data 2005- 2019
Figure 2.6 Marine and Terrestrial Protected Areas in Grenada	UNEP-WCMC and IUCN (2020); OECS (2009)	n/a
Figure 2.8. Terrestrial land use/cover in Grenada in 2014	World Bank (2021)	n/a
Figure 2.9 Watershed extents, and location of rivers/streams, in Grenada	n/a	TNC datasets including: grd_fw_waterbodies_2010; grd_fw_waterbodies_20060713; grd_m_fw_rivers_20110914; grd_fw_watersheds_1994
Figure 2.10 Seabird colonies on offshore islands in Grenada	Coffey and Collier (2020); Coffey and Ollivierre (2019); eBird (2021); Lowrie, Lowrie and Collier (2012); World Bank (2021)	n/a
Figure 2.16 Invasive species on offshore islands.	Coffey and Collier (2021); Charles *et al.* (2021); World Bank (2021)	n/a

Appendix 2. Non-metric multidimensional scaling (NMDS) using data from eBird, January 2013–December 2022

Non-metric multidimensional scaling (NMDS) using data from citizen-science platform (eBird) between January 2013–December 2022 – 56 "Hotspot" locations across several islands. Ellipses show which hotspots, by habitat type, are most similar in community composition of birds (using average abundance). Vectors are the top 20 bird species, by their correlation with one or both axes (r>0.15). Ellipses are 95% confidence intervals by grouped sites, based on their habitat type- the stronger the overlap among habitat types, the more similar the community composition. When an ellipse and vector are aligned, it suggests that this species is more abundant in that habitat type. The NMDS shows that birds on offshore islands (blue) and ponds (orange) represent a subset of the birds found in wetlands (purple). Beaches (dark blue) do share some similarities with wetlands, offshore islands and ponds, though there are some differences (ellipse is slightly oriented below these habitat classes). Coastal areas and forests have similar community structure, though species in coastal areas are a subset of those in forests. As the vectors show, shorebirds and waders (e.g. tricoloured heron, white-rumped sandpiper) and lowland birds (e.g. Caribbean elaenia, mangrove cuckoo) are more common on beaches, along ponds, offshore islands, and wetlands. While seabirds are also observed in these habitats (e.g. laughing gulls, brown pelican, brown booby), they are most common in coastal areas.



Appendix 3. List of birds observed throughout Grenada and its Grenadines on eBird between January 2013–December 2022

n =>25,000 observations of 153 species from 56 “Hotspot” locations across several islands. Species occurrence is indicated across different ecosystems. For a comprehensive list of all birds observed in Grenada and the Grenadines and their detailed statuses, including those that may be rare and not included in this list, see Wiley (2021) (202 species are listed) and Coffey and Ollivierre (2019) (Grenadines-specific).

Common Name	Scientific Name	Endemics	Resident /Visitor	IUCN Status	Mangrove	Beach	Offshore Islands	Inland /Forest	Lake / Pond	*
African collared-dove	*Streptopelia roseogrisea*	Introduced	Resident	LC	x	x				
American coot	*Fulica americana*		Resident	LC	x	x		x	x	
American golden-plover	*Pluvialis dominica*		Visitor	LC	x	x		x		
American kestrel	*Falco sparverius*		Resident	LC				x		
American oystercatcher	*Haematopus palliatus*		Resident	LC	x	x	x			
American wigeon	*Mareca americana*		Visitor	LC	x					
Antillean crested hummingbird	*Orthorhyncus cristatus*	Regional Endemic	Resident	LC	x	x	x	x	x	
Antillean euphonia	*Chlorophonia musica*	Regional Endemic	Resident	LC		x		x		
Antillean nighthawk	*Chordeiles gundlachii*	Near Regional Endemic	Visitor	LC		x		x		*
Aplomado falcon	*Falco femoralis*		Visitor	LC						*
Audubon’s shearwater	*Puffinus lherminieri*		Resident	LC			x			
Baird’s sandpiper	*Calidris bairdii*		Visitor	LC				x		
Bananaquit	*Coereba flaveola*		Resident	LC	x	x	x	x	x	
Bank swallow	*Riparia riparia*		Visitor	LC	x	x				
Barn owl	*Tyto alba*		Resident	LC	x	x		x		
Barn swallow	*Hirundo rustica*		Visitor	LC	x	x	x	x	x	
Belted kingfisher	*Megaceryle alcyon*		Resident	LC	x	x		x	x	
Black kite	*Milvus migrans*		Visitor	LC						*
Black skimmer	*Rynchops niger*		Visitor	LC						
Black swift	*Cypseloides niger*		Resident	LC	x	x		x	x	
Black tern	*Chlidonias niger*		Visitor	LC						*
Black vulture	*Coragyps atratus*		Vagrant	LC						
Black-and-white warbler	*Mniotilta varia*		Visitor	LC	x					*

Common Name	Scientific Name	Endemics	Resident /Visitor	IUCN Status	Mangrove	Beach	Offshore Islands	Inland /Forest	Lake / Pond	*
Black-bellied plover	*Pluvialis squatarola*		Visitor	LC	x	x	x	x		
Black-bellied whistling-duck	*Dendrocygna autumnalis*		Resident	LC	x	x			x	
Black-crowned night-heron	*Nycticorax nycticorax*		Resident	LC	x	x		x	x	
Black-faced grassquit	*Melanospiza bicolor*		Resident	LC	x	x	x	x	x	
Black-necked stilt	*Himantopus mexicanus*		Resident	LC	x					
Blackpoll warbler	*Setophaga striata*		Visitor	LC	x			x	x	
Black-whiskered vireo	*Vireo altiloquus*		Resident	LC	x	x		x	x	
Blue-black grassquit	*Volatinia jacarina*		Visitor	LC	x	x		x	x	
Blue-winged teal	*Spatula discors*		Visitor	LC	x	x	x	x	x	
Bobolink	*Dolichonyx oryzivorus*		Visitor	LC						
Bridled tern	*Onychoprion anaethetus*		Resident	LC		x	x	x		
Broad-winged hawk	*Buteo platypterus*	Regional Endemic Subspecies	Resident	LC	x	x		x	x	
Brown booby	*Sula leucogaster*		Resident	LC	x	x	x		x	
Brown noddy	*Anous stolidus*		Resident	LC		x	x			
Brown pelican	*Pelecanus occidentalis*		Non-breeding Resident	LC	x	x	x		x	
Buff-breasted sandpiper	*Calidris subruficollis*		Visitor	NT	x					*
Carib grackle	*Quiscalus lugubris*		Resident	LC	x	x	x	x	x	
Caribbean elaenia	*Elaenia martinica*		Resident	LC	x	x		x	x	
Caribbean martin	*Progne dominicensis*	Regional Endemic	Visitor	LC	x	x	x	x	x	
Cattle egret	*Bubulcus ibis*	Introduced	Resident	LC	x	x	x	x	x	
Cliff swallow	*Petrochelidon pyrrhonota*		Visitor	LC	x	x	x			
Cocoa thrush	*Turdus fumigatus*		Resident	LC	x	x		x	x	
Collared plover	*Charadrius collaris*		Visitor	LC	x					
Common gallinule	*Gallinula galeata*		Resident	LC	x	x		x	x	
Common ground dove	*Columbina passerina*		Resident	LC	x	x	x	x	x	
Common tern	*Sterna hirundo*		Visitor	LC	x	x	x			
Eared dove	*Zenaida auriculata*		Resident	LC	x	x	x	x	x	

Common Name	Scientific Name	Endemics	Resident /Visitor	IUCN Status	Mangrove	Beach	Offshore Islands	Inland /Forest	Lake / Pond	*
Eurasian collared-dove	*Streptopelia decaocto*	Introduced	Resident	LC	x	x	x	x	x	
European starling	*Sturnus vulgaris*	Introduced	Resident	LC				x		*
Fork-tailed flycatcher	*Tyrannus savana*		Visitor	LC	x	x		x	x	
Gadwall	*Mareca strepera*		Visitor	LC	x				x	*
Glossy ibis	*Plegadis falcinellus*		Visitor	LC	x					
Grassland yellow-finch	*Sicalis luteola*	Introduced	Resident	LC	x	x		x		
Gray kingbird	*Tyrannus dominicensis*		Resident	LC	x	x	x	x	x	
Gray-rumped swift	*Chaetura cinereiventris*		Visitor	LC	x	x		x	x	
Great blue heron	*Ardea herodias*		Resident	LC	x	x		x	x	
Great egret	*Ardea alba*		Resident	LC	x	x		x	x	
Great shearwater	*Ardenna gravis*		Visitor	LC		x				*
Greater yellowlegs	*Tringa melanoleuca*		Visitor	LC	x	x	x	x	x	
Green heron	*Butorides virescens*		Resident	LC	x	x	x	x	x	
Green-throated carib	*Eulampis holosericeus*	Regional Endemic	Resident	LC	x	x	x	x	x	
Green-winged teal	*Anas crecca*		Visitor	LC	x					
Grenada dove	*Leptotila wellsi*	Endemic	Resident	CR	x			x		
Grenada flycatcher	*Myiarchus nugator*	Near Endemic	Resident	LC	x	x	x	x	x	
Gull-billed tern	*Gelochelidon nilotica*		Visitor	LC	x	x			x	*
Hook-billed kite	*Chondrohierax uncinatus*	Endemic Subspecies	Resident	LC	x	x		x	x	
House sparrow	*Passer domesticus*	Introduced	Resident	LC						
House wren	*Troglodytes aedon*	Endemic Subspecies	Resident	LC	x	x		x	x	
Hudsonian godwit	*Limosa haemastica*		Visitor	LC	x					*
Laughing gull	*Leucophaeus atricilla*		Resident	LC	x	x	x	x	x	
Least grebe	*Tachybaptus dominicus*		Resident	LC					x	
Least sandpiper	*Calidris minutilla*		Visitor	LC	x	x	x	x	x	
Least tern	*Sternula antillarum*		Visitor	LC		x	x			
Lesser Antillean bullfinch	*Loxigilla noctis*	Regional Endemic	Resident	LC	x	x		x	x	

Common Name	Scientific Name	Endemics	Resident /Visitor	IUCN Status	Mangrove	Beach	Offshore Islands	Inland /Forest	Lake / Pond	*
Lesser Antillean tanager	*Stilpnia cucullata*	Regional Endemic	Resident	LC	x	x		x	x	
Lesser black-backed gull	*Larus fuscus*		Visitor	LC		x	x			
Lesser scaup	*Aythya affinis*		Visitor	LC					x	
Lesser yellowlegs	*Tringa flavipes*		Visitor	LC	x	x	x	x	x	
Little blue heron	*Egretta caerulea*		Resident	LC	x	x	x	x	x	
Little egret	*Egretta garzetta*		Resident	LC	x					
Magnificent frigatebird	*Fregata magnificens*		Non-breeding Resident	LC	x	x	x		x	
Mangrove cuckoo	*Coccyzus minor*		Resident	LC	x	x	x	x	x	
Masked booby	*Sula dactylatra*		Resident	LC			x			
Masked duck	*Nomonyx dominicus*		Resident	LC					x	
Merlin	*Falco columbarius*		Visitor	LC	x	x		x	x	
Muscovy duck	*Cairina moschata*	Introduced (Domesticated)	Resident	LC	x					*
Northern gannet	*Morus bassanus*		Visitor	LC		x				
Northern shoveler	*Spatula clypeata*		Visitor	LC						*
Northern waterthrush	*Parkesia noveboracensis*		Visitor	LC	x	x	x	x	x	
Orange-winged parrot	*Amazona amazonica*	Introduced	Resident	LC	x	x		x	x	
Osprey	*Pandion haliaetus*		Resident	LC	x	x	x	x	x	
Palm tanager	*Thraupis palmarum*		Vagrant					x		*
Pectoral sandpiper	*Calidris melanotos*		Visitor	LC	x	x		x	x	
Peregrine falcon	*Falco peregrinus*		Visitor	LC	x	x	x	x		
Pied-billed grebe	*Podilymbus podiceps*		Resident	LC	x	x		x	x	
Prothonotary warbler	*Protonotaria citrea*		Visitor	LC	x					
Purple gallinule	*Porphyrio martinica*		Resident	LC	x					
Red junglefowl	*Gallus gallus*	Introduced (Domesticated)	Resident	LC	x		x	x	x	
Red knot	*Calidris canutus*		Visitor	NT		x				
Red-billed tropicbird	*Phaethon aethereus*		Resident	LC			x			
Red-eyed vireo	*Vireo olivaceus*		Visitor	LC						*
Red-footed booby	*Sula sula*		Resident	LC		x	x			

Common Name	Scientific Name	Endemics	Resident /Visitor	IUCN Status	Mangrove	Beach	Offshore Islands	Inland /Forest	Lake / Pond	*
Ring-necked duck	*Aythya collaris*		Visitor	LC	x				x	
Rock pigeon	*Columba livia*	Introduced	Resident	LC	x	x		x	x	
Roseate tern	*Sterna dougallii*		Resident	LC	x	x	x		x	
Royal tern	*Thalasseus maximus*		Non-breeding Resident	LC	x	x	x		x	
Ruddy duck	*Oxyura jamaicensis*		Resident	LC	x	x			x	
Ruddy quail-dove	*Geotrygon montana*		Resident	LC		x		x	x	
Ruddy turnstone	*Arenaria interpres*		Visitor	LC	x	x	x	x		
Rufous-breasted hermit	*Glaucis hirsutus*		Resident	LC	x	x		x	x	
Sanderling	*Calidris alba*		Visitor	LC	x	x			x	
Sandwich tern	*Thalasseus sandvicensis*		Non-breeding Resident	LC	x	x				
Scaly-breasted thrasher	*Allenia fusca*	Regional Endemic	Resident	LC				x		
Scaly-naped pigeon	*Patagioenas squamosa*	Near Regional Endemic	Resident	LC	x	x	x	x	x	
Semipalmated plover	*Charadrius semipalmatus*		Visitor	LC	x	x	x	x	x	
Semipalmated sandpiper	*Calidris pusilla*		Visitor	NT	x	x		x	x	
Shiny cowbird	*Molothrus bonariensis*		Resident	LC	x	x	x	x	x	
Short-billed dowitcher	*Limnodromus griseus*		Visitor	LC	x	x	x	x	x	
Smooth-billed ani	*Crotophaga ani*		Resident	LC	x	x		x	x	
Snail kite	*Rostrhamus sociabilis*		Resident	LC	x					*
Snowy egret	*Egretta thula*		Resident	LC	x	x		x	x	
Solitary sandpiper	*Tringa solitaria*		Visitor	LC	x	x	x	x	x	
Sooty tern	*Onychoprion fuscatus*		Resident	LC	x	x	x			
Sora	*Porzana carolina*		Visitor	LC	x		x		x	
Southern lapwing	*Vanellus chilensis*		Resident	LC	x	x		x	x	
Spectacled thrush	*Turdus nudigenis*		Resident	LC	x	x		x	x	
Spotted sandpiper	*Actitis macularius*		Visitor	LC	x	x	x	x	x	
Stilt sandpiper	*Calidris himantopus*		Visitor	LC	x	x		x	x	
Striated heron	*Butorides striata*		Resident	LC				x		

Common Name	Scientific Name	Endemics	Resident /Visitor	IUCN Status	Mangrove	Beach	Offshore Islands	Inland /Forest	Lake / Pond	*
Summer tanager	*Piranga rubra*		Visitor	LC	x					
Tricolored heron	*Egretta tricolor*		Resident	LC	x	x	x	x	x	
Tropical mockingbird	*Mimus gilvus*		Resident	LC	x	x	x	x	x	
Upland sandpiper	*Bartramia longicauda*		Visitor	LC	x					
Wattled jacana	*Jacana jacana*		Visitor	LC						*
Western sandpiper	*Calidris mauri*		Visitor	LC	x	x				*
Whimbrel	*Numenius phaeopus*		Visitor	LC	x	x		x		
White-collared swift	*Streptoprocne zonaris*		Resident	LC	x					
White-rumped sandpiper	*Calidris fuscicollis*		Visitor	LC	x	x	x	x	x	
White-tailed tropicbird	*Phaethon lepturus*		Non-breeding Resident	LC			x			
White-winged swallow	*Tachycineta albiventer*		Visitor	LC					x	*
Willet	*Tringa semipalmata*		Resident	LC	x	x	x	x	x	
Wilson's phalarope	*Phalaropus tricolor*		Visitor	LC	x					*
Wilson's plover	*Charadrius wilsonia*		Resident	LC	x	x	x	x		
Wilson's snipe	*Gallinago delicata*		Visitor	LC	x	x	x	x	x	
Yellow warbler	*Setophaga petechia*		Resident	LC	x	x		x		
Yellow-bellied elaenia	*Elaenia flavogaster*		Resident	LC	x	x	x	x	x	
Yellow-bellied seedeater	*Sporophila nigricollis*		Visitor	LC	x	x		x	x	
Yellow-billed cuckoo	*Coccyzus americanus*		Visitor	LC	x					*
Yellow-crowned night-heron	*Nyctanassa violacea*		Resident	LC	x	x	x	x	x	
Zenaida dove	*Zenaida aurita*		Resident	LC	x	x	x	x	x	

References:

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* Species not documented in the 2019 Checklist of the West Indies as occurring in Grenada, i.e. rare sightings or new observations since 2019.

Appendix 4. *Important species associated with Coastal Ecosystems in Grenada*

Scientific Name	Common Name	IUCN Status	Beaches	Seagrasses	Mangroves	Coral Reefs	Consumptive Resource
Kingdom: Plantae							
Rhizophora mangle	Red mangrove	Least Concern			x		
Avicennia germinans	Black mangrove	Least Concern			x		
Avicennia schaueriana	Black mangrove	Least Concern					
Laguncularia racemosa	White mangrove	Least Concern	x		x		
Conocarpus erectus	Silver-leafed buttonwood	Least Concern	x		x		
Kingdom: Protista							
Gracilaria sp.							
Eucheuma isiforme							
Eucheuma cottonii	Sea moss	NA	x				x
Kingdom: Animalia							
Phylum: Chordata							
Phylum: Chordata							
Dermochelys coriacea	Leatherback turtle	Vulnerable	x	x	x	x	•
Chelonia mydas	Green turtle	Endangered	x	x	x	x	x*
Eretmochelys imbricata	Hawksbill turtle	Critically Endangered	x	x	x	x	x*
Lepidochelys olivacea	Olive ridley turtle	Vulnerable	x	x	x	x	x*
Caretta caretta	Loggerhead turtle	Vulnerable	x	x	x	x	x*
Corallus grenadensis	Grenada bank tree boa	NA			x		
Iguana insularis insularis	Grenadines pink rhino iguana subspecies	NA	x				
Phylum: Chordata							
Class: Actinopterygii							
Sparisoma viride	Stoplight parrotfish	Least Concern				x	x
Scarus iseri	Striped parrotfish	Least Concern				x	x
Phylum: Chordata							
Class: Actinopterygii							
Scarus guacamaia	Rainbow parrotfish	Near Threatened			x	x	x
Scarus taeniopterus	Princess parrotfish	Least Concern				x	x
Scarus vetula	Queen parrotfish	Least Concern				x	x
Sparisoma aurofrenatum	Redband parrotfish	Least Concern				x	x

Scientific Name	Common Name	IUCN Status	Beaches	Seagrasses	Mangroves	Coral Reefs	Consumptive Resource
Sphyraena barracuda	Great barracuda	Least Concern				x	x
Epinephelus guttatus	Red hind (grouper)	Least Concern				x	x
Cephalopholis fulvus	Coney (grouper)	Least Concern				x	x
Mycteroperca venenose	Yellowfin grouper	Near Threatened				x	x
Epinephelus striatus	Nassau grouper	Critically Endangered				x	x
Lutjanus campechanus	Caribbean red snapper	NA				x	x
Ocyurus chrysurus	Yellowtail snapper	Data Deficient				x	x
Lutjanus griseus	Grey snapper	Least Concern				x	x
Lutjanus analis	Mutton snapper	Near Threatened				x	x
Phylum: Mollusca							
Class: Bivalvia							
Crassostrea rhizophorae	Mangrove oyster	NA			x		x
Isognomon alatus	Flat tree oyster	NA			x		x
Phylum: Arthropoda							
Class: Malacostraca							
Cardisoma guanhumi	Blue land crab	NA			x		x
Callinectes spp		NA			x		
Panulirus argus	Caribbean spiny lobster			x	x	x	x*
Phylum: Echinodermata							
Class: Echinoidea							
Diadema antillarum	Long-spined black sea urchin	NA				x	
Tripneustes ventricosus	West Indian sea urchin White sea egg Sea egg	NA		x		x	x
Phylum: Cnidaria							
Class: Anthozoa							
Acropora cervicornis	Staghorn coral	Critically Endangered			x		
Acropora palmata	Elkhorn coral	Critically Endangered			x		
Dendrogyra cylindrus	Pillar coral	Vulnerable			x		
Orbicella annularis	Boulder star coral	Endangered			x		
Orbicella faveolata	Mountainous star coral	Critically Endangered			x		

*Closed Season (Fisheries Amendment Regulations, 2001); •Closed Fishery/Complete Ban (Government of Grenada, 2001)

Appendix 5. Whales and dolphins reported and/or expected in Grenada's waters

- Whales and dolphins are reported to inhabit Grenada's water. Frequency refers to the rate at which these species are observed in Grenada's waters.
- IUCN status: DD – Data Deficient, LC- Least Concern, NT – Near Threatened, VU- Vulnerable, EN- Endangered, CR- Critically Endangered.
- CITES (appendices): I- species threatened with extinction and provides the greatest level of protection, including restrictions on commercial trade, II- there is a risk that these species they may be threatened with extinction unless trade is regulated, III- the listing country regulates the trade of the listed species and requires an export permit to take live specimens of the species, their parts, or derivatives out of the country.

Species scientific name	Species common name	Frequency (status)	Comments	IUCN Status	CITES
Positively identified species					
Megaptera novaeangliae	Humpback whales	Common	Annually migrate between December to April. Most common species of whale to be observed in Grenada	LC	I
Balaenoptera edeni brydei	Bryde's whales	Fairly common	Two individuals recorded in a 1925 capture records	LC	I
Physeter macrocephalus	Sperm whales	Fairly common	Resident population on the eastern coast of Grenada	VU	I
Tursiops truncatus	Common bottlenose dolphins	Fairly common		LC	II
Stenella frontalis	Atlantic spotted dolphins	Very common		LC	II
Stenella longirostris	Spinner dolphins	Common		LC	II
Delphinus capensis	Long-beaked common dolphins	Common		DD	II
Pseudorca crassidens	False killer whales	Fairly common		NT	II
Orcinus orca	Killer whales	Uncommon		DD	II
Globicephala macrorhynchus	Short-finned pilot whale	Fairly common		LC	II
Expected Species					
Balaenoptera borealis	Sei whale	Rare	Reported on the lee side of Grenada, but frequently mistaken for B. edeni. Should be considered an occasional visitor not resident species.	EN	I
Steno bredanensis	Rough-toothed dolphin	Common	Numerous records through the Caribbean	LC	II
Grampus griseus	Risso's dolphin	Uncommon	Reported in St. Vincent	LC	II
Stenella attenuata	Pantropical spotted dolphin	Uncommon	Reported in St. Vincent	LC	II
Stenella clymene	Clymene dolphin	Uncommon	Reported in St. Vincent	LC	II

Species scientific name	Species common name	Frequency (status)	Comments	IUCN Status	CITES
Stenella coeruleoalba	Striped dolphin	Uncommon	Reported in St. Vincent	LC	II
Feresa attenuata	Pygmy killer whale	Uncommon	Uncommon throughout the Caribbean	LC	II
Ziphius cavirostris	Cuvier's beaked whale	Rare	Reported in St. Vincent	LC	II
Kogia breviceps	Pygmy sperm whale	Uncommon	Reported in St. Vincent	DD	II
Kogia sima	Dwarf sperm whale	Rare	Reported in St. Vincent	DD	II
Lagenodelphis hosei	Fraser's dolphin	Uncommon	Reported in St. Vincent	LC	II
Peponocephala electra	Melon-headed whale	Uncommon	Unconfirmed reports in Grenada. Reported in St. Vincent	LC	II
Mesoplodon densirostris	Blainville's beaked whale	Uncommon	Reported throughout the Caribbean	DD	II
Mesoplodon europaeus	Gervais's beaked whale	Uncommon	Reported in Trinidad	DD	II

Appendix 6. List of Herpetofauna historically found through Grenada, Carriacou and Petite Martinique

Scientific Name	Common name	Status	Source
Lizards			
Gekkonidae			
Thecadactylus rapicauda	Turnip tailed gecko	Introduced	Malhotra and Thorpe, 1999
Hemidactylus mabouia	Wood slave	Introduced	Malhotra and Thorpe, 1999
Iguanidae			
Anolis aeneus	Wall lizard	Least concern	Malhotra and Thorpe, 1999
Anolis richardii	Tree lizard	Least concern	Malhotra and Thorpe, 1999
Iguana iguana	Green iguana or guana	Least concern	Malhotra and Thorpe, 1999
Teiidae			
Ameiva ameiva	Garman's ground lizard or zaggada	Least concern	Malhotra and Thorpe, 1999
Scincidae			
Mabuya mabouya	South-Antillean slippery-back	Possibly extirpated	Malhotra and Thorpe, 1999
Gymnophthalmidae			
Bachia heteropa	Worm lizard	Least concern	Malhotra and Thorpe, 1999
Non-Venomous Snakes			
Typhlopidae			
Amerotyphlops tasymicris	Grenada bank blind snake	Endangered	Malhotra and Thorpe, 1999
Boidae			
Corallus grenadensis	Grenada bank tree boa	Endangered	Malhotra and Thorpe, 1999
Corallus hortulana	Garden tree boa	Least concern	Malhotra and Thorpe, 1999
Colubridae			
Clelia clelia	Mussurana or cribo	Possibly extirpated	Malhotra and Thorpe, 1999
Pseudoboa neuwiedii	Neuwied's false boa	Probably extinct	Malhotra and Thorpe, 1999
Liophis melanotus	Shaw's black-backed snake	Probably extinct	Malhotra and Thorpe, 1999
Mastigodryas bruesi	Barbour's tropical racer	Least concern	Malhotra and Thorpe, 1999

Appendix 7. *List of terrestrial exotic and invasive species in Grenada (Source: Kairo et al., 2003 and Groome, 1970)*

Group	Common Name	Scientific Name	Status	Source
Amphibian	Cane toad	*Rhinella marina*	Invasive	Groome, 1970
	Johnstone's whistling frog	*Eleuthrodactylus johnstonei*	Invasive	Groome, 1970
Insect	Pink hibiscus mealybug	*Maconellicoccus hirsutus*	Invasive	Kairo *et al.*, 2003
Mammal	Mona monkey	*Cercopithecus mona*	Invasive	Groome, 1970
	Small Indian mongoose	*Urva auropunctata*	Invasive	Groome, 1970; Kairo *et al.*, 2003
	Brown rat	*Rattus norvegicus*	Invasive	Groome, 1970
	Black rat	*Rattus rattus*	Invasive	Groome, 1970
	Roof rat	*Rattus alexandrinus*	Invasive	Groome, 1970
	Tree rat	*Ratus frugivorous*	Invasive	Groome, 1970
	House mouse	*Mus musculus*	Invasive	Groome, 1970
Plant (Tree)	Sweet acacia	*Acacia farnesiana*	Exotic	Kairo *et al.*, 2003
	White thorn	*Senegalia polyacantha*	Exotic	Kairo *et al.*, 2003
	Acacia coral	*Adenanthera pavonina*	Exotic	Kairo *et al.*, 2003
	Lebbek tree	*Albizia lebbeck*	Exotic	Kairo *et al.*, 2003
	White siris	*Albizia procera*	Exotic	Kairo *et al.*, 2003
	Candleberry	*Aleurites moluccanus*	Exotic	Kairo *et al.*, 2003
	Breadfruit	*Artocarpus altilis*	Exotic	Kairo *et al.*, 2003
	Purple orchid tree	*Bauhinia variegata*	Exotic	Kairo *et al.*, 2003
	Apple of Sodom	*Calotropis procera*	Exotic	Kairo *et al.*, 2003
	Papaya	*Carica papaya*	Exotic	Kairo *et al.*, 2003
	Common ironwood	*Casuarina equisetifolia*	Exotic	Kairo *et al.*, 2003
	Governor plum	*Flacourtia indica*	Exotic	Kairo *et al.*, 2003
	Gliricidia	*Gliricidia sepium*	Exotic	Kairo *et al.*, 2003
	Blue Mahoe	*Hibiscus elatus*	Exotic	Kairo *et al.*, 2003
	Stinkingtoe	*Hymenaea courbaril*	Exotic	Kairo *et al.*, 2003
	Blue Jacaranda	*Jacaranda mimosifolia*	Exotic	Kairo *et al.*, 2003
	Physic Nut	*Jatropha curcas*	Exotic	Kairo *et al.*, 2003
	Wild Tamarind	*Leucaena diversifolia*	Exotic	Kairo *et al.*, 2003
	Leucaena/White Tamarind	*Leucaena leucocephala*	Exotic	Kairo *et al.*, 2003
	Mango	*Mangifera indica*	Exotic	Kairo *et al.*, 2003
	Sapodilla	*Manilkara zapota*	Exotic	Kairo *et al.*, 2003
	Paper Bark Tea Tree	*Melaleuca quinquenervia*	Exotic	Kairo *et al.*, 2003
	African Locust Bean	*Parkia biglobosa*	Exotic	Kairo *et al.*, 2003
	Avocado	*Persea americana*	Exotic	Kairo *et al.*, 2003
	Mesquite	*Prosopis juliflora*	Exotic	Kairo *et al.*, 2003
	Prickly Sesban	*Sesbania bispinosa*	Exotic	Kairo *et al.*, 2003
	Plum	*Spondias purpurea*	Exotic	Kairo *et al.*, 2003
	Java Plum	*Syzygium cumini*	Exotic	Kairo *et al.*, 2003
	Pink Trumpet Tree	*Tabebuia heterophylla*	Exotic	Kairo *et al.*, 2003
	White Hoarypea	*Tephrosia candida*	Exotic	Kairo *et al.*, 2003
	Beach Almond	*Terminalia catappa*	Exotic	Kairo *et al.*, 2003
	Chinese Apple	*Ziziphus mauritiana*	Exotic	Kairo *et al.*, 2003
Reptile	Brown Anole	*Anolis sagrei*	Invasive	Kairo *et al.*, 2003

Appendix 8. List of selected biotas associated with Grenada's freshwater ecosystems

Scientific Name	Common Name	IUCN Status	Native	Rivers and Streams	Ponds and Lakes	Estuaries	Consumptive Resource	Observed	References
Phylum: Chordata									
Fishes									
Gambusia sp.	Mosquitofish, millionsfish				x			Levera Pond	(Government of Grenada, 2014; Charles, 2018)
Poecilia reticulata	Guppy				x				(Groome, 1970b; Government of Grenada, 2014; Charles, 2018; Ravndal, 2019)
Xiphophorus hellerii	Swordtail				x				(Groome, 1970b; Government of Grenada, 2014; Ravndal, 2019)
Cyprinus rubrofuscus	Koi				x			Grand Etang Lake	(Ravndal, 2019)
Oreochromis mossambicus	Mozambique tilapia, police				x			Levera Pond	(Groome, 1970b; Charles, 2018; Ravndal, 2019)
Oreochromis niloticus	Nile tilapia				x			Levera Pond	(Charles, 2018; Ravndal, 2019)
Eleotris sp.	Zandomay		x				x		(Government of Grenada, 2014)
Sicydium plumieri	Sirajo goby, tritri/ go-bird fish	Data deficient	x	x		x	x Harvested historically		(Groome, 1970b; The Caribbean Conservation Association, 1991; Government of Grenada, 2014)
Mugil liza	Lebranche mullet, mullet	Data deficient	x			x	x Overharvested?		(Groome, 1970b; Government of Grenada, 2014)
Dajaus monticola	Mountain mullet, mullet	Least Concern	x	x			x		(Groome, 1970b; Government of Grenada, 2014)
Centropomus ensiferus	Swordspine snook, river coco/mudfish	Least Concern	x	x		x	x Overharvested		(Groome, 1970b; Government of Grenada, 2014)
Centropomus parallelus	Fat snook, river coco/mudfish	Least Concern	x	x		x	x Overharvested		(Froese and Pauly, 2021)
Centropomus pectinatus	Tarpon snook, river coco/ mudfish	Least Concern	x	x		x	x Overharvested		(Froese and Pauly, 2021)
Centropomus undecimalis	Snook, brushi	Least Concern	x	x		x	x	Levera Pond	(Charles, 2018)
Synbranchus marmoratus	Swamp eel, tete chien/yoca	Least Concern	x	x					(Groome, 1970b; Government of Grenada, 2014; Crask, 2009)

Alosa sp.	Shad	Least Concern	x	x		x	x Overharvested?		(Groome, 1970b)
Caranx hippos	Crevalle jack		x			x			(The Caribbean Conservation Association, 1991)
Oligoplites palometa	Maracaibo leatherjacket	Least Concern	x	x		x			(Froese and Pauly, 2021)
Anguilla rostrata	American eel	Endangered	x	x		x			(Froese and Pauly, 2021)
Carcharhinus leucas	Bull shark	Near Threatened	x			x			(Froese and Pauly, 2021)
Cynoscion acoupa	Acoupa weakfish	Vulnerable	x			x			(Froese and Pauly, 2021)
Eucinostomus argenteus	Silver mojarra	Least Concern	x			x			(Froese and Pauly, 2021)
Eugerres plumieri	Striped mojarra	Least Concern	x			x			(Froese and Pauly, 2021)
Gerres cinereus	Yellowfin mojarra	Least Concern	x			x			(Froese and Pauly, 2021)
Rhonciscus crocro	Burro grunt	Data Deficient	x	x		x			(Froese and Pauly, 2021)
Microphis lineatus	Opossum pipefish	Data Deficient	x	x		x			(Froese and Pauly, 2021)
Hypostomus plecostomus (misidentified?)	Common pleco			x					(Provencher and Gibson, 2016)
Megalops atlanticus	Tarpon, Tocky	Vulnerable	x	x		x		Levera Pond	(Charles, 2018)
Phylum: Chordata									
Amphibians									
Pristimantis euphronides	Grenada frog	Critically Endangered	x						(Kaiser *et al.*, 1994)
Eleutherodactylus johnstonei	Lesser Antillean whistling frog	Least Concern						Grenada and Carriacou	(Kaiser, 1997)
Leptodactylus validus	Smooth-skinned ditch frog	Least Concern		x	x				
Rhinella marina	Cane toad	Least Concern		x	x	x			
Osteopilus septentrionalis	Cuban tree frog	Least Concern		x	x	x			(Somma and Graham, 2015)
Phylum: Arthropoda									
Atya spp.	Crayfish		x	x					(Bass, 2004)
Macrobrachium spp.	Crayfish		x	x			x		(Groome, 1970; Bass, 2004)
Pseudothelphusidae	Freshwater crab		x	x			?		(Wehrtmann, Ramírez and Pérez-Rex, 2016)
Phylum: Mollusca									
Melanoides tuberculata	Red-rimmed melania			x	x				(Bass, 2004)

Appendix 9. List of selected biotas associated with Grenada's offshore island ecosystems

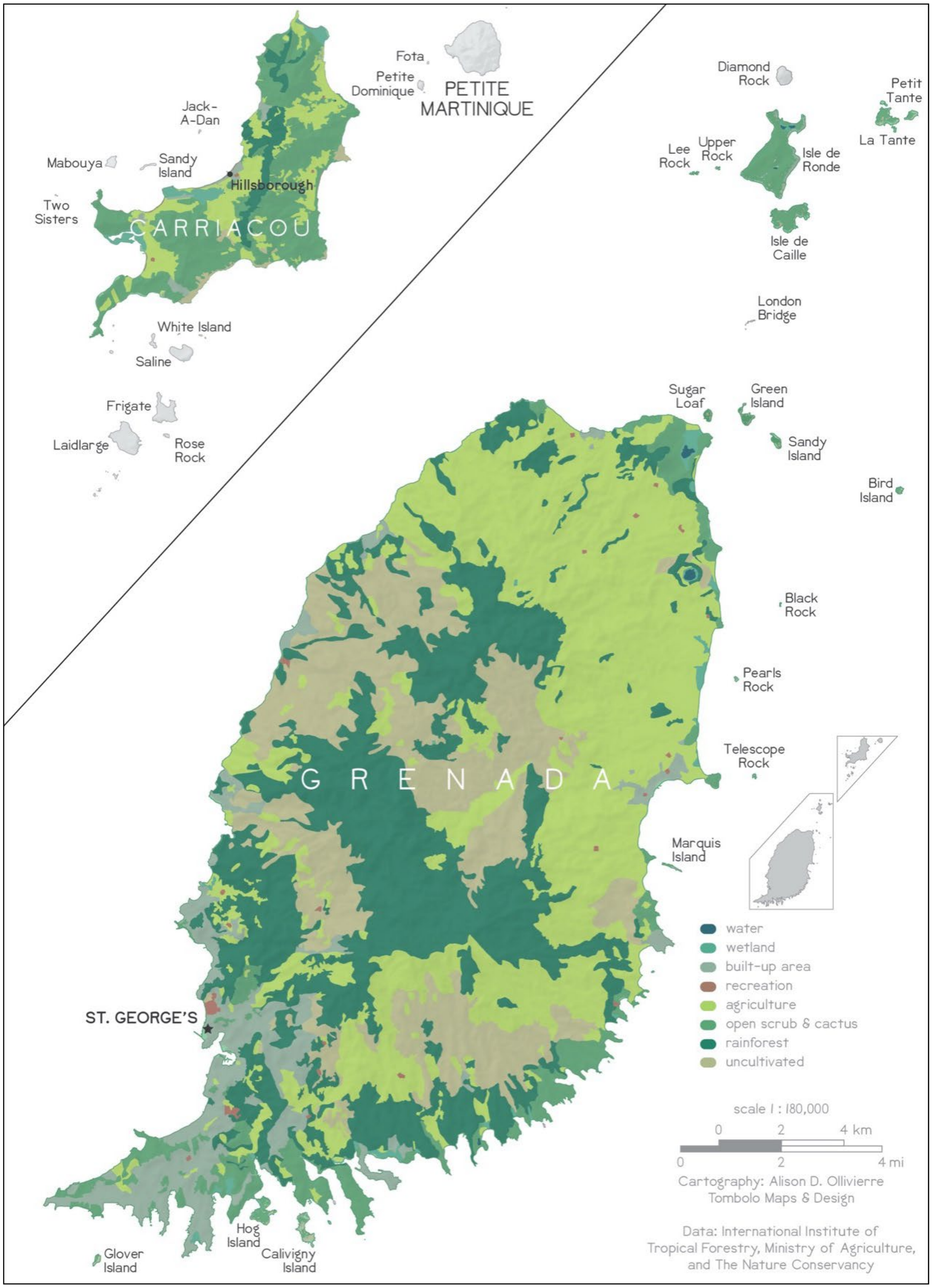
Scientific Name	Common Name	IUCN Status	Status (Other)	Consumptive Resource	References
Birds					
Puffinus iherminieri	Audubon's shearwater	Least concern	Caribbean At-Risk Species (Bradley and Norton 2009)	Yes – illegal harvest	Coffey and Ollivierre, 2019
Onychoprion anaethetus	Bridled tern	Least concern		Yes – illegal harvest	Coffey and Ollivierre, 2019
Sula Leucogaster	Brown booby	Least concern	Caribbean At-Risk Species (Bradley and Norton 2009)	Yes – illegal harvest	Coffey and Ollivierre, 2019
Anous stolidus	Brown noddy	Least concern			Coffey and Ollivierre, 2019
Pelecanus occidentalis	Brown pelican	Least concern	Caribbean At-Risk Species (Bradley and Norton 2009)		Coffey and Ollivierre, 2019
Sterna hirundo	Common tern	Least concern	Caribbean At-Risk Species (Bradley and Norton 2009)		Coffey and Ollivierre, 2019;
Leucophaeus atricilla	Laughing gull	Least concern		Yes – illegal harvest	Coffey and Ollivierre, 2019
Fregata magnificens	Magnificent frigatebird	Least concern	Caribbean At-Risk Species (Bradley and Norton 2009)	Yes – illegal harvest	Coffey and Ollivierre, 2019
Sula dactylatra	Masked booby	Least concern	Caribbean At-Risk Species (Bradley and Norton 2009)	Yes – illegal harvest	Coffey and Ollivierre, 2019
Phaethon aethereus	Red-billed Tropicbird	Least concern		Yes – illegal harvest	Coffey and Ollivierre, 2019
Sula sula	Red-footed booby	Least concern		Yes – illegal harvest	Coffey and Ollivierre, 2019
Sterna dougallii	Roseate tern	Least concern	Caribbean At-Risk Species (Bradley and Norton 2009)		Coffey and Ollivierre, 2019
Thalasseus maximus	Royal tern	Least concern	Caribbean At-Risk Species (Bradley and Norton 2009)		Coffey and Ollivierre, 2019
Thalasseus sandvicensis	Sandwich tern	Least concern	Caribbean At-Risk Species (Bradley and Norton 2009)		Coffey and Ollivierre, 2019;
Onychoprion fuscatus	Sooty tern	Least concern	Caribbean At-Risk Species (Bradley and Norton 2009)	Yes – illegal harvest	Coffey and Ollivierre, 2019
Phaethon lepturus	White-tailed tropicbird	Least concern	Caribbean At-Risk Species (Bradley and Norton 2009)		Coffey and Ollivierre, 2019
Haematopus palliatus	American oystercatcher	Least Concern			Coffey and Ollivierre, 2019
Limnodromus griseus	Short-billed dowitcher	Least Concern			Coffey and Ollivierre, 2019
Charadrius semipalmatus	Semipalmated plover	Least Concern			Coffey and Ollivierre, 2019
Charadrius wilsonia	Wilson's plover	Least Concern			Coffey and Ollivierre, 2019
Pluvialis squatarola	Black bellied plover	Least Concern			Coffey and Ollivierre, 2019
Arenaria interpres	Ruddy turnstone	Least Concern			Coffey and Ollivierre, 2019
Tringa melanoleuca	Greater yellowlegs	Least Concern			Coffey and Ollivierre, 2019
Tringa flavipes	Lesser yellowlegs	Least concern			Coffey and Ollivierre, 2019

Numenius phaeopus	Whimbrel	Least concern			Coffey and Ollivierre, 2019
Calidris minutilla	Least sandpiper	Least Concern			Coffey and Ollivierre, 2019
Actitis macularius	Spotted sandpiper	Least Concern			Coffey and Ollivierre, 2019
Calidris fuscicollis	White-rumped sandpiper	Least Concern			Coffey and Ollivierre, 2019
Ardea herodias	Great blue heron	Least Concern			Coffey and Ollivierre, 2019
Egretta caerulea	Little blue heron	Least Concern			Coffey and Ollivierre, 2019
Nyctanassa violacea	Yellow-crowned night heron	Least Concern			Coffey and Ollivierre, 2019
Butorides virescens	Green heron	Least Concern			Coffey and Ollivierre, 2019
Egretta tricolor	Tricolored heron	Least Concern			Coffey and Ollivierre, 2019
Bubulcus ibis	Cattle egret	Least Concern	Introduced/ Invasive		Coffey and Ollivierre, 2019
Oxyura jamaicensis	Ruddy duck	Least Concern			Coffey and Ollivierre, 2019
Anas crecca	Green-winged teal	Least Concern			Coffey and Ollivierre, 2019
Gallinago delicata	Wilson's snipe	Least Concern			Coffey and Ollivierre, 2019
Porzana carolina	Sora	Least Concern			Coffey and Ollivierre, 2019
Fulica americana	American coot	Least Concern			Coffey and Ollivierre, 2019
Gallinula galeata	Common gallinule	Least Concern			Coffey and Ollivierre, 2019
Tyto alba	Barn owl	Least Concern			Coffey and Ollivierre, 2019
Quiscalus lugubris	Carib grackle	Least Concern			Coffey and Ollivierre, 2019
Tyrannus dominicensis	Gray kingbird	Least Concern			Coffey and Ollivierre, 2019
Mimus gilvus	Tropical mockingbird	Least Concern			Coffey and Ollivierre, 2019
Zenaida aurita	Zenaida dove	Least Concern			Coffey and Ollivierre, 2019
Streptopelia decaocto	Eurasian collared dove	Least Concern	Introduced / Invasive		Coffey and Ollivierre, 2019
Columbina passerina	Common ground dove	Least Concern			Coffey and Ollivierre, 2019
Zenaida auriculata	Eared dove	Least Concern			Coffey and Ollivierre, 2019
Orthorhyncus cristatus	Antillean crested hummingbird	Least Concern			Coffey and Ollivierre, 2019
Myiarchus nugator	Grenada flycatcher	Least Concern			Coffey and Ollivierre, 2019
Coereba flaveola	Bananaquit	Least Concern			Coffey and Ollivierre, 2019
Coccyzus minor	Mangrove cuckoo	Least Concern			Coffey and Ollivierre, 2019
Pandion haliaetus	Osprey	Least Concern			Coffey and Ollivierre, 2019
Falco peregrinus	Peregrine falcon	Least Concern	CITES Appendix I		Coffey and Ollivierre, 2019
Patagioenas squamosa	Scaly-naped Pigeon	Least Concern		Yes- Seasonal harvest	Coffey and Ollivierre, 2019
Hirundo rustica	Barn swallow	Least Concern			Coffey and Ollivierre, 2019
Progne dominicensis	Caribbean martin	Least Concern			Coffey and Ollivierre, 2019

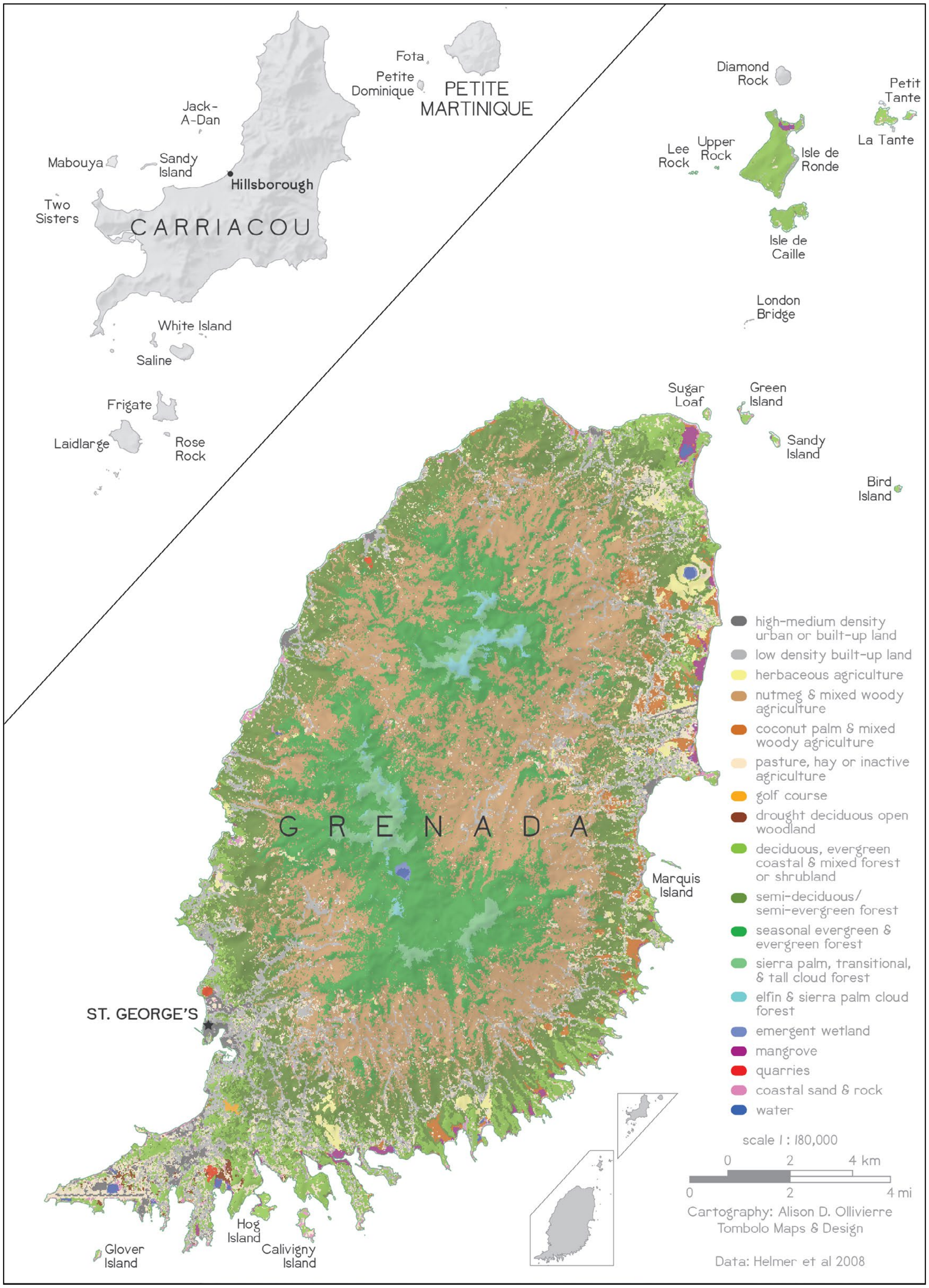
Marine Reptiles					
Dermochelys coriacea	Leatherback turtle	Vulnerable		Yes- illegal harvest	Ocean Spirits, 2019
Eretmochelys imbricata	Hawksbill turtle	Critically endangered		Yes- illegal and seasonal harvest	Ocean Spirits, 2019
Chelonia mydas	Green turtle	Endangered		Yes – illegal and seasonal harvest	Ocean Spirits, 2019
Caretta caretta	Loggerhead turtle	Vulnerable		Yes- illegal and seasonal harvest	Ocean Spirits, 2019
Terrestrial Reptiles					
Iguana iguana	Green iguana	Least Concern	CITES Appendix II	Yes – illegal and seasonal harvest	
Iguana insularis insularis	Grenadines pink rhino iguana	Data deficient		Yes – illegal and seasonal harvest; incidental take	Charles *et al.*, 2021
Mastigodryas bruesi	Barbour's tropical racer	Least Concern			
Ameiva tobagana	Antillean ameiva	Least Concern			
Anolis aeneus	Grenada bush anole	Least Concern			
Anolis richardii	Grenada tree anole	Least Concern			
Marisora aurulae	Lesser Windward skink	Vulnerable			
Corallus grenadensis	Grenada bank tree boa	Least Concern	CITES Appendix II		
Gymnophthalmus underwoodi	Underwood's spectacled tegu	Least Concern			
Hemidactylus mabouia	Common tropical house gecko	Least Concern			
Eleutherodactylus johnstonei	Lesser Antillean whistling frog	Least Concern			
Thecadactylus rapicauda	Turniptail gecko	Least Concern			
Chelonoidis carbonarius	Red-footed tortoise	Not Evaluated	CITES Appendix II- Introduced		Charles *et al.*, 2021
Terrestrial Mammals					
Noctilio leporinus mastivus	Greater fishing bat	Least Concern			Genoways *et al.*, 2010
Glossophaga longirostris rostrata	Miller's Long-tongued bat	Least Concern			Genoways *et al.*, 2010
Artibeus lituratus palmarum	Great fruit-eating Bat	Least Concern			Genoways *et al.*, 2010
Artibeus schwartzi	Schwartz's fruit-eating bat	Data Deficient			Genoways *et al.*, 2010
Molossus molossus	Pallas's mastiff bat	Least Concern			Genoways *et al.*, 2010
Terrestrial Invertebrates					
Erythemis vesiculosa	Great pondhawk	Least Concern			Charles *et al.*, 2021

Phoebis sennae	Cloudless sulphur	Least Concern			Charles *et al.*, 2021
Utetheisa ornatrix	Caribbean red and white moth	Not Evaluated			Charles *et al.*, 2021
Burnsius oileus	Tropical checkered skipper	Not Evaluated			Charles *et al.*, 2021
Phoebis philea	Orange barred sulphur	Not Evaluated			Charles *et al.*, 2021
Phoebis argante	Apricot sulphur	Not Evaluated			Charles *et al.*, 2021
Battus polydamas	Gold rim swallowtail	Least Concern			Charles *et al.*, 2021
Polites dictynna	Lesser whirlabout	Not Evaluated			Charles *et al.*, 2021
Cyclargus dominica	Jamaican blue	Not Evaluated			Charles *et al.*, 2021
Psiloptera lampetis	Green guava beetle	Not Evaluated			
Marine Invertebrates					
Cittarium pica	West Indian whelk	Not Evaluated		Yes – harvested	
Acanthopleura granulata	West Indian fuzzy chiton	Not Evaluated		Yes- harvested	
Cardisoma guanhumi	Blue land crab	Not Evaluated		Yes- harvested	
Grapsus grapsus	Sally lightfoot	Not Evaluated		Occasionally used as fishing bait	
Ocypode quadrata	Atlantic ghost crab	Not Evaluated			
Minuca pugnax	Fiddler crab	Not Evaluated			
Gecarcinus lateralis	Red land crab	Not Evaluated		Yes- harvested	
Coenobita clypeatus	Caribbean hermit crab / soldier crab	Not Evaluated			
Emerita talpoida	Sea cockroach / mole crab	Not Evaluated			
Eriphia gonagra	Warty crab	Not Evaluated			
Terrestrial Flora (see Coastal Ecosystems for marine flora)					
Randia aculeata	Five fingers				Howard, 1952
Tabebuia pallida	White cedar				Howard, 1952
Coccoloba spp.	Sea grape				Howard, 1952
Capparis spp.					Howard, 1952
Alternanthera sessilis					Howard, 1952
Sesuvium portulacastrum	Sea purslane				Howard, 1952
Convolvulaceae spp.					Howard, 1952
Pectis humifusa	Yerba de San Juan				Howard, 1952
Heliotropium spp.					Howard, 1952
Agave caribaeicola	Agave				Howard, 1952
Rhizophora mangle	Red mangrove				Howard, 1952
Opuntia dillenii	Prickly pear				Howard, 1952
Melocactus spp.	Turk's cap cactus				Hawthorne *et al.*, 2004

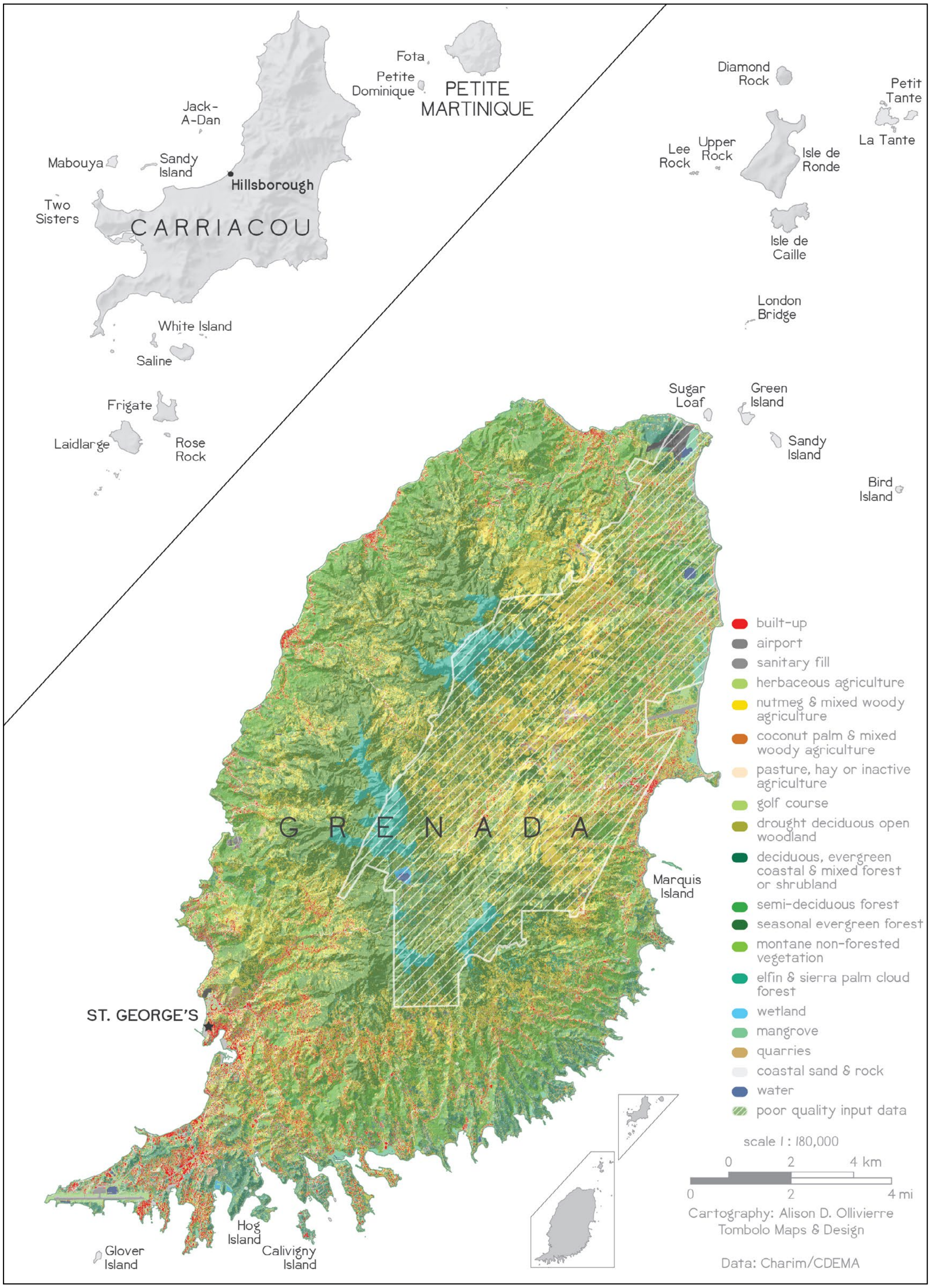
Appendix 10. Manual digitisation of aerial photos work from Grenada's Land Use Division in 2009



Appendix 11. Machine learning the classification of satellite imagery by The Nature Conservancy (Helmer, 2008)

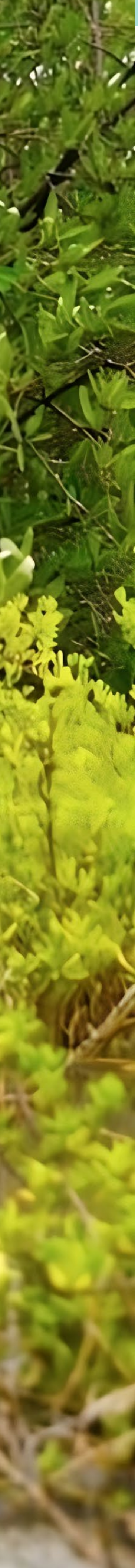


Appendix 12. Machine learning the classification of satellite imagery by the CHARINODE project (CHARIM, 2016)



Planting red mangrove propagules as part of restoration efforts in Petit Carenage, Carriacou

Photo credit: Piero Becker



3. Contribution of Grenada's ecosystems to climate resilience

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Summary

Small Island Developing States (SIDS) including, Grenada, collectively contribute less than 1% of global greenhouse gas (GHG) emissions but face disproportionate risk from climate change impacts (Mead, 2021). SIDS contributed 0.5% of historical cumulative carbon dioxide (CO_2) from fossil fuel combustion, and industrial processes (CO2-FFI) emissions, between 1850 and 2019 and in 2019, emitted approximately 0.6% of global GHG emissions, excluding net CO_2 emissions from land use, land-use change and forestry (CO2-LULUCF) (IPCC, 2022a). The Intergovernmental Panel on Climate Change (IPCC) *Sixth Assessment Report* has amplified the urgency to combat climate change in SIDS.

Ecosystem resilience refers to the ability of the system to continue its functioning amid, and recover from, a perturbation. Community resilience is closely interlinked with ecosystem resilience. Human actions, which drive changes in land use, hydrology, nutrient cycles or increase pollution, can reduce ecosystem resilience, especially when synergised with changing climate conditions.

Climate projections for Grenada (based on projections for the eastern Caribbean) suggest a drying trend, increased drought conditions and increased hurricane frequency and intensity. A drying trend from decreasing rainfall and increasing temperatures is expected by 2050 together with increasing frequency and duration of droughts—with moderate to severe events occurring 26% of the time. Together with increased sea surface temperatures (SSTs), the intensity of hurricanes is projected to increase, with an 80% increase in Category 4 and 5 hurricanes over the next 80 years (A1B scenario).

With changing climate conditions, projections for Grenada and the other islands of the eastern Caribbean, include increasing air and SSTs and changing rainfall patterns. These are expected to result in a range of threats, including sea level rise (SLR), hurricanes, increasing drought and flooding. Synergies between these threats, and the often fragile ecosystems within many of these islands, are expected to yield multiple negative repercussions and have the potential to negatively impact our way of life on these islands, including the ability of the land to support human life and livelihoods (IPCC, 2022b).

Human actions, which lead to changes in land use, hydrology, nutrient cycles or increase in pollution, can reduce ecosystem resilience—especially when synergised with changing climate conditions. Such synergies have the potential to cause cascading effects, which are likely to negatively impact our access to ecosystem services, social and economic well-being, and livelihoods.

Women are increasingly vulnerable to the impacts of changing climate conditions. Climate impacts are expected to increase both the frequency and intensity of economic shocks as global warming continues. Women are particularly vulnerable to such economic shocks, for example, the devastation of the nutmeg plantations from hurricanes destroyed an industry from which women earned their livelihoods.

A Driver-Pressure-State-Impact-Response (DPSIR) Framework was used to assess Grenada's ecosystems in the context of climate change and climate resilience. Drivers (D) are the economic and social factors that are driving forces which exert pressure (P) on the environment, affecting its state (S). These changes in the environmental state tend to have impacts (I) on the ecosystems or human health and well-being, and due to these impacts, society can respond (R) to the driving forces, the pressure, state or impacts through preventive, adaptive or curative measures.

Drivers

The economic drivers for ecosystem change in Grenada include government debt, vulnerability to external shocks (including financial and extreme weather) and external funding directed to priorities other than ecosystems. Other economic drivers originate from manufacturing at the local breweries, demand for resources such as hydrocarbons, tourism-driven events and unsustainable agriculture. The social drivers include demographic trends, including steady population growth, expansion of housing and settlement in coastal/flat/lowland areas. Poverty, poor governance (including inadequate local resource management and weak institutional capacity)**,** absent or incomplete land and sectoral policies, competition for the limited land space, and cultural drivers, such as public perception and patterns of natural resource use, are also social drivers of environmental change.

Pressure

Environmental and societal pressures include land degradation and land-use change caused by agricultural, tourism and residential development, and commercial activities leading to habitat loss, fragmentation, degradation (including erosion and sedimentation) and destruction (for example from an increased incidence of wildfires or removal of seagrass beds and other coastal vegetation for development). Unsustainable land management, with increasing competition for resources, invasive alien species (IAS) and pollution (chemicals, nutrients, sediments, ballast water, waste etc.) are also significant sources of environmental challenges. Land tenure is considered a pressure because problems arise when agricultural land is urbanised and farmers have to move to marginal lands, often near or in forested watershed areas. Unsustainable natural resource management and consumption rates, such as over abstraction of surface water and overharvesting of species, including seafood for local consumption and tourism demand, result in over-exploitation of ecosystems. Pressures related to climate change include increased storm intensity and frequency, drought, SLR and increased SST.

Impacts: Terrestrial ecosystems

Forest loss already observed on Grenada has led to increased flooding and erosion, particularly after hurricanes and droughts. Watershed degradation impacts water-supply intakes and coastal water quality. Reduction in agricultural productivity through altered soil erosion, nutrient cycling, fire and hydrology, and drier conditions could lead to reduced future carbon sequestration. SLR is already impacting Grenada and, together with high development pressure in coastal areas, this could lead to an overall loss of species diversity, abundance and change in habitat composition, including abundance and composition of Non Timber Forest Product (NTFP) species, which could lead to disproportionately negative impacts for vulnerable groups whose livelihoods depend upon these species.

Dry forest composition suggests the expansion of drought-tolerant, non-native and native edge species into intact communities. Increased fragmentation, edge effects and reduced connectivity could reduce a species' dispersal ability, creating a gap between species observed and potential ranges. The impacts of the resultant changes in species compositions, homogenisation of species diversity and increasing introduced species on ecosystems and their services in Grenada is poorly known.

Tourism has been greatly impacted by previous hurricanes, with future species and habitat loss potentially impacting the ecotourism sector. The high cost of insurance and abatement of damage from hurricanes and other extreme weather events, and significant productivity loss due to heat exposure of workers in deforested areas are also potential impacts. Increases in vector-borne diseases are predicted across the Caribbean, due to climatic changes, causing more favourable conditions for species such as the yellow fever mosquito (*Aedes aegypti*). Resource conflicts and internal or external migration due to scarce resources are increasingly likely due to climate change.

Impacts: Agricultural ecosystems

Declining diversity and abundance of pollinators have a negative effect on agricultural production. Too much abandoned or idle land can also affect productivity of adjacent farmlands, leading to food production loss and a consequent reliance on food imports. Increased abundance of pest species would also impact agricultural productivity and biodiversity. The effects of climate change such as saltwater intrusion due to SLR could result in agricultural land abandonment. Freshwater inundation has either compromised the running of coastal farms or resulted in complete land abandonment.

Impacts: Coastal and marine ecosystems

Coastal areas may experience physical damage by extreme storms, and communities may be unable to respond to SLR due to little opportunity for landward retreat. Additionally, SLR is expected to transform fringing mangroves to basin mangroves, diminishing defence against storms and winds. Saltwater intrusion from SLR is also increasing the salinity in salt ponds, backwaters and estuaries, reducing available oxygen and limiting their ability to support brackish water species, and also leading to high algal growth and fish kills in marine ecosystems. Impacts of climate change on fishery production or yields could have wide-ranging implications for Grenada's economy.

Coral bleaching will occur more frequently, and last longer, as mean ocean temperatures increase. Increased ocean warming also favours conditions for coral disease outbreaks. Increased storm intensity and strong storm surge may dislodge and damage corals in coastal lagoons. Extreme storms and wave surges are expected to erode seagrass beds, removing seagrasses. SLR will also increase the depth of seagrasses in the tidal frame, limiting the amount of light that is available for photosynthesis. SLR, coupled with storm surges, also threaten to transform beaches to open ocean and increase coastal erosion, threatening people and property. Increased acidification negatively affects corals, reducing the amount of sand available for beach formation.

Impacts: Freshwater ecosystems

Impacts to freshwater ecosystems will affect crop yields, in turn, threatening food security and economic stability, resulting in vulnerable livelihoods and income. Other impacts include lack of drinking water (e.g. in St. Patrick), changes to precipitation (causing decreased multisectoral resource accessibility and/or availability for tourism), loss of cultural services (e.g. river tubing and baptisms), reduced irrigation for agriculture, reduction in freshwater species, biodiversity loss and homogenisation of species diversity (e.g. tilapia [*Oreochromis niloticus*]), and changes to water quality from wastewater discharge from livestock and mixed farming. Barriers in rivers placed for flood risk management result in poor floodplain habitat (e.g. in River Road), habitat fragmentation and unnatural morphology of the river. Reduction in water availability and quality adversely impact tourism and potentially intensify existing gender inequalities. Generally, freshwater ecosystem health is decreasing, and species diversity and abundance are reducing. This can lead to resource conflicts within communities.

Responses: General

To improve ecosystem resilience, responses can take place through national governance and policy responses, institutional and sectoral systems, technological responses and socioeconomic interventions.

Responses: Policy

Coordinated national and multisectoral policy, laws and regulations, harmonised policies between sectors (that reduce overlaps and gaps to address adaptation, and integration of ecosystem services into national governance), land use planning, policies and legal frameworks are responses to climate change. Systemic and institutional inter-agency coordination requires augmented financial resources for personnel, technical capacity and equipment. Aligned sectoral policies with adaptation planning would include, for example, the emphasis on future-proofing climate resilient Protected Areas (PAs) including Forest Reserves and Marine Protected Areas (MPAs). A priority should include maintaining intact PAs, ensuring effective management of existing PAs and sustainable practices in multi-use reserves. These measures would reduce or remove other pressures such as overexploitation and habitat degradation.

Responses: Incentives

At a local level, incentives (such as Payments for Ecosystem Services [PES]) and suitable financial mechanisms should be explored and implemented to foster sustainable agricultural/land management planning and practices. Given the high proportion of private land ownership, small local actions can promote ownership of climate adaptation and have island-wide cumulative benefits.

Responses: Knowledge and awareness

Enhanced awareness and understanding of climate resilient management techniques and practices integrated with biodiversity and conservation are needed among practitioners and decision makers. Awareness raising and science communication can also be fundamental to providing communities with the knowledge they need to adapt to climate change. Filling knowledge gaps on long-term monitoring of climate, biodiversity, species and ecosystems is crucial. This includes improving access to existing data, establishing information systems, as well as sharing data between and within government departments and all stakeholders. Data collection (such as the establishment of baseline data for ecosystems, climate and water quality monitoring systems, wastewater management reuse systems and Ecosystem-based Adaptation [EbA]) is a direct response to mitigate or adapt to impacts due to climate change. Data analysis and interpretation will lead to policy development to influence behavioural change and, among others, influence legislation and enforcement, education and capacity building, and transparency and accountability tools. Education and capacity building can use existing platforms to share relevant climate information. Adaptive capacity in the fishing industry and in coastal communities can be strengthened by providing training in business skills or safety at sea.

Responses: Community involvement

Community co-management of coastal forest afforestation and mangrove restoration is an important initiative. Furthermore, fisheries cooperatives can be used to develop support schemes, to spread risks and provide a financial 'safety net'. Building resilient communities by having them play a leading role in the conservation, restoration and management of ecosystems in Grenada is a key response to the impacts of climate change.

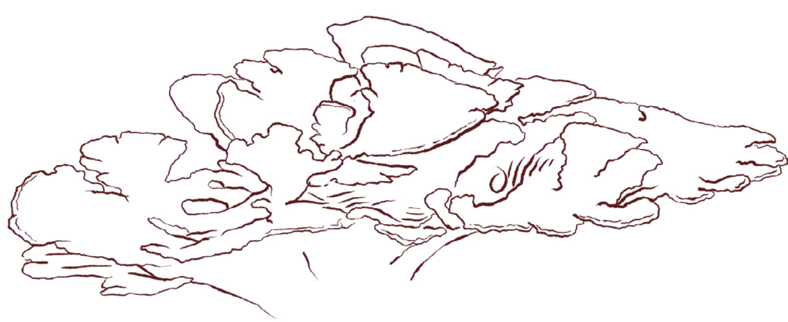
3.1. Chapter concept

The aim of this chapter is to assess the resilience potential of Grenada's terrestrial, freshwater, agricultural, coastal and offshore marine ecosystems to changes in climate. Given that future ecosystem resilience is determined by past and present activities, DPSIR models have been used to illustrate, in a simplified way, the dynamic nature and flux of each ecosystem as these are impacted by climate change across multiple spatial and temporal scales. Potential ecosystem resilience for Grenada as a whole is then suggested based on the synthesising of common trends among each ecosystem's DPSIR model.

3.1.1. Objectives

The objectives of the chapter are to:

- describe the state and current trends across Grenada's ecosystems and ecosystem services in the context of assessing the implications of climate change;
- describe how climate change impacts Grenada's ecosystems and ecosystem services in the present and predict how it might do so in the future given pre-existing and ongoing anthropogenic activity; and
- discuss the current, and predict the future, effect of climate change, in synergy with anthropogenic activities, on the (present) resilience and (future) resilience potential of Grenada's ecosystems.



3.2. Introduction

3.2.1. Climate change adaptation, mitigation and resilience

The *United Nations Framework Convention on Climate Change* (UNFCCC) refers to climate change as "a change in climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable periods of time". From the 1950s and onward, evidence suggests explicit increases in atmospheric levels of GHGs particularly CO_2 and methane (CH_4) compared to prior millennia (IPCC, 2018).

Increasing levels of GHGs stem from human activity, resulting in an increase in global average temperatures well above pre-industrial levels. This is referred to as anthropogenic global warming, which leads to several pervasive impacts. GHGs remain in the atmosphere for hundreds of years and continuous emissions at the present rate will exacerbate impacts that are currently being experienced from emissions decades ago.

Key pathways to addressing the current state of human-induced climate change are founded within climate change mitigation and adaptation measures. The IPCC's *Special Report: Global Warming of 1.5°C* (2018) defines mitigation as "a human intervention to reduce emissions or enhance the sinks of greenhouse gases" and adaptation in human systems as "the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities". Therefore, for countries to become climate resilient, they need to employ an array of mitigation and adaptation measures.

3.2.2. Small islands and climate change

The *Paris Agreement*, which was signed in 2015 on the mitigation, adaptation and financing of climate change within the scope of the UNFCCC, entered into force in 2016 (Rhodes, 2016; Bilgi and Deveci, 2022). Today, nearly all countries across the globe have committed to limiting global warming to 2°C above pre-industrial levels with further ambitions of well below 1.5°C. SIDS collectively contribute less than 1% of global emissions but face disproportionate risk from climate change impacts (IPCC, 2018). The cost of inaction in addressing climate change for Caribbean SIDS is projected to grow every 25 years by at least 5% of gross domestic product (GDP) from 2025. The most recent IPCC report, *the Sixth Assessment Report,* provided strong evidence that even under a global temperature scenario of 1.5°C, the combined and interactive nature of the key climate risks facing small islands mean that habitability is at significant risk (Mycoo *et al.,* 2022).

The impact of global warming and climate change are evident within the Wider Caribbean Region (WCR), including Grenada. Notable impacts include: 1) increasing temperatures and longer droughts, 2) increased extreme weather events and intensification (i.e. torrential rainfall, storms, hurricanes), 3) changes in biological activity, 4) shift in species range with implications for pests, diseases and invasive species, 5) SLR and 6) ocean acidification.

In addition to the temperature and precipitation trends discussed in Chapter 2, in the eastern Caribbean, droughts are projected to increase in frequency and duration with moderate to severe droughts occurring 26% of the time (Commonwealth Marine Economies Programme [CMEP], 2017). Additionally, the intensity of hurricanes is projected to increase, with an 80% increase of Category 4 and 5 hurricanes over the next 80 years (A1B scenario) (Climate Studies Group Mona [CSGM], 2020). Climate change projections for Grenada also suggest the potential for an increase in the intensity of tropical storms and increased SSTs (Government of Grenada [GoG], 2017a).

Box 3.1. Climate impacts in Grenada: droughts, floods, hurricanes and SLR

Droughts

Higher average daily temperatures and lower precipitation are projected to lead to more frequent and severe droughts, and as a result, an increased risk of wildfires. These are likely to impact Caribbean island ecosystems in a variety of ways such as: reductions in area of rainforest zones, the migration of species to higher elevations, increased soil erosion, decline in wild pollinators in tropical dry forest habitats and increased stress within freshwater systems (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services [IPBES], 2016; GoG, 2017b).

Freshwater availability, which is already under pressure from population growth and tourism expansion, is expected to decrease further as groundwater recharge is reduced, river flows are lowered, and increased siltation occurs within dams. In parallel, an increase in groundwater pollution and irrigation demand from agriculture is expected (GoG, 2017b).

Local adaptation responses are generally reactive. For example, while rainwater harvesting is practiced in some remote communities, there is an implementation deficit in key tourism and agricultural regions (GoG, 2015; GoG, 2019). There also remains insufficient access to improved crop and livestock varieties, including drought resistant ones (Food and Agriculture Organization [FAO], 2019a). Further, the draft *Grenada Drought Management Plan* (2019) is yet to be adopted. However, desalination is now being used to supplement potable water shortages (GoG, 2019).

Floods

Expansion of urban areas for housing and economic activity has resulted in increased flood risk due to the removal of forest and vegetative cover and an increase of impermeable concrete surfaces precluding infiltration into the soil, which has resulted in increasing surface runoff. Flooding was a particular concern post-Hurricane Ivan as much of the vegetation within the main watersheds was lost, creating anticipation of downstream flooding, erosion of agricultural soils and impacts on water reservoirs (World Bank, 2005). Additionally, existing drains are not designed to cope with the increased frequency of extreme flood events expected with climate change.

Poor communities have been known to build structurally-unsound homes directly on riverbeds, floodplains, low-lying coastal plains and steep terrain due to limited access to suitable lands, thus significantly increasing their exposure. Steep slopes are vulnerable to landslides and rockfalls, especially under heavy rainfall and flooding (GoG, 2017a). Vector-borne diseases (e.g. Dengue, Zika virus and Leptospirosis) are also likely to increase in prolonged flooded conditions (GoG, 2017a).

Further, destruction of critical coastal infrastructure such as coral reefs and mangroves amplify the impacts of coastal flooding, especially during storm surges. Without enforcement of land-use planning regulations, effective strategies to reduce disaster and climate-related risks could remain elusive. However, in order to adapt to current and future risks such as storm surges, hurricanes, SLR, etc. investment is needed in, for example, climate resilient green/hybrid infrastructure, such as envisioned in The Carenage, the southern corridor to the international airport and Grenville (Department of Economic and Technical Cooperation [DETC], 2018).

Hurricanes

Hurricanes have devastating impact on human populations and biodiversity across the Caribbean. Observed incidences of hurricanes have increased across the Caribbean, including several record-breaking seasons over the last 20 years, with above-average seasons (including Category 5 hurricanes) reported for the period 2016 to 2020. Of the seven seasons on record with multiple Category 5 hurricanes (with the earliest dating back to 1932) four have occurred within the last 20 years. Also noteworthy is the impact of the most powerful storm in history, Hurricane Dorian, which caused US$3.4 billion in damage (74% of GDP) in The Bahamas in 2019 (Deopersad *et al.,* 2020). Other major losses from hurricanes include Hurricane Maria which caused US$1.3 billion (224% of GDP) in damage and losses to Dominica, and Hurricane Ivan which caused US$1.1 billion (212% of GDP) in damage to Grenada (World Meteorological Organisation [WMO], 2005; Government of the Commonwealth of Dominica [GOCD], 2017).

Sea Level Rise (SLR)

Across the Caribbean, low-lying coastal areas face risks from SLR as these areas account for the highest population densities and concentration of critical infrastructure (Cazenave and Llovel, 2010; Church and White, 2011; Nurse *et al.,* 2014). SLR could increase salinity in coastal habitats, and threaten the country's airports, coastal aquifers and as much as 3% of agricultural lands, particularly when compounded by seasonal events such as storm surges, winter swells and the El Niño Southern Oscillation (GoG, 2015; GoG, 2017; IPCC, 2018). Coral bleaching due to elevated SSTs weakens the reefs, already stressed by human-induced physical damage, overfishing and pollution, leading to a decline in wave energy, fishery health and productivity (GoG, 2015; GoG, 2017a).

As the rates of SLR continue to increase, its impact on Grenada will become more evident if protective ecosystems continue to be disrupted. SLR is expected to degrade or destroy many ecosystems, including mangroves, which removes its functions of sediment retention and land accretion (Waycott *et al.,* 2011; GoG, 2017a; Braun de Torrez *et al.,* 2021). This is further compounded by sand mining, which contributes to dissipation of wave energy potential and accelerates erosion; this occurs in areas such as Telescope and Grand Roy in Grenada and Mt. Pleasant in Carriacou (Office of the Commissioner of Police, 2018). With little economic diversification away from tourism and other industries, as well as dense settlements that are highly dependent on, adjacent to and/or destructive to coastal ecosystems, the impact of SLR is likely to be significant.

Given a 1m SLR, 29% of major resorts are projected to suffer from some level of inundation with 49% destroyed or damaged by compounded SLR, storm surges and erosion (Scott, Simpson and Sim, 2012). For Grenada, projected losses include 1% of total land and roads, 3% of agricultural land, 8% of turtle nesting sites, 11% of major resorts and 100% of ports (Simpson *et al.,* 2010).

Box 3.1 provides an overview of some negative impacts of climate-related events on natural and human systems in Grenada and the WCR.

3.2.3. Importance of ecosystems to climate resilience in Grenada

Ecosystem resilience refers to the ability of the system to continue its functioning amid, and recover from, a perturbation. Navigating the factors that alter system resilience and ways to improve it require understanding system dynamics, including component feedback, uncertainty and variability (Walker and Salt, 2006). Resilient ecosystems provide multiple benefits for social and economic well-being. For example, among other societal and cultural benefits, coral reefs, mangroves, seagrass and beaches provide protection against storm surges. Ecosystems can also provide up to one-third of emission reductions needed to keep warming below 2.0°C (IPCC, 2022b).

Community resilience is closely interlinked with ecosystem resilience. Human actions which drive changes in land use, hydrology, nutrient cycles or increase pollution can reduce ecosystem resilience, especially when synergised with changing climate conditions. Further, undiversified economies can lock in patterns of behaviour and cause stress to ecosystems. Conversely, community resilience increases if, for instance, there are diversified sources of income, for which healthy, resilient ecosystems play a vital role (National Research Council [NRC], 2013).

Climate impacts have historically increased poverty among more vulnerable populations, and in the context of Grenada, a main vulnerable population is young people in female-headed households between 15 and 25 years, who experience the highest unemployment rates (FAO, 2008; United Nations Children's Fund [UNICEF], 2017). Farmers, particularly smallholder farmers, including landless livestock farmers in Carriacou, are also vulnerable to variability caused by climate change (International Fund for Agricultural Development [IFAD], 2017). Women are increasingly vulnerable to economic shocks, for example, the devastation of the nutmeg plantations from hurricanes has destroyed an industry in which women earned their livelihood through the sorting and processing of nutmegs at the nutmeg pools and gathering of the nutmegs in the community for sale (United Nations Economic Commission for Latin America and the Caribbean [UNECLAC], 2005).

3.3. Barriers to decision making for climate resilience

3.3.1. Limitations of climate change data and measurable effects on ecosystems

Climate change data

The climate resilient development pathway (CRDP) of Grenada is dependent on the quality, availability, access and application of climate data. Yet, the limited availability of downscaled climate data remains a major challenge for Grenada (Foley, 2017; CSGM, 2020). For this chapter, the *State of the Caribbean Climate (SOCC) Report* was used as the baseline for historic and future climate. In the *SOCC Report*, future climate predictions are based on a combination of Global Climate Models (GCMs), Regional Climate Models (RCMs) and statistical downscaling. GCMs, which are based on Representative Concentration Pathway (RCP) scenarios, are coarse resolution (>100km), in which small islands such as Grenada are represented by one or a few grids (CSGM, 2020). RCMs use dynamic downscaling of GCMs to incorporate greater detail by focusing on a specific region (Foley, 2017). For example, the Caribbean RCM used in the *SOCC Report* has a resolution of 25km.

Statistical downscaling makes fine-scale climate predictions based on mathematical relationships between climatic and local features (e.g. topography) (CSGM, 2020). Such models rely on long-term meteorological weather station data, which in SIDS are often sparsely and irregularly collected and recorded due to economic, logistical and political challenges, leading to much spatial and temporal uncertainty in current climate data (Peterson *et al.,* 2002; Lumbroso *et al.,* 2011; Stephenson *et al.,* 2014; Foley, 2017). Such data and methodological weaknesses in current GCMs/RCMs and statistical downscaling means that these models do not account for the small-scale complex topographical relationship with climate observed on many Caribbean islands (Foley, 2017). This limitation in downscaled climate data means that it can be difficult to make future projections of the impact of climate change on ecological and human systems on small islands (Maharaj and New, 2013; Nelson *et al.,* 2015; Fain *et al.,* 2017).

Measurable effects on ecosystems

Aside from the paucity of climate data and the weaknesses in downscaled data, there is limited long-term monitoring of ecological systems and ecosystem services across the Caribbean (Adam *et al.,* 2015; González and Heartsill-Scalley, 2016;

Nelson *et al.,* 2018; 2020; Devenish-Nelson *et al.,* 2019). This translates into knowledge gaps of the response of terrestrial and marine species and ecosystems to climate change (Latta, 2012; Taylor *et al.,* 2017; Nelson *et al.,* 2018). Similarly, there are substantial knowledge gaps about socioeconomic relationships with ecosystems and their services in the Caribbean, especially at local levels and in the context of synergies between climate change and other anthropogenic pressures (Rhiney, 2015).

While Caribbean coastal and marine systems have undergone fairly extensive economic valuation, economic valuation of terrestrial systems is far less understood (Schuhmann and Mahon, 2015; Nelson *et al.,* 2020). Moreover, cultural and non-use values remain understudied in all systems (see Chapter 4 for further details on ecosystem valuation). It should be recognised that knowledge exists in other formats that do not reach scientific or grey literature, which has varying levels of accessibility, including within local and national non-governmental organisations (NGOs), government ministries and communities. The current cumulative paucity of data means that we have incomplete understanding of how climate change will ultimately impact human populations in the Caribbean, and thus decision making, policy development and management must be viewed through this lens and take an appropriate precautionary approach.

3.4. Ecosystem assessment

3.4.1. A DPSIR Framework assessment of Grenada's ecosystems under a changing climate

Originally developed by the European Environmental Agency, the DPSIR Framework is increasingly being used by a range of international agencies (e.g. United Nations and the United States Environmental Protection Agency) to illustrate the interconnectivity among the components within a given system.
It is based on the concept that components of a system are best understood in the context of their relationships and interactions with one another, and deviates from the traditional approach of focusing on singular aspects of complex systems. It simplifies and enhances communication of complex connections between humans and the environment and so can be easily understood by both stakeholders and scientists.

In this assessment, the DPSIR Framework is used to examine relationships among the social, economic and cultural components of Grenada's ecosystems. Its main purpose is to identify and illustrate potential points within each ecosystem's Drivers, Pressures, States, Impacts and Responses that could be focused upon to increase resilience to changing climate conditions.

The DPSIR Framework used in this Chapter is illustrated in Figure 3.1. This framework was developed collaboratively by the authors of this chapter and has been applied to each of Grenada's key ecosystems: terrestrial, freshwater, agriculture, coastal and marine ecosystems.

According to Mateus and Campuzano (2008), the DPSIR Framework states that economic and social development are often driving forces (D) which exert pressure (P) on the environment affecting its state (S). These changes in the environmental state tend to have impacts (I) on the ecosystems or human health and well-being and due to these impacts, society can respond (R) to the driving forces, the pressure, state or impacts through preventive, adaptive or curative measures. To create effective sustainable development policies, a correct balance between human, natural, economic and manufactured factors must be ensured, according to a 'Drivers and Pressure (causes) — State (conditions) — Impact (effect)' sequence.

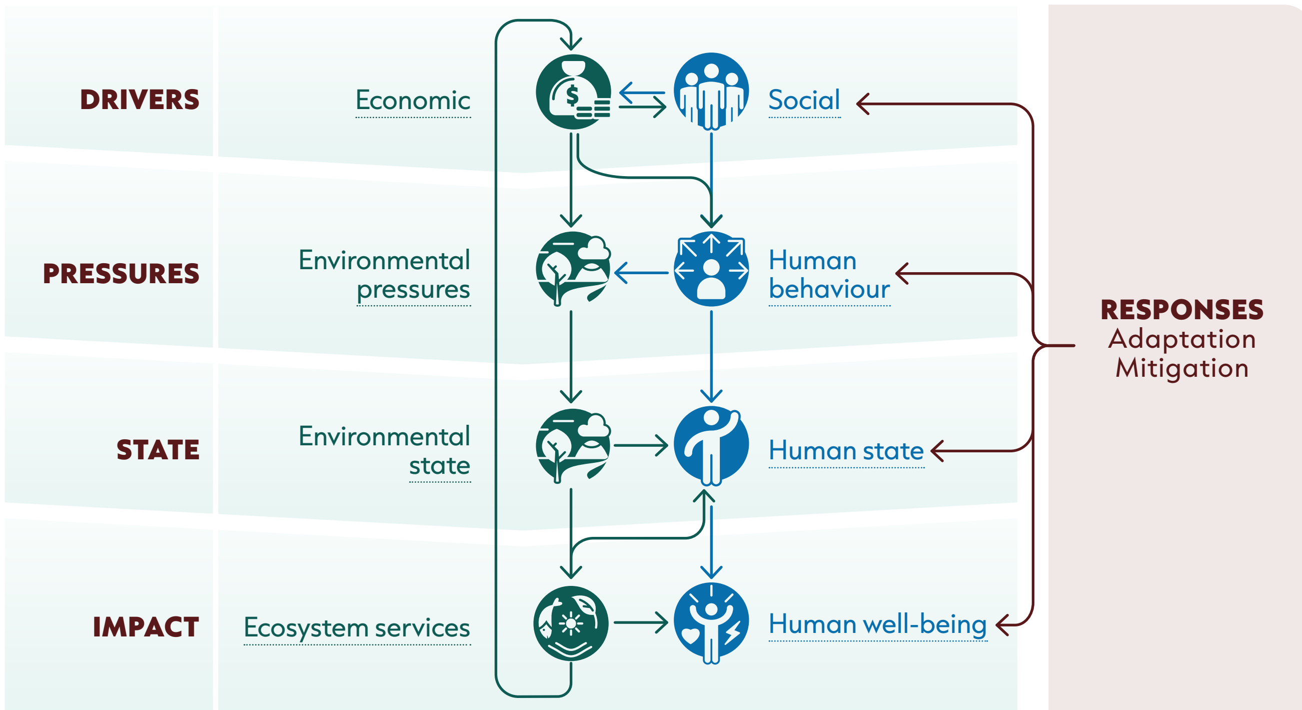


Figure 3.1. DPSIR Framework for assessment of climate change and Grenada's ecosystems

3.4.2. Terrestrial ecosystems

This section covers the main terrestrial systems in Grenada as defined in Chapter 2, namely dry scrub woodlands (e.g. semi-deciduous and deciduous forests), rainforests (e.g. seasonal evergreen, submontane), elfin woodland and palm break (e.g. cloud forest, evergreen lower montane), and forested wetlands (littoral woodlands).

Drivers

The following is a summary of the main socioeconomic drivers of environmental change of terrestrial systems in Grenada. The drivers are divided into two classes: economic and social drivers (Figure 3.2).

The first economic driver is identified as government debt, as the country's debt has increased significantly since the 2000s mainly due to the global financial crisis and impact of hurricanes (GoG, 2014). A second economic driver is vulnerability to external shocks (including financial and extreme weather). Examples include the vulnerability of the agricultural sector to externalities, notably the decline of nutmeg production due to hurricane damage and the decline of bananas due to global economic influences, both of which have resulted in increased reliance on tourism as main contributors to GDP. External funding as a third economic driver has resulted in less funding and prioritisation of terrestrial systems. Funding goals are externally driven; related project-driven activities tend to lack sustainability and long-term monitoring and evaluation (M&E) and are vulnerable to changes in global funding priorities/economic situation (e.g. COVID-19 disrupting funding calls, higher income countries reducing foreign aid for reasons such as COVID-19 or when facing climate crises).

With regards to social drivers, demographic trends include steady population growth (see Chapter 1, Section 1.7) with most settlement occurring in coastal/flat/lowland areas. Poverty includes high unemployment (impact of global recessions,

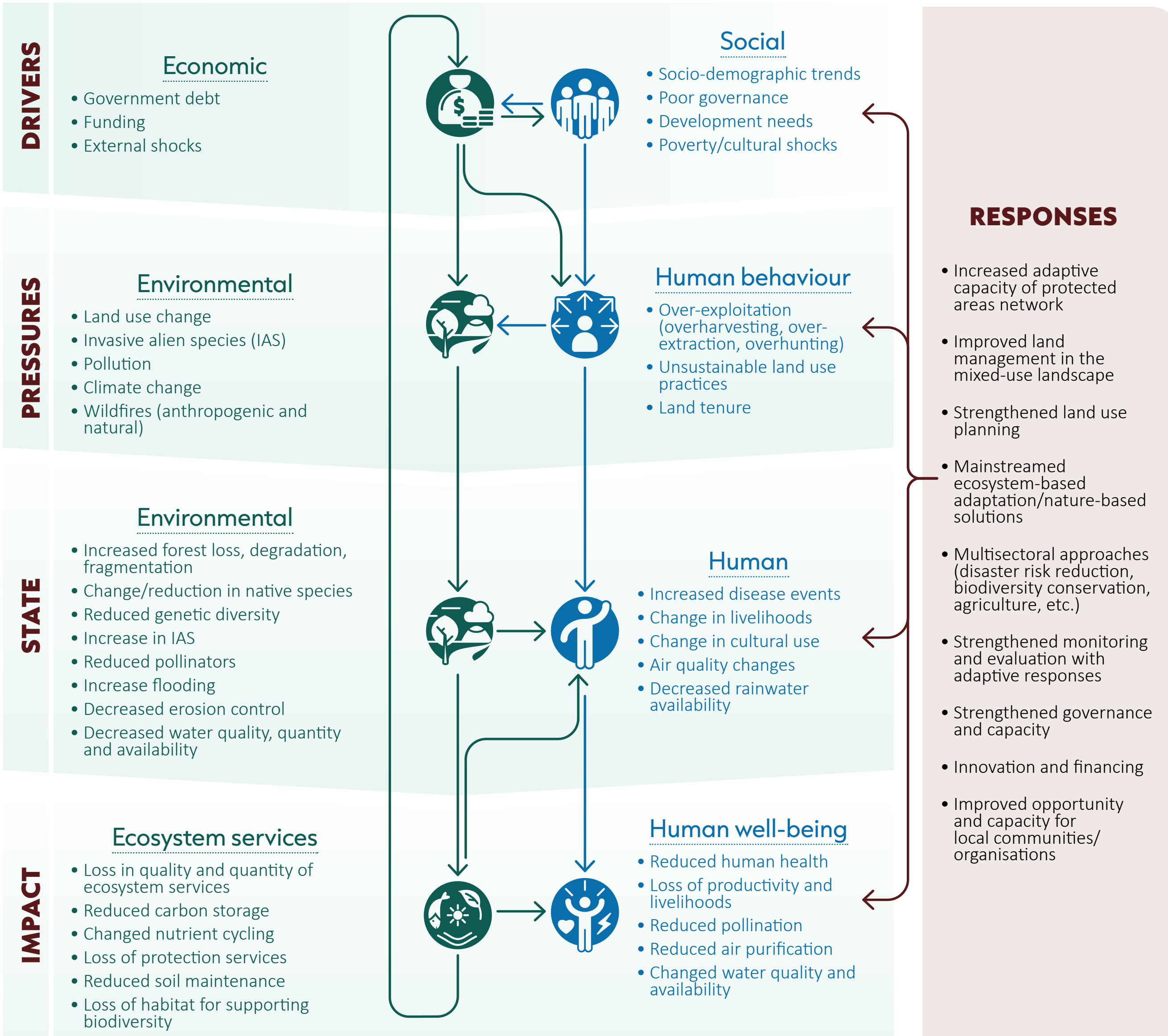


Figure 3.2. Terrestrial ecosystems DPSIR Framework

hurricanes, COVID-19) and high poverty in rural areas, exacerbating gender and minority inequalities. Poor governance, including inadequate local resource management and weak institutional capacity, constrains funding for and prioritisation of terrestrial ecosystems. For example, the attrition policy (due to government debt) limits capacity in the forestry sector to manage natural resources e.g. to monitor endangered or harvested species such as the Grenada dove (*Leptotila wellsi)* and manicou or opossum (*Didelphis* spp.), respectively. Socioeconomic needs and pressures drive the development of transportation networks, communication, utilities and housing. For example, housing needs are increasing due to the increasing population, leading to competition for the limited land space on which to both develop and conserve ecosystems. Cultural drivers relate to public perceptions and patterns of natural resource use e.g. dry forests are perceived as low value.

Pressures

To fully understand the impacts of climate change on terrestrial systems, it is necessary to first identify how the drivers translate into environmental and societal pressures (see Figure 3.2 and Appendix 1).

The most significant causes of land degradation are habitat conversion and agricultural pressure with agricultural production being the largest cause of degradation on Carriacou (GoG, 2015). Unsustainable upstream agricultural practices include sedimentation from clearing of steep slopes (Figure 3.3), removal of riparian buffers for farming adjacent to riverbanks, excessive use of fertiliser and pesticides, and setting of fires to clear forests. These practices impact watersheds and coastal and marine ecosystems and are of particular significance given that slopes of greater than 20^{o} cover over 70% of Grenada, 90% of Petite Martinique and 50% of Carriacou's land area (GoG, 2017a).

The limited land area of islands results in high cross-sectoral pressure for space. Land-use change threatens Grenada's forest ecosystems with fragmentation, degradation and destruction; this is primarily a result of the expansion of agricultural, tourism and residential development, and commercial activities, particularly in lowland forests (Thomas, 2016). Hurricanes, deforestation and replanting in Grenada have resulted in secondary regrowth or cultivation, except for some inaccessible areas on steep mountain slopes in the island's interior. Pressures from forest loss and unsustainable anthropogenic activities cause environmental degradation in the upland watersheds, affecting downstream environmental integrity (United Nations Department of Economic and Social Affairs [UNDESA], 2012). These pressures are further amplified by the effects of climate change. For example, torrential rainfall damages to the parishes of St. John and St. Mark in 2011 and flooding from the extreme rainfall following forest fires in 2007 across Grenada reduced the adaptive capacity of watershed management (Simpson *et al.,* 2012; Charles, 2014).

The widespread degradation of terrestrial ecosystems in Latin America and the Caribbean (LAC) is mostly the result of unsustainable land management, with increasing competition for resources (United Nations Environment Programme [UNEP], 2016). Market demand can shape agricultural expansion and production systems. For example, in areas of the Caribbean, banana production has resulted in increased erosion (UNEP, 2016). Over-exploitation of wildlife and Non Timber Forest Products (NTFPs) is another concern (Blommestein *et al.,* 2012; Nelson, 2013; Smart, Collier and Rolland, 2020).

IAS have been well documented to be a devastating pressure on an island's fauna and flora, with the capacity to cause extinctions of native and endemic species, significant impact on species' range, and population reductions as a result of predation, competition for resources and/or habitat modification (Allen, 1911; Atkinson, 1985; Hoagland *et al.,* 1989; Long, 2003; Jones *et al.,* 2008; Higman, 2011; Francis and Ramnanan, 2012). The arrival and spread of IAS on island nations such as Grenada is facilitated by 1) international travel and commerce (marine and terrestrial), 2) lack of legislation, enforcement and education with regards to biohazard control, 3) changing climatic conditions and 4) the innate vulnerability of island species (which have evolved without predators). Global predictions suggest invasive species are expected to benefit from climate change (Manes, 2021). See Chapter 2 for more details of terrestrial IAS.

Pollution is one of the significant sources of environmental challenges in the region (UNEP, 2016). Sources of air pollution in the Caribbean include industry, combustion, waste and landfills (including fires), hydrogen sulphide (from decaying Sargassum), open burning of biomass, fossil fuel extraction and transport (UNEP, 2016). In the Caribbean, including Grenada, Saharan dust significantly decreases air quality, bringing pollen, microbes, insects and chemicals (Garrison *et al.,* 2006; Monteil, 2008). Soil and water pollution include water contamination from waste, toxins and biological contaminants, via river networks transporting these sediments and other land-based sources of pollution to the oceans,

Figure 3.3. Hillside clearing for cultivation (Photo credit: Jonathan Hanna)

impacting coastal ecosystems (UNEP, 2016; CSGM, 2020).

Land tenure is considered a pressure because problems arise when agricultural land is urbanised and farmers have to move to marginal lands, often near or in forested areas. Further, the majority of land in Grenada, Carriacou and Petite Martinique is privately owned, therefore much of Grenada's forested lands do not fall under the jurisdiction of forest protection laws (see Chapter 5 for further details) (Singh, 2010).

State

Evidence of the relationship between climatic variables and related states of ecosystem, species and human health are used here to infer or indicate climate-driven changes in these states (see Figure 3.2 and Appendix 1).

Ecosystem state

The state of terrestrial systems needs to be viewed within the context of current forest cover and that the small land area of the islands means some forest types have very small distributions (see Chapter 2). Recent hurricanes have caused substantial damage to forest systems in Grenada. Over 80% of middle to upper forested areas were damaged due to Hurricane Ivan, with recovery often taking years (Glenn and Bensen, 2008; Peters, 2009; Nelson *et al.,* 2015). Since 2004, hurricanes and tropical storms have reportedly impacted an estimated 90% of Grenada's forests (GoG, 2014). A significant increase in the frequency and duration of hurricanes has been observed in the Caribbean since 1995, along with an increase in frequency of Category 4 and 5 hurricanes (CSGM, 2020).

Species state

While many species are found island-wide in Grenada, their distribution and abundance are often determined by climatic gradients (medium agreement, medium evidence). Understanding such relationships allows us to anticipate changes in state, including as a result of climate change (Nelson *et al.,* 2015). For example, the Critically Endangered Grenada frog (*Pristimantis euphronides*) is found only in moist forest above elevations of 300m (Henderson and Berg, 2006); the Endangered Grenada bank blind snake (*Amerotyphlops tasymicris*) requires moist substrates (Rodríguez *et al.,* 2011); and the Critically Endangered Grenada dove is currently restricted to lowland dry and moist deciduous forest (Rusk, 2017). Higher densities of the regional endemic Lesser Antillean tanager (*Stilpnia cucullata*) and Grenada flycatcher (*Myiarchus nugator*) are observed in high elevation moist forests and in low elevation dry forests, respectively (Devenish-Nelson and Nelson, 2021). Of the plants endemic to Grenada, the Grenadian gouti tree (*Maytenus grenadensis)* is found in moist forest and the Grenadian towel plant (*Rhytidophyllum caribaeum*) prefers low altitude, often riverine habitat (Hawthorne *et al.,* 2004). The abundance of common species also appears to change along climatic gradients, such as the ratio of colour morphs of bananaquits (*Coereba flaveola*) indicating the potential for the role of climate to influence genetic diversity (Wunderle, 1981). Habitats on the offshore islands tend to be drier, and these islands support important subsets of Grenadian herpetofauna, regional endemic terrestrial birds, seabirds and mammals (Henderson and Berg, 2006; Genoways *et al.,* 2010; Coffey and Ollivierre, 2019).

While habitat degradation and IAS may present more immediate threats to threatened species than climate change, the risk of climate change impacts from storms, droughts and flooding are likely to exacerbate existing stressors (high agreement, low evidence). Endemic species, specifically the Grenada dove, Grenada bank blind snake and Grenada frog, are listed as threatened by climate change (International Union for Conservation of Nature and Natural Resources Species Service Commission [IUCN SSC] Amphibian Specialist Group, 2021). A recent rapid population decline in the Grenada frog is partially attributed to the chytrid fungus (*Batrachochytrium dendrobatidis*), where the high elevation temperature and moisture conditions preferred by the frog are also favourable for the fungus (Harrison *et al.,* 2011). This fungal disease now poses the biggest threat to the species, particularly since the resiliency of the species has been reduced by drought, habitat loss and competition with the invasive Lesser Antillean whistling frog (*Eleutherodactylus johnstonei*) (Harrison *et al.,* 2011).

Evidence for the relationship between climate and the current status of exploited species and NTFPs is patchy, although there is evidence of synergies between hurricane damage and exploitation. For example, a recent significant decline in the Mona monkey (*Cercopithecus mona*) is thought to be due to the combined impact of Hurricane Ivan and overharvesting (Gunst *et al.,* 2016). Hurricane Ivan also resulted in decreased harvesting of NTFPs for crafts, although this was thought to only result in a short to medium term reduction (Dunn, 2005; Simpson *et al.,* 2012).

Human state

Hurricanes have had significant socioeconomic impact, including on built infrastructure, public health, food production and livelihoods (CSGM, 2020). Moreover, these impacts are not felt equally across society. For example, after Hurricane Ivan, women who relied on NTFPs for their livelihoods experienced a longer recovery time than men in the same communities (Simpson *et al.,* 2012).

Predominant climate-related human health issues in Grenada include Dengue, which is already endemic, and increasing respiratory problems due to Saharan dust (Schiøler and Macpherson, 2009; Akpinar-Elci *et al.,* 2015). Climate-induced pressures also influence the state of education, for example, schooling was disrupted in Grenada due to Saharan dust from 2011 to 2015 and from drought during 2009 to 2010 (CSGM, 2020). The end of the 2016 dry season (and during the 2014 to 2016 Caribbean drought) brought an observed deficit of between 20% and 60% in cumulative rainfall over much of the eastern Caribbean, leading to reduced agricultural production, an increase in bushfires, and empty water reservoirs (CSGM, 2020). In Grenada, Carriacou and Petite Martinique, the drying trend is reflected in considerable water deficits in the dry season (see Section 3.4.3 on Freshwater Ecosystems) (Schuttelaar, 2017).

Another state change, which can be classified as both environmental and human-health related, is the significant increase in anthropogenic fire, which has been observed over recent decades, leading to substantial forest degradation (Rusk, 2010; Charles, 2014). Persistent and continuous fires at the Perseverance landfill reduce air quality and are a particular threat to surrounding dry forest systems (Rusk, 2010). Most fires in Grenada occur during the dry season, and although, historically, severe fire seasons have coincided with drought years (e.g. 2010) the link between drought, fire and drying trends remains anecdotal (Charles, 2014).

Impacts

The drivers and pressures of climate change impact ecosystems, biodiversity and the services they provide to humans (see Figure 3.2, Figure 3.4 and Appendix 1).

Ecosystem impacts

Human impact across Grenada is extremely high, with an average Human Footprint Index of 17.83 (>7 is intense impact); this index represents the cumulative pressures of built environment, agriculture, population density, roads and night-time lighting on ecosystems (Venter *et al.,* 2016). The impacts of this ecosystem degradation are greatly exacerbated by climate change. Forest loss has led to increased flooding and erosion, but the impact on many other services, such as air purification, is unknown (Peters, 2009; Nelson *et al.,* 2018; 2020). Forest loss in upland watershed areas impact freshwater supply and coastal water quality (UNDESA, 2012). Debushing in lowland area riverbanks can cause flooding and sedimentation, especially after heavy rainfall. The synergies between land degradation pressures and climate change are likely to increase erosion and soil loss, such as observed following the 2004 to 2005 hurricanes and the 2009 to 2010 drought (Simpson *et al.,* 2012).

In Grenada, dry forests (Figure 3.5) are projected to expand upwards, having potentially-cascading impacts, including contraction of moist forests and reduction in agricultural productivity, such as through altered soil erosion, nutrient cycling, fire and hydrology (Nelson *et al.,* 2015). In Grenada, models suggest dry forests store less carbon than moist forests, as has been observed in the Virgin Islands, thus the potential expansion of drier conditions could lead to reduced future carbon sequestration (Blommestein *et al.,* 2012; Brandeis and Turner, 2013). However, the ability of dry forests to expand in Grenada may be limited by incompatible land use in lowland areas, resulting in altered species communities (Nelson *et al.,* 2015). Further, SLR is already impacting Grenada and, together with high development pressure in coastal areas, could lead to lowland biotic attrition, where species moving upwards are not replaced, resulting in an overall loss of species diversity and change in habitat composition (Cambers, 2009; Buckmire *et al.,* 2022).

The projected increased hurricane intensity could greatly diminish the adaptive capacity within these systems, such as the observed extreme flooding and siltation after Hurricane Emily in watersheds that were already weakened by Hurricane Ivan one year previously (Lugo, 2000; Peters, 2009). Although there is considerable resiliency within natural systems in the Caribbean to recover from hurricane damage, sustained habitat damage and loss from hurricanes and other extreme weather events are exacerbated by forest degradation and agricultural intensification (see Appendix 1) (Tanner *et al.,* 1991). As a result, degraded watersheds are less resilient to climate-induced pressures, including flooding, hurricanes and drought (GoG, 2017a).

Species impacts

Drying trends, exceptional drought conditions and increased temperatures are expected to lead to altered species diversity and abundance in the Caribbean (CSGM, 2020). Species' vulnerability to climate change depends, in part, on their life history characteristics, such as whether they are habitat specialists or have small ranges (Foden *et al.,* 2019). In this context, in Grenada, species restricted to high elevation moist habitats, such as the Grenada frog, would be at risk from a reduction of these areas due to drying conditions. Observed changes in dry forest composition in Grenada suggest the expansion of drought-tolerant, non-native and native edge species into intact communities, likely driven by synergistic factors of human disturbance, fire, drought and hurricanes (Nelson *et al.,* 2015). Species spanning both terrestrial and marine habitats face unique challenges in having to adapt across multiple ecosystems, for example, seabirds that need both land and sea for nesting and foraging (Sandin *et al.,* 2022).

Increased fragmentation, edge effects and reduced connectivity between forested areas potentially decrease a system's climate resiliency, such as through reducing a species' dispersal ability or creating a gap between species observed and potential ranges (see Appendix 1). The impacts of the resultant

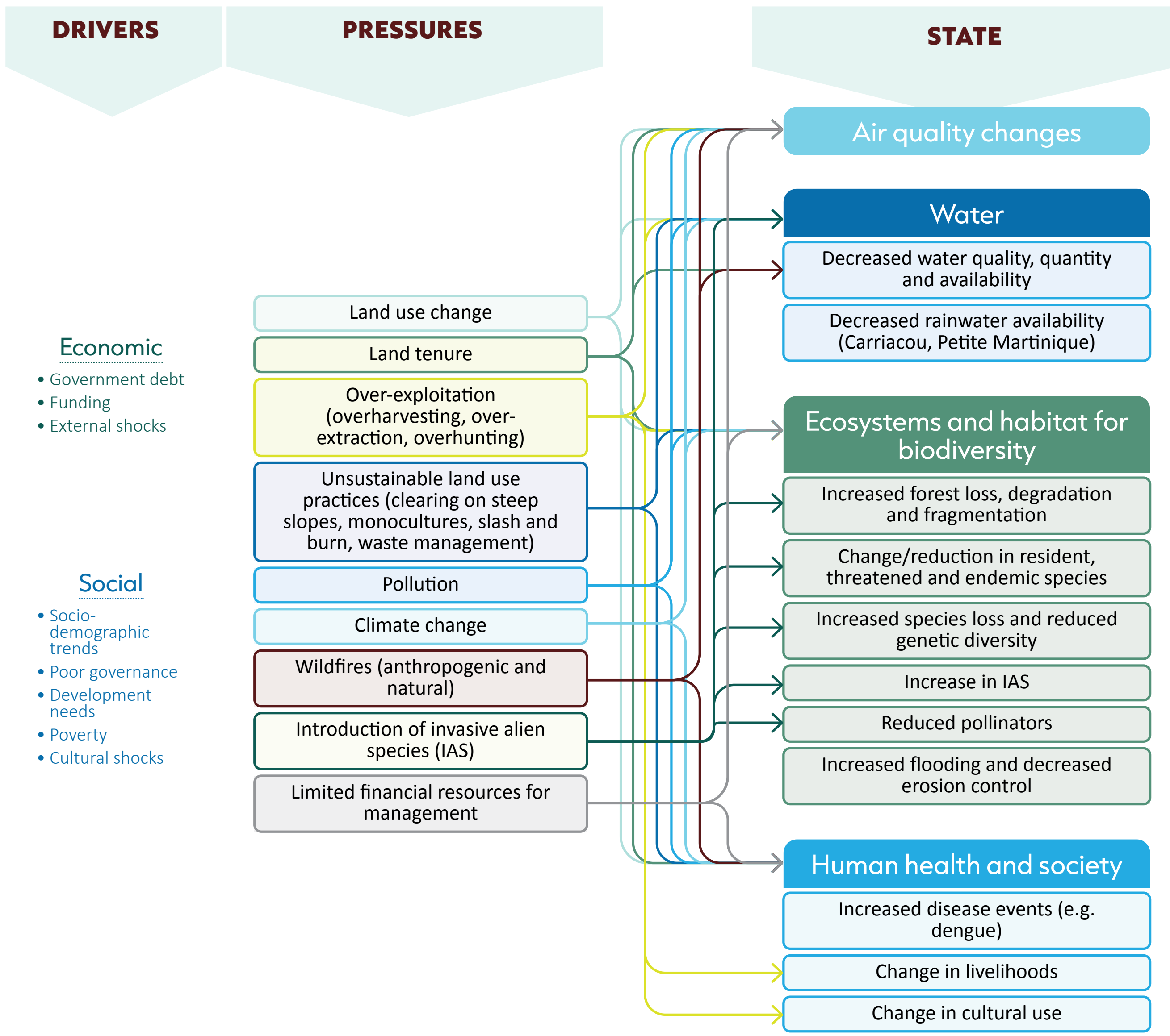


Figure 3.4. Synergies and relationships among drivers, pressures and state

changes in species compositions, homogenisation of species diversity and increasing introduced species on ecosystems and their services in Grenada is poorly known, although regional evidence is useful. Introduced tree species such as *Leucaenea leucocephala* may be less fire resilient than native species, thus increasing the risk of fire to ecosystems and their species, and also human populations and infrastructure (Wolfe and van Bloem, 2012). As

Figure 3.5. Bursera simaruba: A common dry forest tree species in Grenada (Photo credit: Natalie Boodram)

another example, climate-driven changes in species abundance of pollinators (as observed in Jamaica and Trinidad and Tobago) have implications not only for persistence and dispersal of native species, but also for agricultural productivity (Arnold *et al.,* 2018). In Grenada, moisture is known to influence variation in pollinator species and abundance, thus the impact of drying trends is of particular concern for this ecosystem service (Gonzalez *et al.,* 2009). Synergistic impacts between climate change and other ecosystem stressors are largely undocumented for Grenada, such as species-level impacts of pollutants.

Socioeconomic and health impacts

The impacts of climate change on terrestrial ecosystems for Grenada's human population are potentially far reaching (see Appendix 1). For example, Grenadian tourism has been greatly impacted by previous hurricanes, with future species and habitat loss potentially impacting the ecotourism sector (Alexander, 2007). The high cost of insurance and abatement of damage from hurricanes and other extreme weather events is known from previous storms (Alexander, 2007). A recent global study suggests significant productivity is lost due to heat exposure of workers in deforested areas (Parsons *et al., 2*021).

There is a significant knowledge gap on how the availability of NTFPs, such as charcoal, wild meat, and medicinal plants, is impacted by changing species dynamics and synergies with any existing over-exploitation (Hawthorn *et al., 2*004; Nelson, 2013; Smart, Collier and Rolland, 2020). However, observed changes in the abundance and composition of NTFP species due to post-hurricane forest loss suggest that an increase in hurricane intensity would decrease the resiliency of these species, which could lead to disproportionately-negative impacts for vulnerable groups whose livelihoods depend upon these species (Simpson *et al.,* 2012).

Increases in vector-borne diseases are predicted across the Caribbean, due to climatic changes, causing more favourable conditions for species such as *A. aegypti* (CSGM, 2020); Dengue is likely to increase given that outbreaks are observed to be strongly correlated with El Niño events and higher temperatures (Amarakoon *et al.,* 2008; World Health Organisation [WHO], 2020). Non-communicable diseases are also predicted to be exacerbated by climate change, for example, through impacts on underlying risk factors such as water insecurity and food security (WHO, 2020). Existing societal inequalities, such as the vulnerability of rural or poor communities, women, or minority groups to climate change are likely to be exacerbated (CSGM, 2020). For example, there is already limited adaptive capacity to recover from intense hurricanes in Grenada (Alexander, 2007). Women are disproportionately affected, such as post-Hurricane Ivan where the socioeconomic recovery of Grenadian women took longer than men, due to their already-lower skills base, caring responsibilities and higher poverty (CSGM, 2020).

Resource conflicts and internal or external migration due to scarce resources are increasingly likely due to climate change (Cashman, 2014; Gheuens *et al.,* 2019; Lenderking, Robinson and Carlson, 2020). The negative impacts of weather-related disasters erode natural capital and reduce overall wealth and competitiveness of nations (Charles, 2014).

Responses

To effectively address the impacts of climate change on Grenada's terrestrial ecosystems and to improve resilience, responses can take place on many levels, including through national governance and policy responses, institutional and sectoral systems, and socioeconomic conditions. These responses complement the *Grenada, Carriacou & Petite Martinique: Second National Communication to the United Nations Framework Convention on Climate Change* (2017), and the *National Climate Change Policy for Grenada, Carriacou and Petite Martinique (2017-2021)* and align with responses recommended in Chapter 5. Climate resilient terrestrial systems have wide-reaching, multi-sectoral socioeconomic benefits (see Appendix 1) as well as allow Grenada to achieve multilateral environmental agreement (MEA) targets.

National level responses: Multisectoral approach

At the national level, coordinated national and multisectoral policy, laws and regulations, harmonised policies between sectors, national and sectoral land use planning, sector policies and legal frameworks are needed. This includes an active land use policy and/or land use plan that supports sustainable land and forest management and the services they provide.

A multisectoral approach should also address gaps in inter-agency coordination, essential for multisectoral land use planning, systemic and institutional capacity needs, and comprehensive and multi-departmental access to data for risk informed decision making. For example, cross-sectoral coordination is essential for watersheds, managed both by the Forestry Department and the National Water and Sewerage Authority (NAWASA), with ultimately the same goal of water security. Inter-agency coordination requires augmented financial resources for personnel, technical capacity and equipment.

National Level Responses: Landscape approach

At a national level, to mainstream climate change across sectors and promote a whole landscape approach to land use planning, all government projects, planning and initiatives need to be viewed through an adaptation lens. Requiring an adaptation component for terrestrial systems, recognising the link between forest resources, ecosystem services, biodiversity and climate change, will further long-term resilience. For example, reducing upland watershed degradation/development activities by promoting climate-smart agricultural practices in upland watersheds will enhance climate resilience and delivery of ecosystem services. Similarly, using Environmental Impact Assessments (EIAs) as a tool to include climate adaptation in new projects and developments, in alignment with climate change policies and the *National Climate Change Adaptation Plan (NAP) for Grenada, Carriacou and Petite Martinique 2017-2021* will also build climate resilience.

Aligning sectoral policies with adaptation planning would include, for example, an emphasis on future-proofing climate resilient PAs, including Forest Reserves. The island context (e.g. limited land area, small forest areas, high demand on resources) inherently means limited options for PA expansion or addition to the PA network. Thus, a priority should include maintaining intact PAs, ensuring effective management of existing PAs and sustainable practices in multi-use reserves. Beyond this, a whole landscape approach is needed encompassing private lands, providing connectivity between protected and non-protected areas in the mixed-use landscape thus improving climate resiliency across the whole system. For example, an ecosystem-based approach such as 'Ridge to Reef' allows species dispersal between habitats if their ranges shift with climate change.

To support implementation of the above, inter-agency coordination for multisectoral sustainable forest management, biodiversity conservation and land use planning is essential. Improved institutional capacity, availability and access to resources, incentives, national support programmes (e.g. access to low interest loans, microfinancing, public-private partnerships, private sector investment, blended finance, and PES mechanisms at both individual and community levels) will provide a mechanism to support implementation, as would financing to enable reducing unsustainable land use practices that inhibit climate resilience. For example, if climate change leads to reduced agricultural productivity, meaning farmers have to expand land to maintain income, offering PES as an alternative to keep land forested will increase resilience to flooding and erosion, maintain habitat for pollinators, etc. Grenada has a strong history of leadership in climate change and environmental governance on which it can build and capitalise in terms of engaging with MEAs to access climate finance. For example, there is potential for exploring the role of Reducing Emissions from Deforestation and Forest Degradation (REDD+) to achieve Grenada's Nationally Determined Contributions (NDCs) and voluntary contributions to Land Degradation Neutrality (LDN) targets, as well as accessing the Green Climate Fund (GCF) and Global Forest Finance Pledge for forest-related finance.

Local level responses: Incentives

At the local level, producers (agroforestry, NTFPs, agriculture) require sufficient incentives (such as PES) and access to financial mechanisms for sustainable agricultural/land management planning and practices. Given the high proportion of private land ownership across Grenada, small local actions can promote ownership of climate adaptation and have nationwide cumulative benefits. Some of these actions can be fast-changing, incrementally increasing resilience at the local level (see Appendix 2).

Local level responses: Knowledge and awareness

Enhanced awareness and understanding is needed among practitioners and decision makers on climate resilient agriculture and sustainable land management (SLM) techniques and practices integrated with biodiversity and forest conservation. SLM and climate change knowledge, attitude and practices (KAP) surveys indicate where efforts need to be targeted. For example, Fontenard (2016) noted that more than half of the population reported having no knowledge of land degradation (64%) and SLM (52%), and only approximately one third of respondents (37%) stated that SLM was important or very important to Grenada's development. Similarly, only 17.7% of the population considered climate change a serious problem for Grenada and over 60% cited lack of information as an issue.

Local level responses: Monitoring and knowledge gaps

Filling knowledge gaps on long-term monitoring of climate, biodiversity, species and ecosystems is critical for understanding future ecosystem and socioeconomic impacts. A part of this is to improve access to existing data, as well as sharing data between and within government departments. This ties back to strengthening inter-agency coordination. However, lack of data does not mean we cannot implement adaptation actions. Since climate change is already impacting Grenada, we need to use the precautionary principle in the absence of data, whilst improving data collection and access as part of an adaptive response. Grenada could draw on the opportunities, tools and expertise of the Caribbean

Community Climate Change Centre (CCCCC) to increase capacity for generating knowledge.

Monitoring and evaluation (M&E) is critical to ensure an adaptive response approach to adaptation and must be driven by adequate policies, regulations and enforcement. Project-based funding is short-term and does not provide a mechanism for long-term national adaptation M&E. Access to long-term M&E data is critical for developing successful, long-term sustainable adaptation actions that government agencies need to address in their national budgeting, planning and capacity development.

3.4.3. Freshwater ecosystems

Freshwater ecosystems include groundwater and surface water, which can be either lentic (still) or lotic (flowing). Most of Grenada's freshwater ecosystems are surface water, which is the island's main source of potable water (Department of Economic Affairs, 2001; Murray, 2015). Grenada's freshwater ecosystems include two natural lakes, 50 rivers and streams, and 12 main rivers (Department of Economic Affairs, 2001; CCCCC, 2015). The major rivers have perennial flows, though these are significantly reduced during the dry season (FAO, 2015). See Chapter 2 for further details.

Ecosystem services provided by freshwater ecosystems include: 1) provisioning services e.g. food and water, 2) regulating services, e.g. water regulation and purification, and 3) cultural services e.g. recreational and religious activities (Institute for European Environmental Policy [IEEP], 2009). This DPSIR analysis is expected to consequently help to maintain or enhance current health, adaptability and resilience of Grenada's freshwater ecosystems.

Drivers

Direct drivers acting on freshwater ecosystems in Grenada include economic, social and natural activities (Figure 3.6). Economic drivers exerting pressure on this ecosystem primarily come from manufacturing at the local breweries, tourism-driven events, agriculture and activities surrounding education, most specifically from the university at the south of the island. Social drivers include shifts in demographic trends i.e. increases in the national population which increase the freshwater demand for domestic use (UNECLAC, 2011; UNDESA, 2012; FAO, 2015). Demographic shifts have caused increased demands for water for domestic and tourist use from increased housing projects and hotels, resulting in over-abstraction of water which lowers river flows and water levels e.g. in Grand Etang Lake. Increases in population (i.e. natural and migration) also lead to the over-use of springs for bathing, washing and recreational activities.

Pressures

Climate change related pressures on freshwater systems result from changing precipitation regimes and extreme weather events e.g. drought and flooding. Drought conditions can lead to over-abstraction of water sources, reducing habitat for freshwater organisms (CCCCC, 2015). Climate change pressures are often coupled with other anthropogenic factors including: 1) chemical and biological pollution and 2) the alteration of natural watershed boundaries and river channel geomorphology (UNDESA, 2012). Other pressures include the introduction of invasive species e.g. tilapia introduced in Grand Etang Lake, St. John's River and River Road (GoG, 2009).

State

Grenada has experienced significant droughts in recent decades. This includes the period between 2009 to 2011, which is noted as the driest period in historical records, attributed to climate change (UNDESA, 2012). Limited freshwater availability during droughts or even a regular dry season can result in resource conflicts among farmers.

Extreme rainfall events in Grenada increase turbidity in the water supply, reducing quality and leading to disruptions in water supply (Schuttelaar, 2017). Flooding usually occurs during the rainy season from June to November (Charles, 2014). However, there has been uncharacteristic, localised flooding during the dry season, such as in 2011 (Charles, 2014). Freshwater plumes from rain events after droughts have resulted in substantial soil loss, such as after the 2009 to 2010 drought in Carriacou (Peters, 2015).

There is limited ambient water quality data available for Grenada. However, Compton and Forde (2020) have noted high *Escherichia coli* (*E. coli*) bacteria concentrations in Little River, St. John exceeding recommended limits for total faecal coliform (60%). Further, pollution-tolerant indicator species have been recorded in tributaries leading to the mangroves of Woburn Bay.

Impacts

Given the reliance on rivers for agricultural irrigation, changes to the state of freshwater ecosystems impact crop yields, in turn threatening food security and economic stability, resulting in vulnerable livelihoods and income. Other ensuing impacts of climate change on freshwater ecosystems include reduced availability of drinking water (e.g. in St. Patrick) and loss of cultural services e.g. river tubing and baptisms. Further, climate change leads to freshwater biodiversity loss and homogenisation of species diversity, favouring species such as tilapia (GoG, 2014). Barriers in rivers placed for flood risk management result in poor floodplain habitat (e.g.

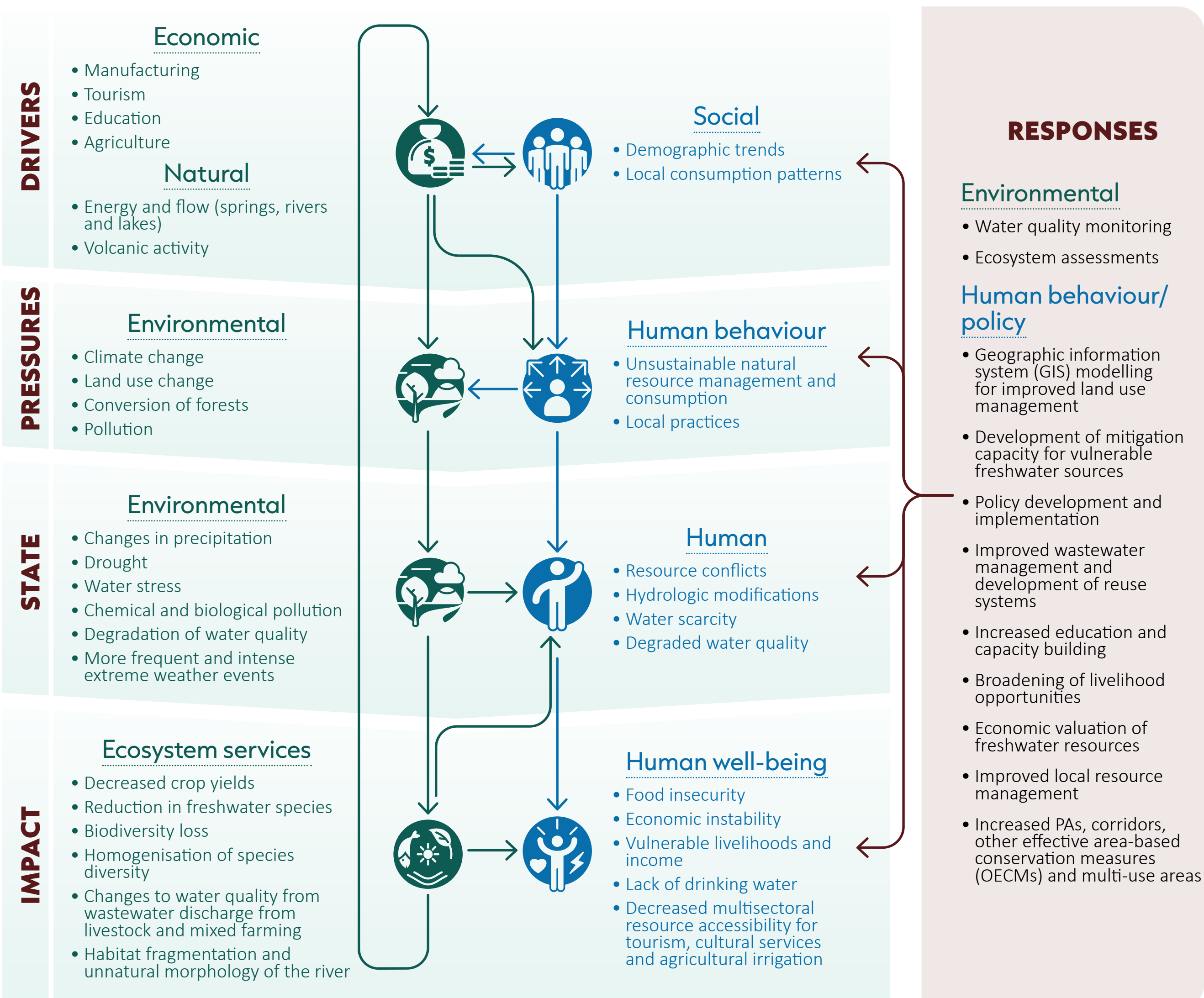


Figure 3.6. Freshwater ecosystems DPSIR Framework

in River Road), habitat fragmentation and unnatural morphology of the river.

Reduction in water availability and quality not only directly impacts human health and well-being but is also associated with increased costs due to redistribution of potable water and agricultural irrigation (see Section 3.4.4 Agricultural Ecosystems). Limited water availability and poor water quality can also adversely impact tourism, potentially intensifying existing gender inequalities (GoG, 2019). Generally, freshwater ecosystem health is decreasing, and species diversity and abundance are declining; this can lead to resource conflicts within the communities.

Responses

Responses or interventions to address the impacts of climate change on freshwater ecosystems could include policy, governance, research and capacity building. In terms of research, water quality monitoring systems and data are needed. These can be used to inform water resources policies and ensuing legislation (including enforcement) pertinent to pollution and other drivers of change of freshwater ecosystems. Capacity building regarding the need to protect freshwater ecosystems and methods of doing so is also needed.

3.4.4. Agricultural ecosystems

Agricultural ecosystems, or agroecosystems, refer to regionally-defined systems managed for the production of food, fibre and other agricultural products. These ecosystems are dominated by agriculture, containing assets, biodiversity functions, ecological succession and food webs (IPBES, 2022). Notably, people—both as producers and consumers—are integral to agroecosystems, which have socioeconomic, public health, and environmental dimensions (Hünnemeyer, de Camino and Müller, 1997). Agroecosystems are important to consider in this assessment because of their significant influence on land use and land allocation systems, the key services they provide and their critical role in climate resilience. According to the *IPCC Sixth Assessment Report*, increasing agroecosystem diversification improves the resilience, productivity and sustainability of farming systems under climate change with high confidence (Bezner Kerr *et al.,* 2022).

Introduction

Grenada's agroecosystems consist of a variety of traditional crops, like nutmeg, cocoa, bananas, and non-traditional fruits, vegetables, and food crops. Grenada is the world's second largest producer and the 12th largest exporter of nutmeg, mace and cardamom. Other major exports include bananas, cocoa, soursop and citrus fruits (GoG, 2017a). These farming systems are primarily managed by small-scale farmers (approximately 9,200 farmers) in rural areas where poverty and land insecurity are highest (FAO, 2020). Small-scale farmers are the main stewards of agrobiodiversity in Grenada but often lack the necessary resources to address emerging risks to biodiversity loss and climate change. In particular, climate change has caused losses and damages that undermine climate-sensitive agricultural livelihoods and exacerbate food and nutritional security challenges for the majority of rural households in Grenada (McCubbin *et al.,* 2017; Haynes *et al.,* 2020; Campbell, 2021).

As part of the Grenada NEA, an online survey on *Perception of Ecosystems and Ecosystem Services in Grenada* was conducted to determine local stakeholders' attitudes and perceptions towards ecosystems across Grenada (Box 3.2). The results show that, of all the ecosystems assessed, agroecosystems are considered the most important by the highest percentage of surveyed stakeholders (28%) and 75% of the respondents consider agroecosystem food provision services to be very important. This may possibly be correlated with the fact that the livelihoods of 41% of the respondents primarily depend on agriculture. The high percentage of stakeholders who view agroecosystems as crucial reflects their significance to the Grenadian economy, society and culture.

This agroecosystem DPSIR analysis in the context of Grenada is expected to consequently help to maintain or enhance current health, adaptability and resilience of agroecosystems (Figure 3.7).

Box 3.2. Online survey on *Perception of Ecosystems and Ecosystem Services in Grenada*

The *Perception of Ecosystems and Ecosystem Services in Grenada* online survey was conducted from January 7th to January 31st 2022 via SurveyMonkey and targeted Grenadian stakeholders with the objective to investigate the perceptions of Grenadian citizens/residents regarding Grenada's ecosystems and ecosystems services. The survey collected information on demographics, livelihoods, perceived importance of ecosystems and ecosystem services, perceived importance of threats to ecosystems, concerns regarding climate change, importance of ecosystem protection for improving resilience, perceived importance of Protected Areas, and perceived contribution of different species to ecosystem functions and services as well as the cultural and social value of different species. Eighty responses were received and the results of the survey were utilised to fill information gaps in Chapters 3 and 4.

See Appendix 3 for the survey questions.

Drivers

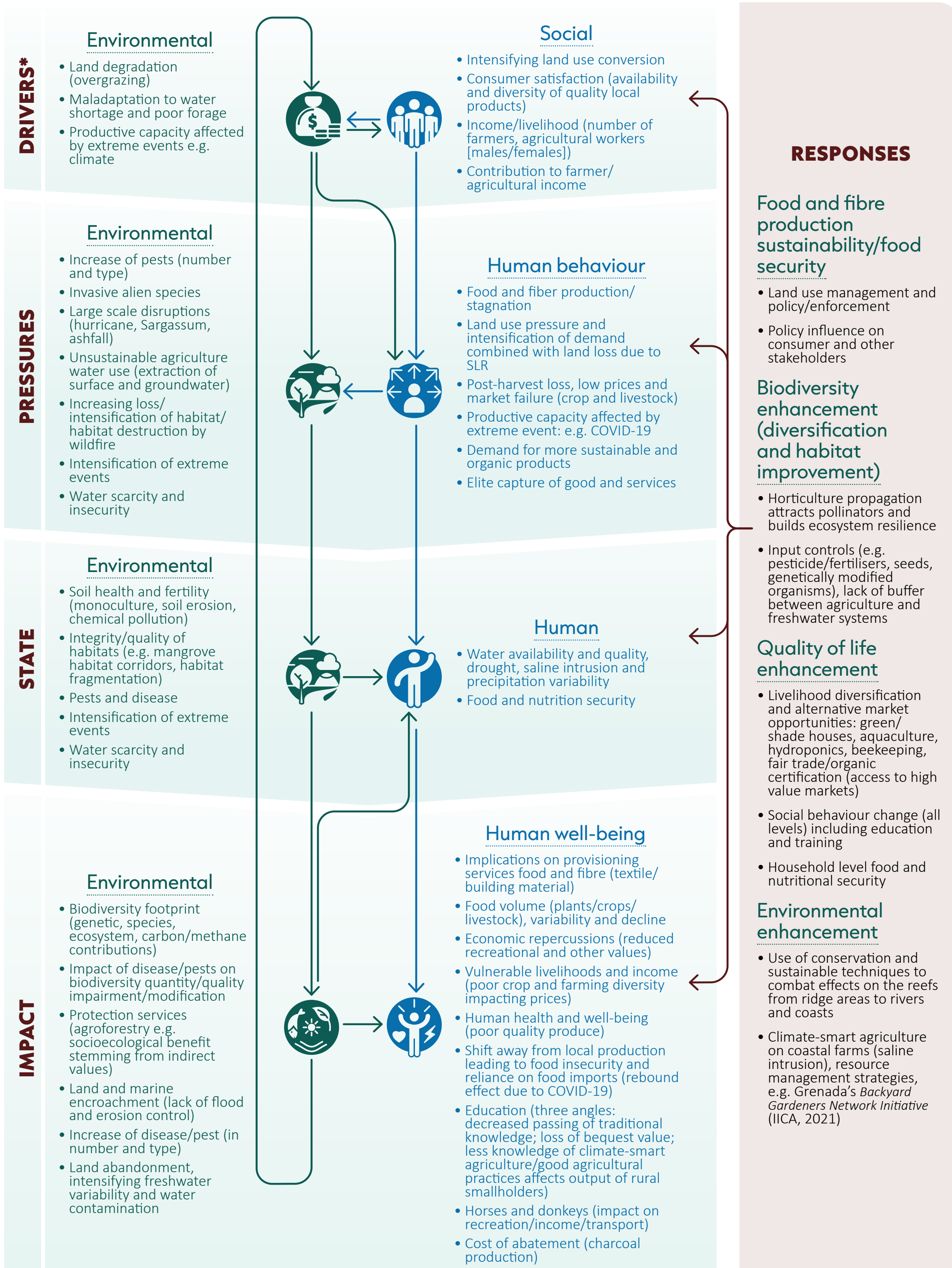
Several economic, biophysical, political and social drivers dictate the scale, quantity and quality of agroecosystems in Grenada. Although agriculture's contribution to GDP has declined from around 20% in 1977 to 4.5% in 2021, it remains important as a source of employment and livelihood, and because of its influence on land use, biodiversity and environmental quality (Eastern Caribbean Central Bank [ECCB], 2021). However, the services provided by agroecosystems are undervalued, overexploited and underexplored in some areas, despite their contributions to natural and economic capital.

Poor agricultural practices continue to pose a significant threat to Grenada's biodiversity. The clearing of land for commercial agricultural production has caused the most significant environmental impacts (Thomas, 2016; GoG, 2018; Convention on Biological Diversity [CBD], 2020). These poor land-management practices are also attributed to governance challenges, the lack of modernisation of the agricultural sector through suitable policies for national development, the absence of key land policies, incomplete sectoral policies, land tenure realities, climate variability, and other external issues (GoG and United Nations Convention to Combat Desertification [UNCCD], 2015).

Grenada's agroecosystems are highly sensitive to biophysical changes. The absence of reliable water flows is a major challenge to farming on Grenada's smaller islands of Carriacou and Petite Martinique (Cashman *et al.,* 2019). The agroprocessing sector comprises an estimated 265 small and nine medium-size processors, 65% of whom are females, operating at the cottage level and for whom economic as well as climate shocks present a significant challenge (GoG, 2015).

An analysis of food utilisation and nutritional adequacy indicates a shift in consumption patterns of Grenadians. More than 70% of the food consumed is imported and local production faces serious challenges (GoG, 2015). Changes in interactions with agroecosystems are needed (FAO, 2016). On Carriacou and Petite Martinique, land degradation associated with overgrazing is a severe issue. During the dry season, herds are allowed to roam freely in search of pasture. This overgrazing has caused significant damage to the land, making it difficult for farmers to produce crops and livestock (Cashman *et al.,* 2019).

Climate change worsens land degradation, leading to significant water insecurity challenges (Cashman *et al.,* 2019). According to the stakeholder survey (Box 3.2) Grenadians are particularly concerned about the impact of climate change on agriculture and food supply (48%). Except for pollution (40%) local stakeholders also view climate change as the most serious threat (35%) to the benefits derived from ecosystems. Between 2009 and 2011, Grenada experienced a 20-month drought event – the worst in the country's history. The *Synthesis Report of the IPCC Sixth Assessment Report* projects (with high confidence) that droughts will become more frequent, including concurrent events across multiple locations



**Positive changes may be possible as well in these drivers*

Figure 3.7. Agroecosystems DPSIR Framework

(IPCC, 2023). As a result, there is an urgent need to strengthen climate resilience in the agricultural sector in Grenada (NOW Grenada, 2021).

Pressures

The drivers identified in the preceding section contribute to a combination of pressures which are both environmental and human/behavioural in nature. Notably, climate change can be characterised as a pressure affecting agroecosystems. Seventy-three percent (73%) of stakeholders who completed the survey for this assessment agree that climate change is the greatest threat to Grenada's major natural ecosystems, with its exacerbation of the impacts of existing unsustainable patterns of resource extraction, consumption and production. These include the intensification of land use conversion from agriculture to other forms (and the attendant implications this has for ecosystem services via an ever-increasing demand for water that outstrips supply), the increasing incidence of wildfires, and the increased intensity and frequency of periodic catastrophic events. The 2009 Land Use Division map in Chapter 2, Appendix 10, shows a shift of agricultural activity concentrated throughout and in the middle of the country to one which is increasingly focused on the coastal periphery of the island, tracking closely available water bodies.

In the land use context, key amongst these pressures is to produce more food, due to more frequent post-harvest losses, food insecurity due to poor distribution, generalised market failure and poor productivity due to climate variability and change. Coupled with SLR as well as other climate hazards, the availability of arable land to innovate and expand food production is limited in scope (Eckstein, Künzel and Schäfer, 2021). The scale of such extreme events creates significant pressure on agroecosystems including the amount of time it takes them to recover (Box 3.3).

The challenges for agroecosystems are multifaceted, including coping with limited and finite water resources. The ecosystem services which might mitigate against these shocks are impaired and under threat (Environmental Performance Index [EPI], 2020). In Carriacou and Petite Martinique, water consumption by livestock is a pressure on scarce groundwater resources (GCF, 2018). Water loss in general in the tri-island state is approximately 29% and the current tariff structure does not serve as an incentive for efficient use, or management of water resources or water capture and storage (GCF, 2018). The variability of rainfall patterns has made it challenging for farmers to predict and manage production and harvest activities (FAO, 2016). Wildfires are frequent, destroying an average of over 200ha per year during 2007 to 2010. These are all human-induced from charcoal production and slash and burn by farmers (GoG, 2014).

In the stakeholder survey conducted (Box 3.2) stakeholders recognised the interdependence between ecosystem resilience and climate change

Box 3.3. Natural and climate hazards: wind and water

High velocity winds were deemed to be the cause of the extensive loss to crops and livestock in Grenada (Patil *et al.,* 2016). Eighty-five percent (85%) of the nutmeg crop was lost, and an estimated 50% of the nutmeg population and 25-40% of cocoa were removed, changing the make-up of ecosystems (GoG, 2018).

Though mainland Grenada boasts of both surface and ground water capacity, generation and storage capacity in Carriacou and Petite Martinique are much less. Yields are increasingly variable and decline significantly between the rainy and dry seasons (an upper band of 54,600m^3 of water in the former, down by 42% to 31,800m^3 in the latter) (GoG, 2018). Demand is lower in the rainy season than the dry season (almost the opposite of yields) with 45,500m^3 in the former and 54,600m^3 during the dry season or an increase of 18% and is in addition to a projected decrease in rainfall of up to 21% leading to an increasing likelihood of drought (GoG, 2018).

adaptation. In addition to being a threat to ecosystem function as described above, respondents also consider climate change a significant threat to people deriving ecosystem benefits (35%). However, they also recognise PAs, which could be extended to encompass EbA and nature-based solutions (NbS), as a strategy for reducing these impacts and enhancing ecosystem resilience to climate change (65%). This connection is affirmed through some of the outcomes of the 27th session of the Conference of the Parties to the UNFCCC (COP 27) in which countries are encouraged to utilise NbS and EbA as adaptation strategies, which is also confirmed in the *IPCC Sixth Assessment Report* (IPCC, 2022a).

State

The use of unsustainable practices and intensification of agriculture threaten human health through: 1) contamination of soil and freshwater sources (limiting water access and security), 2) absorption of agrochemicals into consumed foods, 3) air pollution from slash and burn clearance, 4) altered local habitats and climates and 5) diminished forest foods, aesthetic and other values. Agricultural activities are a significant contributor to groundwater and coastal pollution e.g. from pesticide runoff, soil erosion and increased demand for irrigation (GoG, 2014; GoG, 2017). Intense drought conditions have also affected these demands and impacts. Several datasets and analyses underscore the fact that Grenada has become water-stressed (FAO, 2015) (see Box 3.4).

Conversely, unpredictable rains have become more intense, leading to nutrient leaching and flower loss as well as negative impacts on soil structure and water retention. Intense rainfall can also increase root rot and the risk of crop diseases during wet periods; increased soil erosion and fertiliser runoff can threaten quality of surface waters, reef health and MPA integrity (James, 2015). The hurricanes which impacted Grenada (Figure 3.8) have destroyed large expanses of cultivated and forested land, and in the case of post-2005 Grenada, regrowth was accompanied by a proliferation of the fast-growing bamboo, an invasive species (Inter-American Institute for Cooperation on Agriculture [IICA], 2017). Such disruptions are expected to increase with climate

Box 3.4. The impact of drought on agriculture in Grenada

Ninety percent (90%) of Grenada's water supply is from surface water and is challenged by the increasing frequency of extended dry seasons, unpredictable rainfall patterns and multi-year droughts. The 2009 to 2010 drought saw a 150% increase in bushfires, negatively impacting agricultural production and cultivation, and increased demand for irrigation water (Trotman and Farrell, 2010; Caribbean Institute for Meteorology and Hydrology [CIMH] and FAO, 2016). Carriacou and Petite Martinique have had severe impacts as water catchments have very little storage capacity, with the main supply from harvested rainwater and desalination.

Extended dry periods can trigger temporary food scarcity and reduced grazing and thus livestock yields (James, 2015). "Population growth and tourism expansion have contributed to reductions in stream and river flow volumes, increased siltation of dams and reduced groundwater recharge rates" (GoG, 2017b). Notably, it is reported that significant portions of arable land are not close to an accessible water source (GoG, 2012). Projections are that 3% of agricultural lands could be lost due to SLR and salinisation of water sources at an annual cost of US$4 million by 2050 (GoG, 2017b).

Livestock production, particularly goats, is a mainstay of agriculture in Carriacou, accounting for 30% of the country's production. However, yields are affected by the drying of grazing areas, heat stress due to increasing temperatures, and the fragility of houses during extreme weather events. This increases the dependence on expensive imported feed. Droughts in 1984 and 1992 respectively saw livestock losses of 20% and 40% (Paul, n.d.).

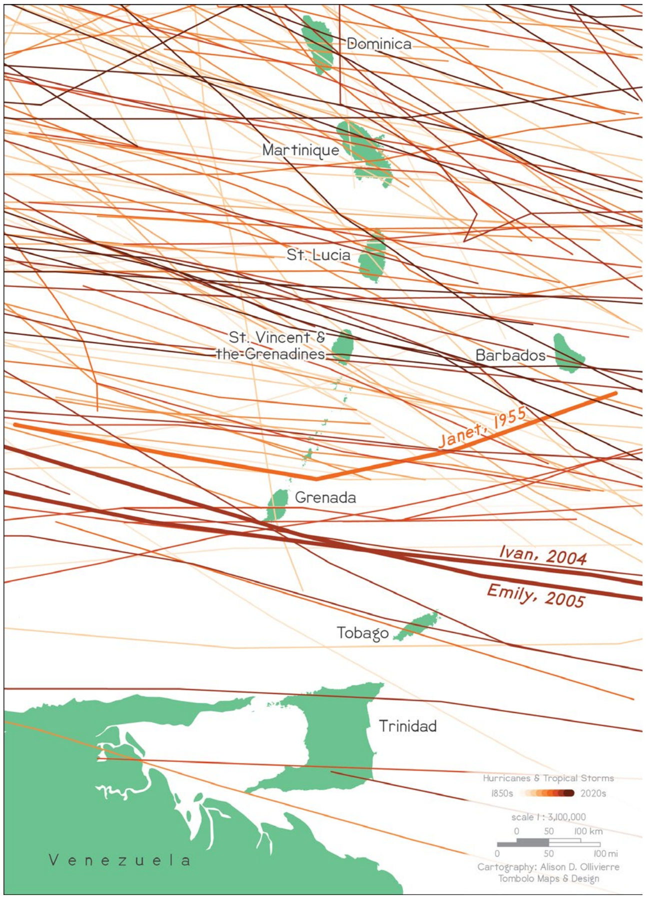


Figure 3.8. Major hurricanes and storms Grenada (1851-2021) (Data source: National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management, Historical Hurricane Tracks, 2016)

change, thus increasing risk of acute and longer-term food and nutrition security (GoG, 2012). Women farmers and women face specific challenges coping with these combined stressors without external support, labour and time-saving technologies (The United Nations Entity for Gender Equality and the Empowerment of Women [UN Women], 2014).

Consequently, the contribution of agriculture, fisheries and forestry to GDP in Grenada is in a state of decline, most pronounced after the impact of Hurricanes Ivan and Emily in 2005 (Figure 3.9). Production is estimated to have dropped by as much as 50% with the hurricanes exacerbating an already negative trend since the 1960s, suggesting poor resilience and adaptive capacity at a systemic level.

Declines in biodiversity and environmental quality further exacerbate unfavourable conditions for social and ecological resilience building. Surveyed stakeholders (Box 3.2) expressed high value of the contribution of a range of agrobiodiversity to ecosystem functions and services, with pollinators being the most critical among all species (65%) as well as in cultural and social value (50%). Fruit trees were also considered by 43% of surveyed stakeholders to be critical to ecosystems, while tree crops, livestock, root crops, timber and spices were considered to be important by over 30% of respondents. This reflects the diversity of the local agroecosystems and the varied contribution of such to effective function and

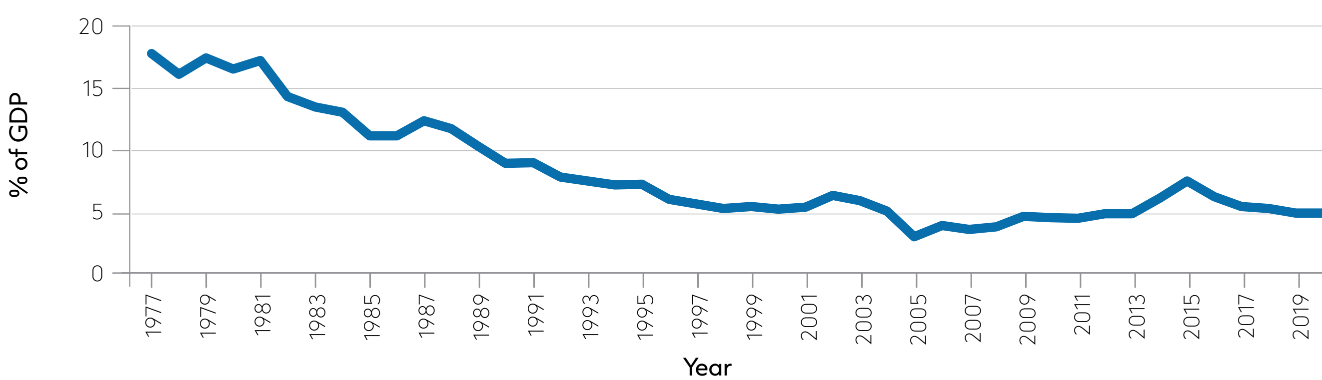


Figure 3.9. Contribution of agriculture to GDP in Grenada 1977 to 2020

D-P-S-IMPACT-R

Food production Loss (yield and quality)

- Implications on provisioning services – food and textile/building materials/reliance on food imports
- Food volume (plants/crops/livestock), variability and decline

Biodiversity enhancement

- Biodiversity footprint (impacts on genetic, species, and ecosystem levels); however there can be possible positive impacts related to carbon sequestration
- Economic repercussions (reduced recreational value as well as other values)
- Impact of diseases/pests on biodiversity quantity/quality

Implications on quality of life

- Vulnerable livelihoods and income (poor crop and farming diversity; this can further impact prices)
- Human health and well-being (due to poor quality produce)
- Education (three angles: decreased passing of traditional knowledge; loss of bequest value; limited knowledge of climate-smart agriculture/good agricultural practice affects output of rural smallholders); and Cultural (social capital-structural and cognitive)
- Horses and donkeys (impact on recreation/income/transport at a small-scale)
- Cost of abatement (e.g. charcoal production)

Environmental enhancement

- Impairment/modification of protection services (agroforestry e.g. socioecological benefits stemming from indirect values)
- Land and marine encroachment (e.g. lack of flood and erosion control)
- Land abandonment, intensifying freshwater variability (reduced amount, poorer quality and more unpredictable due to climate), and soil and water contamination.

Figure 3.10. Impacts on agroecosystem services

resilience of the ecosystem. Culturally and socially, tree crops and spices were also highly valued at 49% and 47% respectively, being elements which connect to a Grenadian identity, such as nutmeg and cocoa. The agriculture sector contributes to land degradation through excessive use of agrochemicals, overploughing and overgrazing, vegetation clearance, and farming on steep or marginal lands (James, 2015). Declining levels of soil fertility and organic matter are also observed in annual croplands in some locations. Traditional crops and domesticated animals are also decreasing, even as use of genetically modified organisms (GMOs) and their attendant risks, including genetic erosion, increase (GoG, 2014).

Agrobiodiversity is also being negatively impacted by land-use change and increased use of mechanisation and inorganic chemicals (GoG, 2014). Pollinators which serve agroecosystems and influence the availability of genetic diversity to support resilience to droughts, floods, pests and disease, are often killed by broad spectrum agrochemicals.

Impacts

Agroecosystems are a major part of Grenada's economy (CANARI, 2020). In addition to freshwater supply, agricultural outputs are, in turn, underpinned by essential pollination services supported by adjacent forested areas (CANARI, 2020). However, the declining diversity and abundance of pollinators have a negative effect on agricultural production. At the same time, too much abandoned or idle land can also affect productivity. Thus, there is an urgent need to improve Grenada's ecosystems, food production, and quality of life.

Figure 3.10 illustrates key impacts (and few resulting benefits) of agriculture on the four essential areas of resilience. Examples of these impacts with their associated indirect/proxy indications/evidence are presented in Table 3.1.

Table 3.1. Impacts on agroecosystems

Theme	Impact	Indications/Evidence
Food production loss	Reliance on food imports	Grenada depends on food imports for up to 80% of its consumption (IFAD, 2017)
Biodiversity loss	Increase in pest populations	The recent emergence and high infestation rate of a scale insect affecting soursop, plums, mangoes, and other fruits and flowers (Department of Agriculture, Water and the Environment (DAWE), 2021)
Quality of life	Missed opportunities to improve quality of life	There are a few successful and sustainable agroprocessing companies in Grenada which are not Grenadian owned[1]
Land loss/ abandonment	Climate change- SLR resulting in saltwater intrusion and land abandonment	Saltwater intrusion has either compromised coastal farms or resulted in complete land abandonment. According to the World Bank Group, International Centre for Tropical Agriculture (CIAT) and the Tropical Agricultural Research and Higher Education Center (CATIE) (2014) it is expected that there will be a 3% increase in agricultural land abandonment if sea level rises by 1m.

Responses

It is important to first recognise the current barriers to responding to the components (D-P-S-I). According to the FAO (2008), institutional gaps are a significant barrier and include limited integration and coordination of activities among key sectors and institutions. Ineffective intersectoral dialogue and lack of M&E of policies are among the institutional challenges cited nationally (GoG, 2015). Other barriers identified include: inadequate agricultural information system, excessive rules and procedures, lack of adequately trained personnel, high institutional cost of providing services to the farming community and lack of recognition of the dual nature and characteristics of the agricultural sector. Response to these is critical to target broad-spectrum interventions that tackle the needs of ecosystems and people at the same time (Box 3.5).

Respondents to the survey carried out in support of this assessment (Box 3.2) identified an important role for PAs in responses to ecosystem resilience and climate change in the context of agroecosystems. More than 60% affirmed that increasing the number of PAs will increase the resilience of Grenada to climate change impacts. Agroecosystems are critical to Grenadian society, identity, culture, well-being, resilience and sustainable development in multiple ways. In approaching the question of long-term ecosystem management and resilience to climate change, the functioning of these critical ecosystems is not a singular concern but part of a mosaic of interlinked issues and challenges facing the government and the people of

[1] The growing shift away from agriculture and the lack of higher learning in current and future farmers are key reasons why improved quality of life is challenging in the context of agriculture. According to IICA (2017), small-scale processors and entrepreneurs require more education (not just on techniques but also of scientific knowledge) and technical capacity improvement to further advance their business, opportunities and income

Box 3.5. Key agricultural response initiatives in Grenada

Key initiatives to date include:

- Food and fibre production sustainability/food security
  - Land use management and policy/ enforcement
  - Policy influence on consumers and other stakeholders
- Biodiversity enhancement (diversification and habitat improvement)
  - Horticulture – propagation attracts pollinators and builds ecosystem resilience input controls (e.g. pesticide/fertilisers, seeds, GMOs)
- Quality of life enhancement
  - Livelihood diversification and alternative market opportunities e.g. green/shade-houses, aquaculture, hydroponics, beekeeping, fair trade/organic certification (soft market-based/access to high value markets); also has an environmental enhancement effect as well.
  - Social behaviour change (all levels) including education and training-household level food and nutritional security.
- Environmental enhancement
  - Use of conservation and sustainable techniques to combat downstream impacts of activities in upland watershed areas.
  - Climate-smart agriculture on coastal farms (saline intrusion), local resource management/co-management strategies (PAs/corridors/buffers/multi-use areas). One such example is the Grenada *Backyard Gardeners Network Initiative*.

Grenada. Efforts to sustain the quantity and quality of agroecosystems are unlikely to be sustained without linkages to the other ecosystem types explored in this chapter and throughout this entire assessment.

3.4.5. Coastal ecosystems

Introduction

One of the greatest assets to the state of Grenada is its 121km long coast (see Chapter 2, Figure 2.4). Some of its features include rocky coasts, estuaries, headlands, bays, lagoons and inlets, coastal cliffs and numerous black and white sand beaches which attract substantial tourism development (Kairi Consultants Ltd, 2008). Clear waters and sandy beaches provide the basis for a broad range of economic activity directly linked to Grenada's GDP (The Nature Conservancy [TNC] and Grenada Fisheries Division, 2007; Spalding *et al.,* 2017; Gentner and Obregon, 2018). Coral reefs, mangroves and seagrass beds provide habitat for a wide range of marine organisms, including critically endangered sea turtles and marine mammals (see Chapter 2) and protect the coast from powerful storm surges (GoG, 2014; GoG, 2017a). Mangroves, seagrasses and coastal forest help to stabilise and trap carbon in the soil. Coral reefs provide sand to beaches, as well as support commercially-important fish species.

However, climate change is exerting significant pressure on these ecosystem services, putting livelihoods and the economy at risk. It is estimated that climate change-driven SLR would result in approximately 60% of Grenada's beaches and associated ecosystems being lost (Scott, Simpson and Sim, 2012). Additionally, climate change-driven ocean warming is closely linked to losses in coral reef ecosystems, including those around Grenada (Reguero *et al.,* 2018). Further, coastal erosion is being exacerbated by increasingly severe and frequent storms (Moore, Gilmer and Schill, 2015; Lincoln, 2017).

Looking ahead, as Grenada aspires toward its blue economy and Sustainable Development Goals in the era of climate change, adaptive management has become an important and strategic first step to mitigate potential damages, to take advantage of opportunities and to cope with the consequences of climate change. This coastal DPSIR analysis (see Figure 3.11 and Appendix 4) done in the context of Grenada is expected to consequently help to maintain or enhance current health, adaptability and resilience of associated ecosystems.

Drivers

Post-independence, a defining feature of the Grenadian coastal landscape has been human-induced changes as Grenada seeks to unlock the contribution of coastal and marine based assets to promote economic growth, social inclusion, livelihood opportunities and environmental sustainability (UNDESA, 2012). Human driven changes in the coastal zone affect the resilience of coastal ecosystems such as mangroves, seagrass meadows and coral reefs, with important implications for climate change mitigation and adaptation endpoints, as well as sustainable development and conservation goals. Consequently, any attempt to explain or predict the sustainability and resilience of Grenada's coastal landscape can no longer succeed without addressing human actions as a central concern. Moreover, the socioeconomic drivers underlying these human actions, such as trade, consumer demands and human migration are all predicted to increase over the rest of the 21st century (Norström *et al.,* 2016).

The primary drivers impacting Grenada's coastal landscape are the increasing global movement of people, coupled with global and regional demand for coastal and marine tourism products (Pattullo, 2005; Bishop, 2010). The intersection of these forces

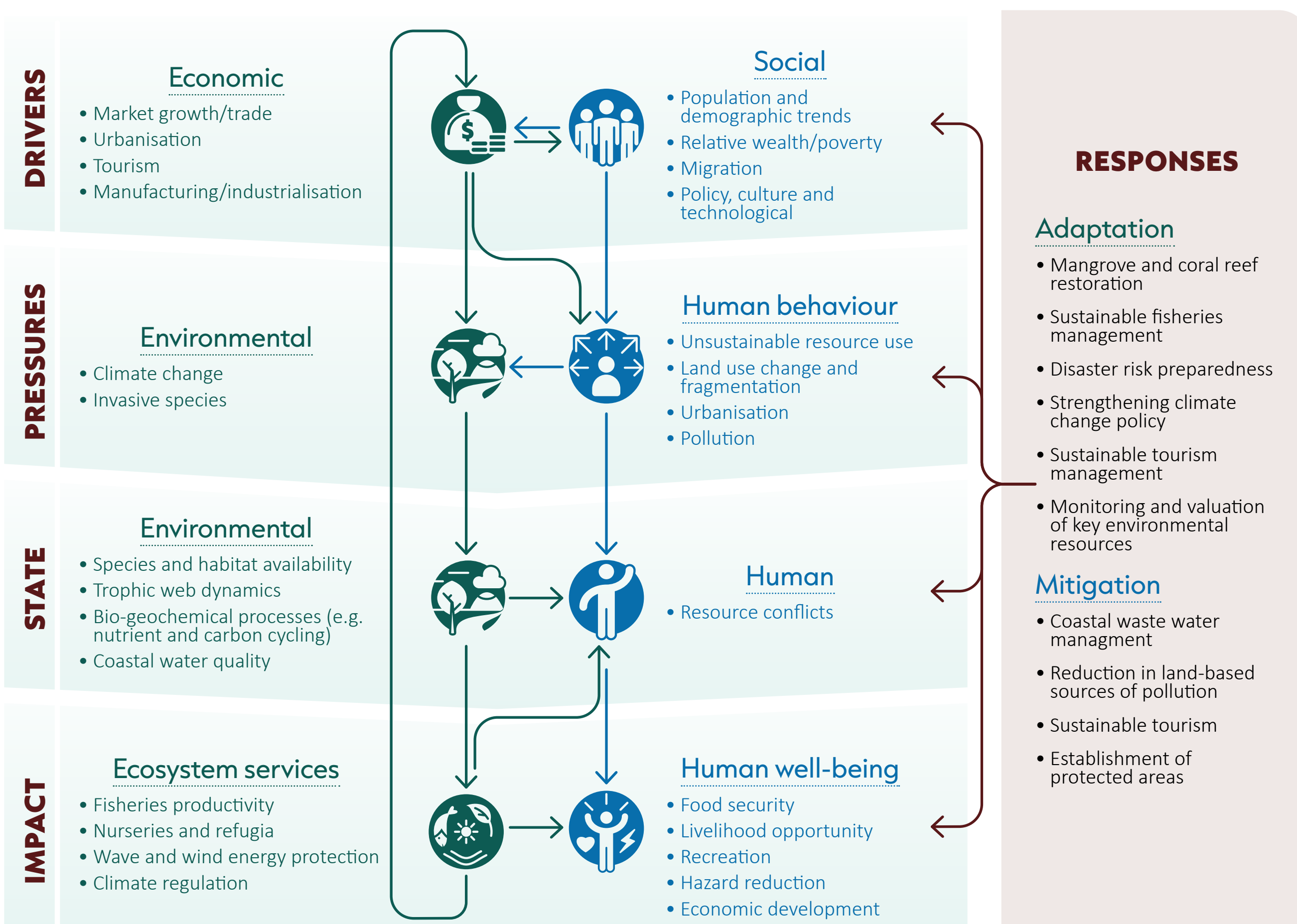


Figure 3.11. Coastal ecosystems DPSIR Framework

with a failing agricultural sector, has led to Grenada becoming a largely tourism-based economy, where over the past two decades the economy has shifted from agricultural dominance to tourism and tourism services.

Tourism is an important growth industry in Grenada (contributing 40% to Gross National Product [GNP]/ GDP) (United Nations World Trade Organisation [UNWTO], 2022) that has required strong economic and environmental reforms. These economic and environmental reforms have also driven changes in the way coastal spaces are used. For instance, in order to remain competitive on the global market, Grenada has adopted several legal provisions, leading to the formation of MPA networks to conserve shelf (coral reefs, seagrass) and nearshore habitats (mangroves, beaches, lagoons) (Byrne, 2006). However, strides toward economic growth and environmental protection are often in conflict as Grenada exploits more new tourism markets to remain competitive in a global market. An unintended consequence of land-use change for tourism growth are the social, environmental and economic inequities, which, if not properly managed, can be damaging to the island (Bhola-Paul, 2015). These inequities were especially revealed post-pandemic, owing to the contraction of the global tourism economy due to the dampening of international movement of people, international trade and manufacturing.

Pressures

The key pressures being put on Grenada's coastal landscape include climate change (increased storm intensity and frequency, SLR and increased temperature), land degradation, pollution, land-use change (including urbanisation). Although Grenada does not have an extensive hurricane history as it is situated to the south of most hurricane tracks, Grenada is not immune to hurricane impact. Most notably, extreme storm surges and wave run-up in 1999 (Hurricane Lenny), 2004 (Hurricane Ivan) and 2005 (Hurricane Emily) have caused devastating damages and losses to settlements, infrastructure and the environment (Simpson *et al.,* 2012). Current projections indicate hurricane intensity is likely to increase an average of 8-10% per degree ocean warming (oC) (Knutson and Tuleya, 2008; CCCCC, 2015; IPCC, 2018).

Extreme storm surges also drive increased coastal erosion risks, including beach loss, which is already occurring in the north along Sauteurs and La Poterie, and in low lying areas such as Grand Anse (Figure 3.12), Marquis Beach and Soubise. As storm intensity and wave surge increases, further changes in the coastal profile would transform coastal tourism with implications for local employment and economic well-being (Simpson *et al.,* 2012). In concert with storm surge, SLR magnifies these pressures, accelerating coastal erosion and in some cases outpacing the ability of coastal ecosystems to maintain their place in the coastal zone.

Although there is some debate on the rate at which SLR is occurring, there is general consensus that Grenada's coastlines will continue to face the threat of rising seas, which pose a substantial risk considering the associated impacts of erosion and exacerbation of storm surge. Current estimates suggest that a 1m increase in sea level would result in the disappearance of about 22% of Grand Anse Beach (a major tourism attraction) and all of Marquis Beach could be lost with a SLR of 0.5m (Simpson *et al.,* 2012). Rising sea level is an acute risk to the population, most of which live coastally, and where almost all of the major economic infrastructure is located. SLR of 1m is also expected to affect 73% of all major tourism resorts as well as 40% of all seaports.

Sea surface temperature (SST) has significantly increased over the last decades and is projected to continue to increase, with implications for storm activity, SLR and ocean productivity. Ocean warming, combined with the threat of SLR, also pose a significant threat to Grenada's coastal ecosystems. Ocean warming events have become more frequent and intense in the last decades, resulting in coral bleaching and disease outbreaks on coral reefs. In the last decades these incidents have driven profound shifts in coral reefs, reducing their ability to buffer powerful wave energy, provide food and sustain tourism (Jackson *et al.,* 2014; Hughes *et al.,* 2018; Muñiz-Castillo *et al.,* 2019). The implications for other coastal ecosystems remain unclear.

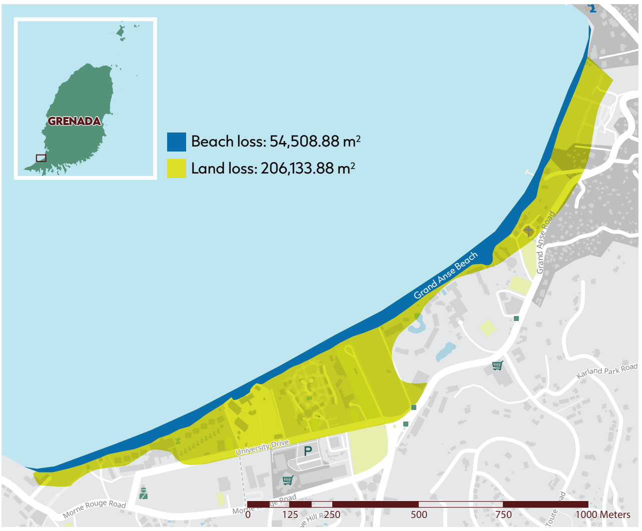


Figure 3.12. SLR impacts at Grand Anse Beach
(Simpson et al., 2012)

Other non-climate specific pressures include the backfilling, dredging and land reclamation of mangroves to make way for commercial and residential development, and the harvesting of mangroves for fuel (charcoal) and other human uses. These pressures remain a significant threat to the physical and ecological functioning of this ecosystem, including their ability to filter fertiliser and sediment-rich runoff from watersheds due to unsustainable farming practices increasing pressures on coastal resources. The removal of seagrass beds and other coastal vegetation that bind sediment and assist in the prevention of coastal erosion also continues to be a problem. The erosion of sandy beaches is being accelerated by illegal sand mining for commercial and residential development and tourism developments. Presently, sand mining is only permitted in a few locations (Galby Bay, Bacolette Beach and the Canals) and only permitted entities (such as the Gravel, Concrete and Emulsion Production Corporation and to a much lesser extent NAWASA) are allowed to mine for sand (GoG, 2017a). Further, fisheries resources especially in nearshore areas of Grenada, face overharvesting pressure by spearfishing and nets and traps set directly in the nearshore areas, threatening ecologically and commercially important species such as parrotfish, turtles, conch and urchins.

State

Environmental reporting has, until recently, not been a priority in Grenada, with environmental reports being released as part of international commitments such as to the CBD. Coastal ecosystems in Grenada include coral reefs, lagoons, coastal forests, seagrass meadows, mangroves and salt ponds. These ecosystems are often described as over-exploited and degraded, owing to a combination of pressures, with the foremost pressure being climate change. Consequently, the confluence of ocean warming, pollution and unsustainable fishing practices have been attributed to significant declines in reef health and function, threatening ecologically and commercially important species, including endangered turtles, sharks, groupers and rays (Anderson *et al.,* 2012). The recent invasion of the lionfish (*Pterois* spp.) in the last decades also threatens already declining reef fish stocks and the livelihoods they support (GoG, 2014).

By international standards Grenada's mangroves are considered to be in good health but declining. Mangrove cover was estimated to decline by 1.2-1.5% between 1980 to 2005 (FAO, 2007). More contemporary research suggests limited recovery in some areas, and that fringing mangroves are highly vulnerable to coastal storms with limited opportunity for landward retreat (Moore, Gilmer and Schill, 2015). While the status of the other coastal ecosystems (seagrass beds, lagoons and salt ponds) remains unassessed, their integrity and functioning continue to be an issue of national concern, as beach sand mining, unsustainable fishing and agricultural practices and tourism development exert strong negative pressures on these ecosystems. Currently, large tourism and yachting related projects in the south, east and north of mainland Grenada threaten to remove large numbers of mangrove and associated coastal forest.

Impacts

Grenada's coastal ecosystems are already experiencing some of the effects of climate change, through damage from severe storms and other extreme events, as well as increasing ocean temperature and more subtle changes in rainfall patterns (Simpson *et al.,* 2012; CCCCC, 2015). Past storm events such as Hurricane Ivan in 2004 significantly deforested the island, causing damages in excess of twice Grenada's GDP (GoG, 2019). Entire areas of mangrove were completely destroyed, and several others ranged from different levels of defoliation to being completely blown down. Moore, Gilmer and Schill (2015) conclude that fringing mangroves are highly vulnerable to physical damage by extreme storms and might also be unable to respond to SLR due to little option for landward retreat. Additionally, SLR is expected to transform fringing mangroves to basin mangroves, diminishing defence against storms and winds. Saltwater intrusion from SLR is also increasing the salinity in salt ponds, backwaters and estuaries, creating hypoxic conditions and limiting their ability to support brackish water species. The effect of saltwater intrusion on coastal groundwater sources is likely to have impacts on coastal vegetation and potentially potable water in the limited areas where coastal wells exist.

Coral reefs are particularly vulnerable to climate impacts arising out of increased ocean temperatures, ocean acidification and increased intense storm activity. Although the data record for Grenada's coral reefs is poor, there is a consensus that coral bleaching will occur more frequently, and last longer, as mean ocean temperatures increase (Hughes *et al.,* 2018). As ocean temperatures rise above optimal temperature for coral growth, corals will eject their zooxanthellae and bleach. Coral bleaching has been observed for several monitored reefs with intense events occurring in 1999, 2005 and 2010 (Eakin *et al.,* 2010; Muñiz-Castillo *et al.,* 2019). Increased ocean warming also favours conditions for coral disease outbreaks. Increased storm intensity and strong storm surge may dislodge and damage corals, reducing the three-dimensional complexity of the reef and its functionality. Additionally, SLR threatens to 'drown' corals by limiting the amount of light available to them (Braithwaite and Miller, 2001; Hughes *et al.,* 2018). Extreme weather events may also generate nutrient and sediment-rich runoff which may further stress corals.

There are no specific reports available on climate-related impacts on Grenada's coastal lagoons, seagrass meadows and beaches, but as low-lying shallow intertidal ecosystems they share similar expected impacts. The scientific literature suggests that in coastal lagoons SLR increases the potential for increased salinity and reduced oxygen, increasing the likelihood of fish kills. Additionally, the potential for eutrophication (algal overgrowth) increases with storm runoff. Temperature changes affect flushing and oxygenation of the waters, and under high algal growth and low oxygen conditions, fish kills are likely (GoG, 2014). Significant eutrophication has been observed in Clarkes Court Bay (Kotelnikova *et al.,* 2015). Similarly, extreme storms and wave surge are expected to erode seagrass beds, removing seagrasses. SLR will also increase the depth of seagrasses in the tidal frame, limiting the amount of light that is available for photosynthesis. SLR coupled with storm surges also threaten to transform beaches to open ocean, impacting people and property. When considering ocean acidification, increased acidification negatively affects corals reducing the amount of sand available for beach formation.

Responses

Grenada has a myriad of legislative documents dealing with coastal ecosystems at national, regional and international scales. The key responses for the purpose of increasing climate resilience include:

- strategic adaptation programmes and projects: Grenada has been implementing a number of policy directives which seek to increase resilience to climate change which include:
  - increasing the amount of coastal and marine areas that is protected under the Grenada Protected Area System;
  - providing infrastructural and technical assistance to projects in order to reduce threats and damages to key coastal resources (beaches, mangroves, seagrasses and coral reefs);
  - producing a *National Climate Change Adaptation Plan (NAP) for Grenada, Carriacou and Petite Martinique 2017-2021*, an umbrella

document with the objective to "provide strategic, coordinating framework for building climate resilience in Grenada"*;*

  - developing an *Integrated Coastal Zone Management (ICZM) Policy for Grenada, Carriacou and Petite Martinique* which was completed in 2015 with the objective to further regulate the integrated use, development and protection of the coastal zone. As part of the *ICZM Policy for Grenada, Carriacou and Petite Martinique* (2015) Grenada restarted beach monitoring but there are still difficulties with human capacity which means that data collection is not continuous; and
  - Grenada passed the *ICZM Act* in 2019 which calls for greater zoning and protection of coastal resources, including beaches and coastal vegetation. To date, enforcement and implementation of this Act on the ground has not been initiated and regulations to enforce this Act have not yet been promulgated. Grenada is also undertaking several community EbA actions including coral restoration and mangrove rehabilitation, all with alternative livelihood implications.
- community co-management of coastal forest afforestation and mangrove restoration on the main island of Grenada on the south, east and north coasts, with the aim of providing alternative livelihoods and building awareness around the sustainable use of mangroves;
- coral restoration under a programme of coastal EbA, in partnership with the United Nations Environment Programme (UNEP) initiated on coral reefs in Grand Anse and Carriacou which could be scaled up and replicated in other areas and involve local communities; and
- building resilient coastal communities by having them play a leading role in the conservation, restoration and management of coastal ecosystems in Grenada.

3.4.6. Marine ecosystems

Introduction

The island nation of Grenada has a land area of only 340km2, but the Exclusive Economic Zone (territorial waters) cover a much greater area (more than 27,426km2) with the second largest shelf (~2,237km2) among OECS countries (see Chapter 1 Figure 1.4). Consequently, rather than considering Grenada as a 'small island state' it might be more accurate to consider it as a 'large ocean state' (LOS), recognising the central role that the ocean plays in Grenada's development (Hume *et al.,* 2021).

Depths on the shelf vary from 36 to 73m with average depths of 27–36m (Coastal Conservation Association [CCA], 1991). Offshore, beyond the shelf edge, depths reach >2,500m on the Caribbean side and >1,300m on the Atlantic Side of the islands, characterised by a relatively flat abyssal plain of fine sediments (volcanic silts from erosion of the islands themselves and siliceous materials carried in by plume of the Amazon and Orinoco rivers). Notable deep sea features include Kick-'em-Jenny, the only active submarine volcano in the Caribbean Sea. This volcano crater is approximately 300m in diameter with the shallowest point located at 180m water depth (Carey *et al.,* 2016).

The dominant ocean currents in the vicinity of Grenada flow from the east-southeast. Upwelling of deeper ocean waters is thought to exist along the eastern part of the insular shelf. During the South American rainy season, enormous quantities of freshwater are discharged from the Orinoco and Amazon rivers, this water drifts north-westwards, greatly influencing marine ecosystems around Grenada and the Grenadines (CCA, 1991).

Drivers

Various socioeconomic and environmental drivers are of relevance to the marine ecosystems around Grenada (see Figure 3.13 and Appendix 4). The demand for seafood is anticipated to rise in the future coupled in part with an increased global demand for recreation and leisure. Cruise and commercial

DRIVERS

Economic

- Economic development and availability of capital
- Demand for mineral resources and hydrocarbons
- Demand for transport (shipping)
- Communication (cables and pipelines)

Social

- Per capita seafood demand
- Number of citizens and visitors
- Affluence or poverty
- Demand for recreation and leisure
- Need for waste disposal (litter, sewage, etc.)
- Demand for energy (carbon emissions)

PRESSURES

Human

- Overfishing
- Introduction of invasive or non-native species
- Anthropogenic noise
- Eutrophication (release of nutrients)
- Pollution (contaminants and litter)
- Dredging and offshore construction
- Cables and pipelines

Climate-related

- Increasing seawater temperatures
- Increase in seawater salinity or change in precipitation
- Decline in pH and carbonate saturation state (ocean acidification)
- Decline in seawater oxygen concentration (especially in deep-waters)
- Change in the frequency or severity of cyclones and storms
- Change in wind speed and offshore upwelling intensity/ seasonality

STATE

Changes

- Changes in the productivity, standing stock and seasonality of offshore plankton community
- Changes to the productivity, resilience and distribution of small pelagic fish populations (e.g. sardines, scads, flyingfish)
- Changes to the productivity, resilience, distribution and migrations patterns of large pelagic fish (e.g. tunas, billfish, dolphinfish)
- Changes to the distribution and migration patterns of marine mammals and turtles
- Influxes of Sargassum seaweed from elsewhere in the Atlantic
- Disruption to the life-cycle and productivity of deep sea and continental slope communities, including deep-water snappers
- Disruption/decline in the ability of offshore sediments to store carbon

IMPACTS

- Decline/impact on fish supplies and hence on food security, source of income, source of export revenue, employment, and cultural identity
- Indirect impact on the wider maritime economy (e.g. boat builders, fish retailers, wholesalers, processors, government revenues/taxes)
- Decline in sport/recreational fisheries associated employment and revenues
- Decline/impact on ecotourism (attractiveness to visitors) including recreational scuba-divers, whale watching and associated revenues
- Harmful algal blooms, Ciguatera Fish Poisoning (CFP), vibriosis cases, jellyfish outbreaks that could present a risk to human health

RESPONSES

- Removal of other human pressures (e.g. overfishing) through the designation and enforcement of Marine Protected Areas (MPAs)
- Enhance climate change resilience of fish stocks through careful management (within 'safe biological limits'), necessitating improved data collection
- Marine Spatial Planning system, including actions that enhance resilience to natural disasters and the impact of climate change
- Engineering measures to protect infrastructure and property from storm surges and sea level rise, and voluntary resettlement of coastal assets and people vulnerable to climate and natural hazards
- Training in business skills, or safety at sea. Established fisheries cooperatives share best practice and offer a financial 'safety net'
- The Caribbean Oceans and Aquaculture Sustainability Facility (COAST) is an insurance scheme aimed at making the fisheries sector more resilient to climate events. Rapid pay-outs provide compensation for lost income and damaged fishing equipment
- Hurricane warnings and disaster planning etc. (e.g. the 'FEWER' mobile phone app under the *Pilot Programme for Climate Resilience*). The app sends alerts of bad weather conditions or sea state to fishers, giving them early warning of any potentially dangerous conditions

Figure 3.13. Marine ecosystems DPSIR Framework

shipping activity have been increasing around the islands, with associated increases in emissions of ballast water and waste. Other human drivers in the offshore marine area include the introduction of non-native species, pollutants, including litter and exploration for deep sea resources and hydrocarbons (GoG, 2014; GoG, 2017b). Grenada's southern waters are known to suffer from poor water quality as a result of sewage discharges (GoG, 2017b; Compton and Forde, 2020). Plastic litter remains a problem due to inappropriate waste-disposal behaviour, public lack of awareness, and careless tourism activities (Deutsche Gesellschaft für Internationale Zusammenarbeit [GIZ], 2015) (see Chapter 2 for further details on marine pollution). Added to this, IAS such as the non-native lionfish or influxes of Sargassum seaweed are becoming problematic (Fisheries Division, 2015; Ince, 2017). Climate change adds to these cumulative pressures on marine species and reduces ecosystem resilience.

Pressures

Both increasing SST (see Chapter 2) and salinity (waters will become 'saltier' by as much as 0.8psu in 2070 to 2090 compared to the historic reference period, under the RCP 8.5 scenario) are climate change-related pressures that affect marine ecosystems. In addition, ocean acidification will affect these ecosystems. Few empirical measurements have been taken in waters surrounding Grenada itself, however, using the Caribbean model of Gledhill *et al.* (2008) from 1992 to 2015, Melendez and Salisbury (2017) demonstrated a sustained regional increase in surface ocean acidity of ~10% (a decline in pH) and a concomitant decrease in the surface ocean aragonite saturation status (Ωarg) of ~8% (Figure 3.14).

These values agree with those reported across the wider Caribbean and Atlantic regions (Gledhill *et al.,* 2008; Bates *et al.,* 2012; Jiang *et al.,* 2015). The IPCC (2014) within their *Fifth Assessment Report* (IPCC-AR5 WG2b) assigned a high confidence assessment to the finding that the Caribbean region has experienced a sustained decrease in aragonite saturation state from 1996 to 2006. Over the course of the 21st century the pH of the surface of the global ocean is expected to decrease due to the increase in concentration of CO_2 in the atmosphere above it. For the models in the Coupled Model Intercomparison Project Phase 5 (CMIP5) ensemble that have surface ocean pH (13 members are in this ensemble available in National Oceanic and Atmospheric Administration [NOAA] Physical Sciences Laboratory (n.d.), the expected change is reflected in a decrease of pH of the order of 0.1 for the 2006 to 2055 period versus the previous five decades (Dye, Buckley, and Pinnegar, 2017; Melendez and Salisbury, 2017). Over the past half century, the ocean below 200m has experienced warming, oxygen loss, and acidification (Desbruyères *et al.,* 2016; Chen *et al.,* 2017; Breitburg *et al.,* 2018). Food supply to the deep seafloor has been impacted by declines in oceanic plankton productivity at certain localities and this could affect the productivity of benthic food webs (Levin *et al.,* 2020). Figure 3.14 below shows the Caribbean Time series from 1980 to 2015 with the monthly regional mean of dry atmospheric CO_2 mole fraction (µmol/mol) in the Caribbean in yellow. In blue is a time series from 1992 to 2015 of monthly regional mean of seawater pH (total scale). Data covered the domain defined as [30°N, 15°N, 90°W, 60°W] (Melendez and Salisbury, 2017).

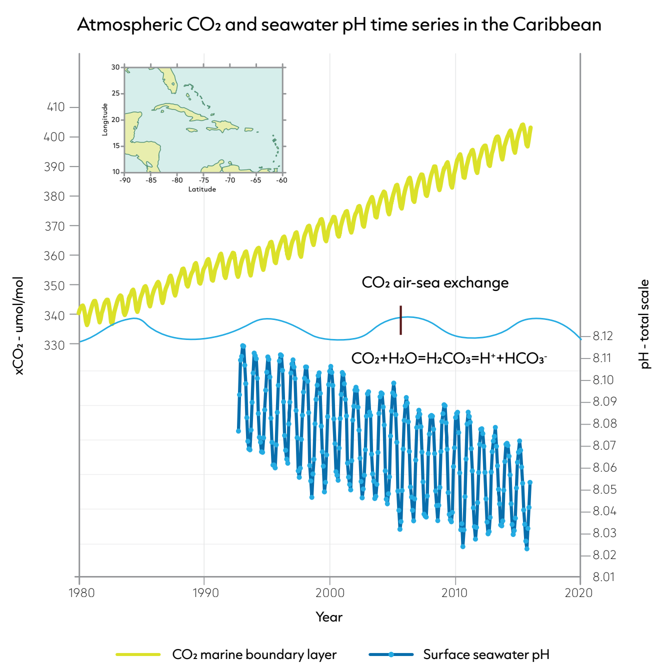


Figure 3.14. *Atmospheric CO2 and seawater pH time series in the Caribbean*

There is a projected increase in the frequency and intensity of tropical cyclones (hurricanes) in the North Atlantic (IPCC, 2022b) for which empirical studies have noted overall higher North Atlantic tropical cyclone activity (+60% °C-1) (Goldenberg *et al.,* 2001) and increased frequency of very intense tropical cyclones (~+17% °C-1) since the 1970's (Emanuel, 2007; Holland and Webster, 2007; Bender *et al.,* 2010). The *CARIBSAVE Climate Change Risk Atlas (CCCRA) - Grenada* report identified some evidence for significant trends in monthly mean windspeeds over the years 1960 to 2006 (Simpson *et al.,* 2012). However, around Grenada the trends were only significant in summer and autumn (at about 0.25ms^{-1}/decade). This trend will exert additional pressure on already stressed marine systems (see Chapter 2). The effects of climate change and warming oceans and volcanic activity are independent stressors that, when coupled together with negative anthropogenic impacts, might provide detrimental results for marine ecosystems.

State

As it pertains to the state of the marine environment and the influence of climate change, there are several factors that can be used as a proxy or observations made that can infer on the current and changing conditions of Grenada's marine environment. First, although little is known about the current oceanic plankton community that exists around Grenada, past studies can provide some insight. For instance, Agard, Hubbard, and Griffith (1996) suggested that phytoplankton species diversity and richness is heavily influenced by the seasonal incursion of waters deriving from the Amazon and Orinoco rivers. Satellite image data suggests that an apparently coherent plume of dispersed Amazon water enters the Caribbean between Barbados and Tobago with Grenada at its centre. It is the disturbance caused by intrusion of this low salinity water during the wet season from January to June that contributes to elevated plankton biodiversity observed in its path.

However, recent studies focused on the southern Caribbean have tended to suggest decreasing levels of plankton production, resulting from a reduction in ocean upwelling, whereby nutrients crucial for plankton production are brought from the sea floor to the surface. The decrease in upwelling has, in turn, been driven by observed changes in wind patterns and wind strength linked to global climate change, and this may have serious repercussions for offshore pelagic fisheries. Most of the available information on plankton and consequences resulting from climate change are based on regional assessments (Nurse *et al.,* 2014). CMIP5 model outputs suggest that both Total Chlorophyll Mass and primary organic carbon production by all types of phytoplankton types will decline around Grenada under an RCP8.5 scenario by 2050 to 2099 compared to the historic reference period (NOAA Physical Sciences Laboratory, n.d.). The pattern of diversity in harvested living marine resources (pelagic fish) has been shown to closely parallel phytoplankton diversity across the region, peaking around Grenada (Agard, Hubbard, and Griffith, 1996).

Since 2011, the Caribbean region has been experiencing unprecedented influxes of the pelagic seaweed Sargassum (Figure 3.15). These extraordinary Sargassum 'blooms' have resulted in mass strandings throughout the Lesser Antilles including Grenada (Ince, 2017), with significant damage to coastal habitats (van Tussenbroek *et al.,* 2017), as well as consequences for fisheries and tourism. Whether or not such events are related to long-term climate change in the open ocean remains unclear, however, it has been suggested that the influx may be related to strong Amazon discharge, enhanced West African upwelling, together with rising seawater temperatures in the Atlantic (Wang *et al.,* 2019; Oviatt *et al.,* 2019).

The International Commission for the Conservation of Atlantic Tunas (ICCAT) assessments indicate that large tunas and billfishes are either fully exploited or overexploited, with observed declines in some stocks (FAO, 2018). A climate-induced reduction in phytoplankton productivity of the southern Caribbean has been linked to a collapse of sardine populations (Oxenford and Monnereau, 2017). Scad landings have shrunken enormously in recent years. It is not clear whether this trend has been a result of climatic influences, over-exploitation, or simply a change in fishing practices. The status of small tunas

Figure 3.15. *Incidence of Sargassum in Grenada's bays* *(Data sources: Degia et al. (2022); TNC (2010) Shapefile - Beaches: grd_mar_beaches_2010; TNC (2012)- Shapefile -Landing sites: grd_soec_landingsites_2012)*

(Scombridae), dolphinfish (*Coryphaena hippurus)* and mackerels around Grenada are unknown.

Further, there is anecdotal evidence that mass influxes of pelagic Sargassum seaweed into the Caribbean over the last few years have impacted the availability and/or size of commercially important pelagic species including flying fish (Exocoetidae) and dolphin fish. While the flying fish can use this habitat for egg laying, the Sargassum can provide habitats for other species such as the frog fish (*Histrio histrio*) which is a voracious ambush piscivorous predator.

Tunas are thought to be relatively robust to climate change pressures and readily adjust their distribution depending on the prevailing conditions and local food availability. Erauskin-Extramiana *et al.* (2019) reported poleward shifts in distribution for 20 out of 22 tuna stocks between 1958 and 2004 at a rate of approximately 6.5km per decade in the northern hemisphere. Further (perhaps even larger) shifts are expected in the future, especially by the end of the century (2080 to 2099), and this could take fishery resources beyond the reach of most small-scale fishing vessels in Grenada, or perhaps even beyond the limits of the EEZ. It is, however, also possible that large tuna and billfishes may be forced to aggregate closer to the surface by a rising oxygen minimum layer in the deep ocean, which could increase catchability, at least in the short-term, though this might threaten the long-term sustainability of the stocks and leave them vulnerable to over-fishing (Oxenford and Monnereau, 2017).

Current evidence suggests that the migration patterns, distribution and/or abundance of cetaceans could be altered as a consequence of continued changes in SST (Lambert *et al.,* 2010). Humpback whales (*Megaptera novaeangliae*) are considered to have relatively high adaptive capacity to ocean warming, yet modelling suggests that certain breeding grounds will become unsuitably warm for this species (>28°C) by the end of the twenty-first century (Derville *et al.,* 2019). One of the greatest threats to marine mammals comes from changes in their food resources. Many prey species such as fish, cephalopods and plankton are anticipated to be impacted by changes in environmental conditions.

A decrease in the population of sperm whales in the eastern Caribbean (-4.5% per year since 2010) has been documented by Gero and Whithead (2016). It is possible that changes in ocean currents and temperatures, through their impacts on prey resources, may have contributed to this decline, but observations are inconclusive.

It is not thought that climate change will greatly affect deep-sea seep communities e.g. those associated with the sub-marine volcano, Kick-'em-Jenny. However, Levin *et al.* (2020) has suggested that organisms inhabiting the wider abyssal plain could be impacted. This could have consequences for the structure and functioning of deep-water food-webs, as well as shifting damaging fishing practices further offshore into vulnerable habitats.

Impacts

In the context of offshore marine environments, climate change affects the indirect values of these ecosystems. For instance, as seas become warmer due to climate change, blooms of toxic microalgae are expected to increase, affecting water quality. This presents a health risk to humans. Ciguatera fish poisoning (CFP) is the most common non-bacterial cause of human illness associated with seafood consumption globally and is associated with ciguatoxin bioaccumulation in predatory fish species such as groupers, barracuda and snappers, all commercially-exploited fish species for Grenada. Distribution and abundance of the organisms that ultimately produce these toxins, chiefly dinoflagellates of the genus *Gambierdiscus*, are reported to correlate positively with seawater temperature (Kibler *et al.,* 2017). Consequently, there is growing concern that increasing temperatures associated with climate change could increase the incidence of CFP in the island regions of the Caribbean (Morrison *et al.,* 2008). There are indications that warmer sea temperatures may drive outbreaks of CFP (Tester *et al.,* 2010; Simpson *et al.,* 2012; Nurse *et al.,* 2014).

Changes to the 'state' of a natural ecosystem can have serious impacts or consequences for human society and economies. These are usually viewed through the lens of 'direct use value of ecosystem services', however, there are critical indirect and non-use values (see Chapters 1 and 4) that are also impacted (Lau *et al.* 2019; Abson and Termansen, 2011).

In the context of direct values in the offshore marine environment, some of the most important provisioning services are related to commercial fisheries. Fish are one of the few products for which the island is self-sufficient. Seafood exports (mostly yellowfin tuna, *T. albacares*) provide an important source of revenue for the country and amounted to around US$5.2 million in 2017. The United States of America receives more than 90% of seafood exports from Grenada (FAO, 2019b). Any impact of climate change on fishery production or yields could have wide-ranging implications for the Grenada economy.

In Grenada, shelf-edge fisheries exist for certain deep-water snappers and groupers. It is possible that the abundance and productivity of deep-water fish species might be affected by climate change as eggs and larvae would be vulnerable to changes in ocean currents and SST change, while newly settled larvae and juveniles typically use shallow coral reef habitats as nursery areas (Oxenford and Monnereau, 2017). In addition, deep-water snappers and groupers could be affected through impacts of increased SST on the timing and location of spawning aggregations (Erisman & Asch, 2014). Warming temperatures can lead to previously shallow-water species shifting their distribution into deeper waters, in order to avoid excessive temperatures near the coast.

Cheung *et al.* (2018), used a range of different models to make projections of future catch potential (% change) assuming an RCP8.5 climate change scenario for the 21st century. For Grenada the models suggest a 7-12% decline in fishery catch potential by mid-century, but prospects in the longer-term are more uncertain. Monnereau *et al.* (2015), examined the relative 'vulnerability' of the fisheries sector in 33 Caribbean countries or territories, building on a framework developed by Allison *et al.* (2009). This analysis considered 'exposure' (temperature and SLR), 'sensitivity' (reliance on fisheries) and 'adaptive capacity' (governance, economic resilience). Grenada emerged as one of the most vulnerable small island states because it is highly dependent on marine resources and has limited access to financial resources to adapt.

Future climate change could threaten this important income stream. Changes in species distribution or a change in offshore weather (more frequent or severe storms) could deter fishing activity as well as tourism activity e.g. whale watching activities that operate out of Grand Anse (Townhill *et al.,* 2019).

Responses

Responses or interventions to address climate change impacts in the offshore marine environment can take several different forms: policy or governance responses, societal or industry responses, technological responses (Townhill *et al.,* 2021). All of these adaptation responses can be observed or have been trialled in Grenada.

One of the most effective interventions to enhance climate change resilience is to reduce or remove other pressures such as overfishing and habitat degradation, for example by creating MPAs. Those in Grenada (see Chapter 2) are primarily designed to protect coastal habitats such as coral reefs. However, the Sandy Island MPA in Carriacou and Grand Anse MPA extend offshore to a limited extent. The Woburn/Clarke's Court Bay MPA is located on Grenada's south-eastern coast and is recognised as one of the most important spawning grounds for commercial fish species in the entire OECS.

Grenada has a number of frameworks relevant to climate change adaptation inclusive of its National Adaptation Plan (GOG, 2017b). As it pertains to the coastal and offshore environment, the plan calls for "increased resilience of selected infrastructure to climate change, including increasingly extreme weather events through location, planning, design and maintenance to be resilient and managing land sustainably." Recommended actions include improving the available datasets on coastal infrastructure and ecosystems, addressing sand removal and improving technical capacity for coastal zone management (GOG, 2017b).

At the local scale, adaptive capacity in the fishing industry and in coastal communities can be strengthened by providing training in business skills, or safety at sea. Awareness raising and good science communication can be fundamental to providing communities with the knowledge they need to adapt to climate change. Furthermore, fisheries cooperatives can be used to develop support schemes, to spread risks and provide a financial 'safety net' (Townhill *et al.,* 2021).

To improve safety at sea, the *Fisheries Early Warning and Emergency Response (FEWER*) mobile phone app is being rolled out to fisherfolk in Grenada, under the *Pilot Programme for Climate Resilience (PPCR),* (Townhill *et al.,* 2021). The app sends alerts of bad weather conditions or sea state to fishers, giving them early warning of any potentially-dangerous conditions. Users can share information on local conditions and about missing persons. Having information sent directly to mobile phones is valuable, as many fishers do not check weather conditions each day before they go to sea.

Those involved in fisheries (both offshore and onshore) can be severely impacted by extreme events such as hurricanes, through loss of life, or damage to fishing gear, vessels and infrastructure (Sainsbury *et al.,* 2018). In 2019, a new insurance scheme was created for the fisheries sector throughout the Caribbean. The Caribbean Ocean and Aquaculture Sustainability Facility (COAST) is a parametric, or index-based insurance scheme, which aims to make the fisheries sector resilient to climatic events by releasing funds directly in the event of extreme weather conditions (Caribbean Catastrophe Risk Insurance Facility [CCRIF], 2019). Rapid pay-outs provide compensation for lost income and damaged fishing equipment. The COAST insurance scheme has been piloted in Saint Lucia and Grenada (Sainsbury *et al.,* 2019; World Bank, 2019).

Sala *et al.* (2021) pointed out that deep sea marine sediments are the largest pool of organic carbon on the planet and that they can act as a crucial reservoir for long-term storage of carbon (Atwood *et al.,* 2020). Little is known about the biogeochemical properties of the seabed around Grenada but given the size of the country's EEZ this could represent a vast reservoir of stored carbon. If left undisturbed, organic carbon in marine sediments can remain there for millennia. However, disturbance of these carbon stores (e.g. by mineral extraction or damaging fisheries) can re-mineralise sedimentary carbon to CO_2. Protecting carbon-rich seabed could potentially be an important nature-based solution to help combat climate change in the long term (Levin *et al.,* 2020).

It is also important to acknowledge the current barriers to responding to the components (D-P-S-I) appropriately in marine ecosystems. First, there is a lack of high-resolution, downscaled climate-model outputs that can adequately resolve oceanographic processes around Grenada. Second, few empirical measurements of pH or carbonate chemistry (ocean acidification) have been made in waters surrounding Grenada. Third, little is known about the oceanic plankton community that exists around Grenada, and especially how this might be impacted by future climate change. Fourth, the status of key fisheries resources around Grenada are poorly understood, for example tunas, dolphinfish and mackerels etc., hence it is impossible to assess how resilient these populations might be to over-fishing and future climate change. Fifth, very little is known about deep-sea habitats and biodiversity around Grenada, including possible indirect consequences of a decline in surface plankton productivity and the role that deep-sea habitat might offer in long-term storage of carbon. Sixth, models suggest a 7-12% decline in fishery catch potential for Grenada by mid-century, but prospects in the longer-term are more uncertain, this could have consequences for livelihoods, employment, and food security.

Long-term monitoring of climate, biodiversity, species and ecosystems is important. Increased surveillance of oceanographic parameters and the status of offshore fish stocks is particularly needed. Also, as seas become warmer due to climate change, blooms of toxic microalgae are expected to increase and could present a health risk to humans. Regional partnerships should be established with meteorological institutes and climate modellers to provide future projections at a spatial scale that is useful for risk assessment and disaster planning. Other pressures such as overfishing, or habitat degradation need to be reduced or removed in order to enhance resilience of ecosystems and fish stocks to climate change and periodic shocks (e.g. hurricanes). Efforts to build resilience within the maritime economy, include early warning systems, structural measures to protect infrastructure and property, financial 'safety nets' to spread risks and institutions to share 'best practice' (e.g. fisheries cooperatives, disaster insurance schemes).

3.5. Local knowledge on the contribution of Grenada's ecosystems to climate resilience

The Grenada NEA has been a highly-participatory process, with strong stakeholder engagement through mechanisms described in the introductory section of this assessment. This section documents the local knowledge contributed by stakeholders, specific to the focus of this chapter, namely on climate resilience aspects. This information was captured through various feedback mechanisms including a workshop in September 2022, where civil society, private sector and youth shared information they had on the knowledge gaps the chapter's authors were trying to fill. Priority stakeholder concerns and recommendations were also captured as documented below.

Stakeholder recommendations to improve climate resilience of ecosystems, particularly coastal and marine systems, included:

- increase the coverage of MPAs. The current target of 20% is considered to be insufficient;
- increase protection of overfished species such as snapper, lobster and conch;
- increase the engagement with locals on climate related issues;
- create opportunities for co-management between government and communities;
- empower communities to protect ecosystems;
- increase and find innovative ways to educate the public on climate issues affecting Grenada, with particular emphasis on actionable messages and timelines. Importantly, these messages should empower communities especially the youth to be involved;
- humans should move sea urchins to coral reefs most affected by algal overgrowth;
- prioritise reducing land-based pollution; and
- give greater consideration to the impacts of artificial reef structures on coastlines.

The workshop findings arising from Grenadian stakeholders highlighted the need for urgent and clear action on maintaining and sustaining ecosystems and a need for a shift from assessments and policies to action.

3.6. Conclusion

Healthy ecosystems are the basis of resilience to climate change while the resilience of the ecosystems themselves is important to ensuring the ability of Grenada and other small islands to mitigate and adapt to climate change. Additionally, communities and their economic activities are dependent on ecosystems for their livelihoods and development. Keeping ecosystems and their services intact while pursuing social and economic development goals in the form of climate resilient development should be the cornerstone of present and future initiatives (see Chapter 5 for specific policy recommendations). Consequently, ecosystem stewardship is a key recommendation of IPCC AR6 (IPCC, 2022a) to move toward climate resilient pathways.

The responses suggested in this chapter highlight that in order to improve resilience, responses can take place within a comprehensive, synergistic framework that encompasses national governance and policy responses, institutional and sectoral systems, technological responses and socioeconomic conditions to alleviate poverty while contributing to climate resilient development. Current and past initiatives undertaken in Grenada such as coral restoration, improving the climate resilience of the water sector and developing national policies are important. Similar endeavours should be implemented within the country, and successful, small-scale projects could be scaled up to a national level.

Specific measures need to be undertaken in the areas of energy, industry, urban and infrastructure, land and ecosystems and societal. Such measures include:

- preserving agroecosystems and implementing climate smart agriculture (see Figure 3.16);
- maintaining and improving the network of PAs, in particular, by revitalising forests and wetlands and supporting natural coastal environments;
- integrating equity and gender at local and national levels;
- increasing climate change education and awareness, recognising local, indigenous knowledge;
- developing downscaled climate data for Grenada and other small islands;
- generating clean energy while providing energy and water access for all members of society; and
- greening infrastructure, communities, and cities.

In order to achieve climate resilience of ecosystems and implement these recommendations, EbA and NbS are key strategies that should be a part of national development planning processes and instruments to interlink nature and climate.

Figure 3.16. Greenhouse managed by the Petite Martinique Women in Action Group as part their climate-smart agriculture work (Photo credit: CANARI)

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Appendices

Appendix 1. Terrestrial ecosystems – DPSIR table

This table provides further details of the potential impacts of climate change on ecosystem services in Grenada in the context of pressures, state and impacts, using evidence from local examples and those across the region.

Ecosystem service/function	Pressure	State	Impacts
Water availability (provisioning)	• Land-use change (e.g. Agriculture/Agricultural Intensification) • Land tenure (e.g. high proportion of private land limits state management of natural resources) • Unsustainable natural resource management & over-exploitation (e.g. farmers pumping water from the rivers, 'let go' season in Carriacou reducing vegetation) • Pollution (e.g. contaminants, nutrients, sediments, waste management) • Wildfires • Climate change (including extreme events, increased temperatures, drought/ reduced rainfall, saline intrusion, SLR etc.)	• Temperatures increased by an average of 0.14°C per decade between 1960 and 2006 (GoG, 2017c); Grenada recorded all-time highest temperature in 2020 (WMO, 2020). • No significant trend in rainfall between 1900-2014 due to inter-annual variability in rainfall but number of consecutive dry days has increased (CSGM, 2020). Dry season surface water decreases by up to 30 to 40% (Simpson *et al.,* 2012). • Carriacou and Petite Martinique are significantly drier than mainland Grenada (UNECLAC, 2011). • Ten periods of severe droughts between 1900 and 2010; in 2009 annual rainfall recorded a 24-year low (Charles, 2014). • Land-use change in upper watersheds has reduced flows in streams and rivers (UNECLAC, 2011). • Carriacou and Petite Martinique depend on rainwater for potable water; rainwater storage in Carriacou has been depleted during periods of drought (e.g. 2009/2010) (Trotman and Farrell, 2010). • More than 80% of land on Grenada is privately owned (UNECLAC, 2011); on Petite Martinique all lands are privately owned and on Carriacou approximately 94% (UNDESA, 2012)	• Potential for increased mortality in non-drought tolerant native species as observed in Jamaica (McLaren and McDonald, 2003) and Puerto Rico (Wolfe and van Bloem, 2012) leading to potential changes in species composition e.g. drought resistant and selection for species with shallow roots/invasive species • With increasing drying trends, potential expansion of dry forest and contraction of moist forest (Nelson *et al.,* 2015) • Increased need for irrigation due to drying conditions will negatively impact water availability (Simpson *et al.,* 2012), potentially increasing water stress for biodiversity during the dry season. • By 2050 a gap is predicted between water supply and demand, potentially increasing costs e.g. redistribution of water to driest areas, increasing rainwater storage (UNECLAC, 2011) • Predicted reduction in precipitation and increased drought events; increased vulnerability for populations relying on rainwater (e.g. Carriacou), including increased migration (Cashman and Yawson, 2019) • Livelihoods impacts (e.g. decreased water availability for agriculture and tourism (SCC, 2020), rainwater insufficient to meet tourism demands on Carriacou and Petite Martinique (UNDESA, 2012) • Health impacts (e.g. malnutrition due to food shortages, water storage during droughts leading to increased vector-borne diseases (SCC, 2020)) • Land ownership issues leading to non-optimal use of lands (e.g. abandoned agricultural lands in Carriacou) (UNDESA, 2012)

Ecosystem service/function	Pressure	State	Impacts
Air quality (regulating)	• Wildfires • Pollution (e.g. contaminants, nutrients, sediments, waste management) • Climate change (including extreme events, increased temperatures, drought/ reduced rainfall, saline intrusion, SLR etc.)	• Little data on air quality trends; 2016 data (22.87µg/m³) on concentrations of fine particulate matter (PM2.5) are well above the WHO threshold of 5µg/m³ (WHO, 2020). • Between 2009 and 2013, an estimated 869ha of forest was destroyed by fire, all due to human interaction. Fires occurred mainly in the dry season, with worst fire years being 2007, 2008 and 2010 (Charles, 2014) • An increase in Saharan dust has been observed over recent decades across the Caribbean, including notable events in Grenada between 2011 and 2015 (CSGM, 2020). • A significant increase in Sargassum events in Grenada since 2011 (CRFM 2019, Resiere *et al.,* 2021	• Likely increase in respiratory problems due to increasing temperatures, humidity, wind patterns and Sahara dust (SCC, 2020) e.g. asthma attacks correlated with Sahara dust exposure (Martin *et al.,* 2011). • Ambient air exposure to hydrogen sulphide fumes from Sargassum events can be high enough to cause respiratory, neurological and respiratory problems (e.g. in Martinique) (Resiere *et al.,* 2021)
Carbon sequestration (regulating)	• Land-use change (e.g. agriculture/agriculture intensification) • Unsustainable natural resource management & consumption (e.g. over-exploitation of timber species) • Land tenure • Wildfires • Climate change (including extreme events, increased temperatures, drought/ reduced rainfall, saline intrusion, SLR etc.)	• Approximately 23% of Grenada and 65% of Carriacou is forested (Rusk, 2008). • Grenadian dry forest is estimated to sequester 0.5 tC/ha/yr and moist forest 2.5 tC/ha/yr (Blommestein *et al.,* 2012) • Increasing drying and temperature trend [discussed above] • Fire data suggests significant fires over recent years (Charles, 2014) • Hurricane return rates; recent extreme weather includes Category 5 Hurricane Ivan and Category 2 Emily (2004 and 2005, respectively)	• Forest cover loss and degradation could result in altered carbon sequestration due to change in species composition and biomass (e.g. invasives with lower carbon storage) (no data exists) • With increasing drying trends, potential expansion of dry forests and contraction of moist forest due to drying trends (Nelson *et al.,* 2015) could alter rates of carbon sequestration. • Potential impairment or modification of below and above ground carbon storage potential e.g. data from Jamaica suggest changes to dry forest carbon storage after hurricanes, potentially decreasing if hurricane frequency increases by >50% (Holm *et al.,* 2017)

Ecosystem service/function	Pressure	State	Impacts
Soil maintenance (regulating)	• Land-use change (e.g. agriculture/agriculture intensification) • Unsustainable agricultural practices (e.g. farming on steep slopes, livestock grazing during dry season) • Pollution (e.g. contaminants, nutrients, sediments, waste management) • Wildfires • Climate change (including extreme events, increased temperatures, drought/ reduced rainfall, saline intrusion, SLR etc.)	• Significant increase of abandoned agricultural land between 2000 and 2009 (1614% increase) (GoG, 2014), converted to tourism, commercial and residential infrastructure (Simpson *et al.*, 2012) • More than 30% of eastern hillsides of Petite Martinique are severely eroded, with 10-15% moderately eroded (UNDESA, 2012) • Carriacou land degradation estimated at 20-40%; soil loss from freshwater plumes after droughts, extended 1.2km from shore after 2009-2010 drought (Peters, 2015). • Little data on trends in soil properties • Fire data suggests increase in fire [discussed above]	• Increased soil loss due to synergies between pressures e.g. forest loss induced soil erosion and sedimentation following 2004/2005 hurricanes and 2009/2010 drought (Simpson *et al.*, 2012). • Potential increase in drought-resistant introduced species that increase resiliency of disturbed habitats e.g. nitrogen fixing by Leucaena leucocephela in Puerto Rico (Colon and Lugo, 2006). • Climate-induced changes in species composition [discussed above] • Changes in composition and amount of soil nutrients and belowground biomass (little data) • Implications for watershed management and adaptive capacity to extreme events
Protection services e.g. flood/ erosion control (regulating)	• Land-use change (e.g. farming too close to riverbanks, reduced ground absorption of water from concrete/ development) • Unsustainable agricultural practices (e.g. farming on steep slopes, slash and burn) • Wildfires • Climate change (including extreme events, increased temperatures, drought/ reduced rainfall, saline intrusion, SLR etc.)	• Forest cover [discussed above] • Rainfall has not significantly changed between 1900 and 2014 but has become more variable and extreme rainfall events have increased (GoG, 2017c). • Flooding usually due to heavy rain or storm surge, most frequent from June to November (Charles, 2014). Areas most prone to flooding are slopes of 0-2 degrees, encompassing 583ha or 1.9% of land area on Grenada; river basins with highest vulnerability are St. John's, St. Mark's, St. Patrick's, St. Andrew's, particularly coastal communities (Charles, 2014).	• Changes in species composition that increase vulnerability to erosion e.g. introduced species with shallow roots [discussed above] • Implications for watershed management e.g. flooding and siltation of reservoirs after forest fires in 2007 (Simpson *et al.*, 2012). • Impairment/modification of flood/erosion control e.g. cost of maintaining roads and trails will increase with predicted intensification of extreme weather (Simpson *et al.*, 2012). • High concentration of poor in parishes most vulnerable to flooding means a reduced capacity to respond to natural hazards (Charles, 2014); response to unusual weather events e.g. extreme dry season rainfall event and flooding in Gouyave in 2011 (GIZ, 2017)

Ecosystem service/function	Pressure	State	Impacts
Food, NTFPs (provisioning)	• Land-use change (e.g. agriculture/agriculture intensification) • Unsustainable natural resource management and consumption (e.g. over-exploitation of game species) • Introduction of IAS • Climate change (including extreme events, increased temperatures, drought/reduced rainfall, saline intrusion, SLR etc.)	• Five terrestrial game species on Grenada hunted commercially and recreationally for meat (Mona monkey, nine-banded armadillo, manicou, iguana and Ramier/scaly-naped pigeon]) (Nelson, 2013) • Manicou estimated in 2011 to be below carrying capacity for sustainable harvest (Nelson, 2013) but no more recent data exist. • 1980s report suggested armadillo considered endangered, iguana threatened (Ludeke *et al.,* 1989), but little more recent data exist. • Mona monkey experienced a significant population decline between 1994 and 2014, due to Hurricane Ivan and persistent over-harvesting (Gunst *et al.,* 2016) • On Carriacou, manicou and iguana populations are reported to be higher than the mainland and viewed as pest species (Nelson, 2013). • Medicinal and flowering plants, firewood, fruits, extracted from forest areas in Grenada (Blommestein *et al.,* 2012) (little data on trends) • Limited cottage industry of plant-based fragrances from forest species in Grenada (Rodriguez, 2003) • Impacts of Hurricane Ivan resulted in a reduction in screw pine (Pandanus utilis) harvesting for crafts (Simpson *et al.,* 2012) and other NTFPs including red bead and donkey eye trees (Dunn, 2005), although no subsequent data exist they were thought to recover quickly in the short-medium term. • Seabird harvest on offshore islands (Smart, Collier and Rolland, 2020)	• Unknown climate resilience of NTFP species (no data exist) but climate change impacts likely to exacerbate existing impacts of threats to forest systems (FAO, 2021). • Post-hurricane forest loss changes abundance, composition of NTFP species (Simpson *et al.,* 2012); predicted increasing hurricane intensity could reduce resilience of NTFP species (no data exist). • Reduction or changes in NTFPs could mean increased vulnerability of specific groups which rely on NTFPs for livelihoods e.g. women in Clozier/Apres Tout communities after hurricane Ivan (Simpson *et al.,* 2012). • Climate-induced change in species composition, homogenisation of species diversity [discussed above], with potential impacts on livelihoods and for resource conflicts e.g. PAs and charcoal/fire

Ecosystem service/function	Pressure	State	Impacts
Habitat for biodiversity (supporting)	• Land-use change (e.g. agriculture/agriculture intensification) • Unsustainable natural resource management & consumption (e.g. over-exploitation of game species) • Pollution (e.g. contaminants, nutrients, sediments, waste management) • Wildfires • Introduction of IAS • Climate change (including extreme events, increased temperatures, drought/ reduced rainfall, saline intrusion, SLR etc.)	• Resident, threatened, endemic species changes due to invasives, over-exploitation, hunting, habitat loss, forest loss, etc.) [discussed above] • Genetic diversity [see Chapter 4] • Forest cover (e.g. increase in secondary growth mixed agroforestry) (GoG, 2014) • High average human footprint of 17.83 (>7 is intense impact) (Venter *et al.,* 2016)	• Climate-induced homogenisation and changes in species composition and diversity e.g. evidence of increase in introduced and edge species in dry forests (Nelson *et al.,* 2015). • Native species may be less resilient to fire than introduced species e.g. L. leucocephala in Puerto Rico (Wolfe and van Bloem, 2012), resulting in changes to species composition. • Fire resistance of many dry forest species is low (Santiago-Garcia *et al.,* 2009) • Potential increase in drought-resistant introduced species e.g. L. leucocephela increases in areas with less precipitation in Puerto Rico (Brandeis *et al.,* 2009) • Caribbean forests are generally resilient to hurricanes at current frequency and intensity (e.g. van Bloem *et al.,* 2007; Imbert and Portecorp, 2008; Rojas-Sandoval *et al.,* 2014), but predicted increase in intensity could lower this resilience (no data exists). • Natural regeneration of abandoned agricultural lands could lead to species homogenisation and increase in introduced species e.g. systems dominated by L. leucocephala in Puerto Rico (Erickson, Davidson and Keller 2002), potentially changing adaptive capacity. • Climate-induced disruption to migratory species routes/habitats (e.g. Culp *et al.,* 2017), with potential to impact regulating services (e.g. nutrient cycling) • Loss of habitat connectivity due to climate and other anthropogenic pressures (e.g. predicted for endemic species in Hispaniola) (Gibson *et al.,* 2019). • Increase in edge effects (e.g. fires) around PAs due to increased secondary growth and fragmentation • Reduced genetic variation lowering adaptive capacity [see Chapter 4] • Sedimentation impacts, freshwater, coastal and marine biodiversity (GoG, 2017c)

Ecosystem service/function	Pressure	State	Impacts
Pollination (regulating)	• Land-use change (e.g. agriculture/agriculture intensification) • Wildfires • Introduction of IAS • Climate change (including extreme events, increased temperatures, drought/ reduced rainfall, saline intrusion, SLR etc.)	• No available data on trends in species abundance of pollinators [also see Chapter 4 for known agricultural pollinator species]. • Variation in pollinator richness and relative importance dependent on moisture gradient; on Grenada birds visited more species with increasing moisture, bee pollination declined with increasing rainfall, wasps increased with rainfall, dipterans had lower richness with increasing temperature and rainfall (Gonzalez *et al.,* 2009)	• Potential changes in pollinator relative importance and composition with drying trends and increasing temperature in Grenada (Gonzalez *et al.,* 2009) • Reduced fruit set and pollination was observed in the Bahamas following hurricanes (Rathcke, 2001) • Climate-driven loss or reduction in species-specific pollinators of native species (e.g. observed in Trinidad, Tobago and Jamaica, Arnold *et al.,* 2018) • Loss of habitat connectivity [discussed above] • Lower agricultural productivity [little data exists]
Disease control (regulating)	• Land-use change (e.g. agriculture/agriculture intensification) • Introduction of IAS • Unsustainable land use practices (e.g. standing water) • Climate change (including extreme events, increased temperatures, drought/ reduced rainfall, saline intrusion, SLR etc.)	• Increased ecosystem and habitat loss, degradation and fragmentation (GoG, 2014) • Increased disease events e.g. Dengue every year (Schiøler and Macpherson, 2009) • Disease and IAS e.g. Bartonella spp. in mongoose (Jaffe *et al.,* 2018)	• Loss and change in species composition reduces resilience of system [discussed above] • Potential for emerging zoonotic diseases and increase in vector-borne diseases due to higher temperatures and extreme rainfall (Simpson *et al.,* 2012, WHO, 2020) • Increased drying conditions could increase use of water storage leading to increases in Dengue (Simpson *et al.,* 2012) • If flood events increase, waterborne diseases e.g. Leptospirosis could increase (Simpson *et al.,* 2012) • Human livelihood and education impact due to loss of productivity from ill health (CSGM, 2020) and increased climate impacts on non-communicable diseases (WHO, 2020) • Greater prevalence of crop pests and diseases (Simpson *et al.,* 2012) e.g. red palm mite is invasive to Caribbean and in Brazil is predicted to spread with increased drying conditions (Gondim *et al.,* 2012)

Ecosystem service/function	Pressure	State	Impacts
Tourism	• Land-use change (e.g. agriculture/agriculture intensification) • Unsustainable natural resource management & consumption (e.g. over-exploitation of game species) • Wildfires • Introduction of IAS • Climate change (including extreme events, increased temperatures, drought/ reduced rainfall, saline intrusion, SLR etc.)	• Resident, threatened, endemics, etc., changes due to invasives, over-exploitation, hunting, habitat loss, forest loss, etc.) [discussed above] • Tourism is the dominant services sector in Carriacou and Petite Martinique (UNDESA, 2012) • Ecosystem and habitat loss, degradation, fragmentation due to tourism development (GoG, 2014)	• Predicted drying conditions and higher temperatures will increase water demand from tourist sector (Simpson *et al.*, 2012), with potential impacts for water availability for wildlife and habitats. • Potential reduction in foreign tourists due to more extreme weather and temperature increases (Simpson *et al.*, 2012), resulting in reduced income from livelihoods
Cultural services-recreational, aesthetics, spiritual, education	• Land-use change (e.g. coastal development exclusion of use, recreational development in natural habitats e.g. zipline at Seven Sisters Falls) • Wildfires • Introduction of IAS • Climate change (including extreme events, increased temperatures, drought/ reduced rainfall, saline Intrusion, SLR etc.)	• Use of habitats by local people e.g. recreational, spiritual (Turner, 2009) • School and public environmental education and increasing awareness of climate change (UNDESA, 2012, GoG, 2017c)	• Climate-induced habitat loss (e.g. hurricane damage) interacting with synergistic pressures reduces opportunity and experience of recreation in natural areas (GoG, 2017c) e.g. surface runoff reduces aesthetic appeal and water quality, changes in species composition • Potential loss of native species impacts cultural identity (e.g. national species) • Reduced well-being from reduced interaction with environment [discussed above] • Increased risk to health and safety of forest users (e.g. disease transmission from IAS) [discussed above]

Appendix 2. Case study on terrestrial resilience

The conceptual socioecological models presented in this Appendix provide examples of current ecological and socioeconomic pressures that impact the resilience of terrestrial systems and their stakeholders to future potential climate change impacts.

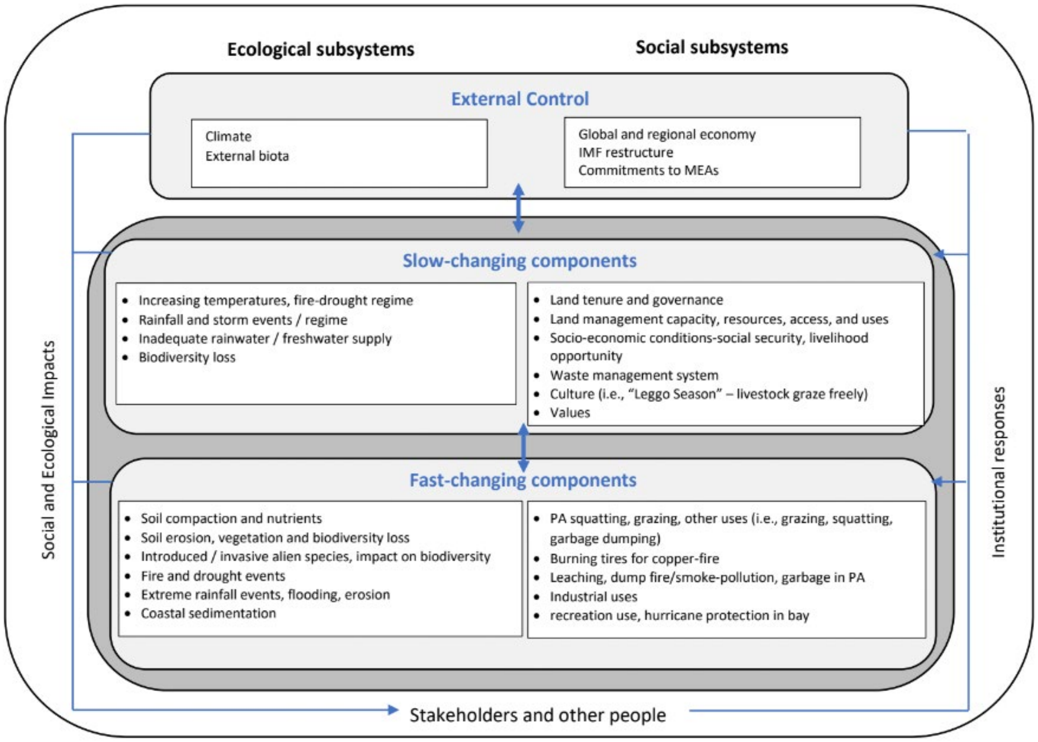
Socioecological systems are dynamic; thus, the components are framed here using the speed at which they change over time. Temporal context is a useful lens for climate change, to understand how responses can address mismatches in speeds of ecological and socioeconomic change. The slow-changing components are influenced by external controls, while the fast-changing components are those that tend to have a more direct impact on stakeholders and have a feedback mechanism with the slow-changing components. Three examples, Perseverance, Annandale and Carriacou, illustrate components of resilience in three different terrestrial systems (Appendix 2 Figures 1;2;3). The external controls are shared across all systems. Some fast- and slow-changing components are common to all (e.g. land tenure, values), whilst others are unique to the system. These unique components include 'let go' season and rainwater dependency on Carriacou (impacting drought, overgrazing impacts for erosion), waste management and pollution in Perseverance (impacting leaching during extreme rainfall events, increased fire risk droughts), and forest plantations and tourism in Annandale (affecting non-native species impacts for future watershed management, livelihoods).

Understanding these fast and slow-changing components is key to identifying the mechanisms needed to increase the resiliency of ecosystems and human systems to climate change. For example, land tenure (common to all examples, Figures 1-3) is slow-changing (although it could be best described as punctuated as when changes happen they can be fast and abrupt) but has a big potential impact on sustainable land management. Resolving insecure land tenure at a national policy level is needed to increase resiliency in the system, but that is a long-term process that is slow to change. Thus, shorter-term incentives to support those with insecure land tenure could improve local level climate resiliency (e.g. PES, government programmes such as climate resilient agriculture, reducing unsustainable practices on steep slopes).

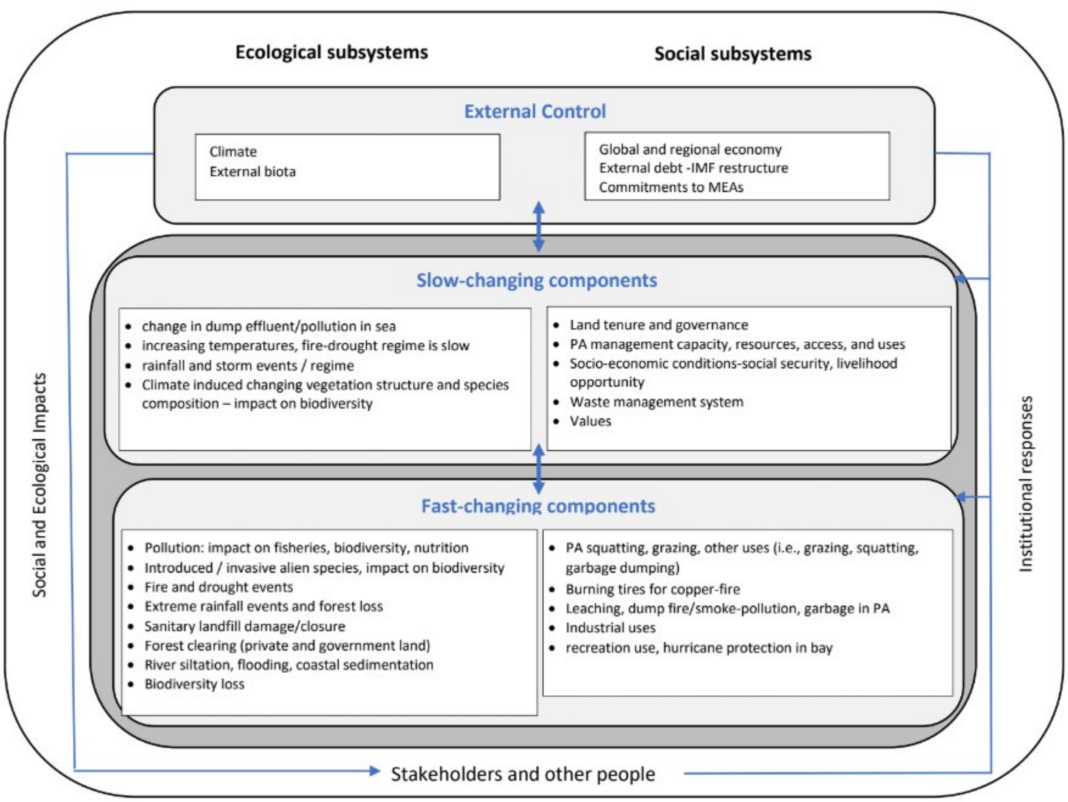
A fast-changing component common to all examples, that of forest clearing (e.g. erosion after clear- cutting on steep slopes in Perseverance and Annandale, and increased erosion and flood risk on Carriacou, see Terrestrial DPSIR Impacts and State) requires the implementation of a land use plan, regulations and policy that address climate adaptation and sustainable forest management. Physical planning regulations for building restrictions on steep slopes are a potentially relative fast-changing action.

In the context of Perseverance and Annandale, river siltation is a fast-changing component (Figures 2,3) with potential large downstream impacts (e.g. after extreme rainfall events, see Terrestrial DPSIR Impacts and State). However, the mechanisms to address this component can be longer-term and slow changing i.e. changing values and systemic agricultural practices and strengthening legislation and enforcement for watershed management. Relatively fast-changing actions include education and outreach by forest rangers/extension officers about river setbacks for agricultural, development and domestic activities.

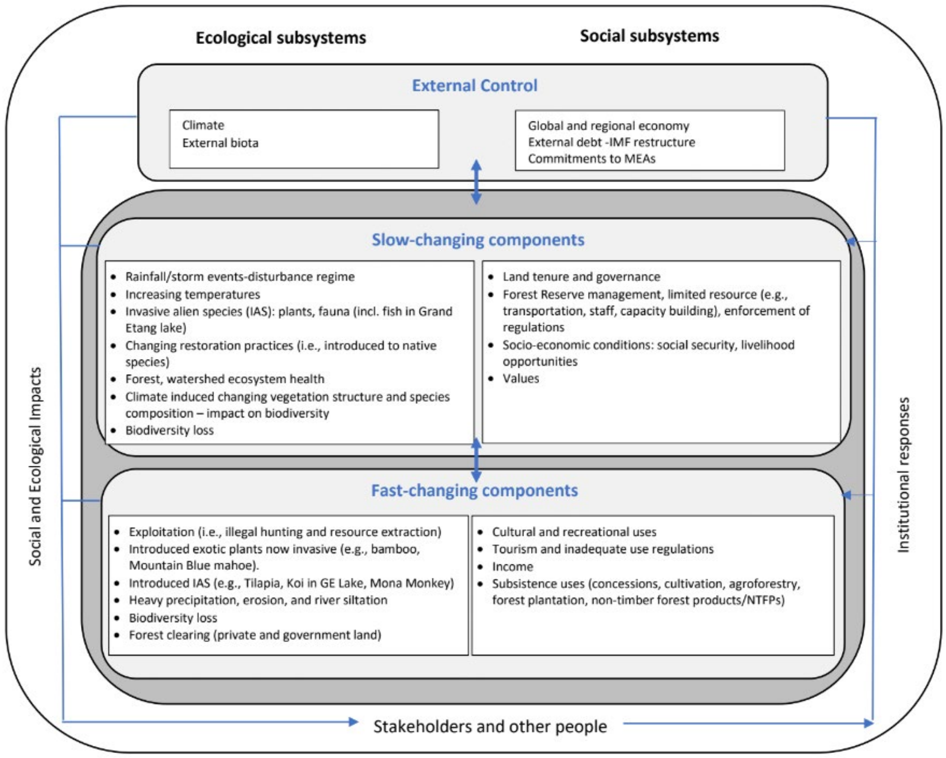
Slow-changing components relating to water regimes (Figures 1-3), such as increasing drought conditions on Carriacou, are exacerbated by unsustainable land-use practices such as grazing pressure that puts pressure on remaining natural forest that is already water-stressed (see Terrestrial DPSIR Impacts and State). Mechanisms to address this component can be longer-term and slow-changing i.e. changing values and systemic agricultural practices and strengthening legislation addressing land degradation and sustainable water use. Relatively fast-changing actions include education and outreach by forest rangers/ extension officers about climate-smart grazing practices.



Appendix 2 Figure 1 Conceptual model–socioeconomic systems - Carriacou



Appendix 2 Figure 2 Conceptual model–socioeconomic systems - Perseverance



Appendix 2 Figure 3 Conceptual model–socioeconomic systems - Annandale

Appendix 3. Perception of Ecosystems and Ecosystem Services survey in support of the Grenada NEA

Introduction

The Government of Grenada through the Environment Division within the Ministry of Tourism, Civil Aviation, Climate Resilience and the Environment is conducting the Grenada National Ecosystem Assessment (NEA) with support from the Caribbean Natural Resources Institute (CANARI). As part of this assessment, NEA authors are investigating the perceptions of Grenadian citizens and residents regarding Grenadian ecosystems and ecosystems services.

Section 1: Respondent Characteristics

1. Gender:
   - ○ Male
   - ○ Female
   - ● Prefer not to say

2. Age:
   - ○ 18-24
   - ○ 25-39
   - ○ 40-59
   - ○ 60 and over

* 3. Marital status
   - ● Single
   - ○ Married
   - ○ Divorced
   - ○ Widowed
   - Other (please specify)

* 4. Are you a Grenada resident, citizen or a visitor?
   - ● Permanent resident
   - ○ Citizen
   - ○ Visitor
   - ○ None of the above

5. What Parish are you from or reside in?
   - ● St. Georges
   - ○ St. Andrews
   - ○ St. Mark
   - ○ St. John
   - ○ St. David
   - ○ St. Patrick
   - ○ Carriacou
   - ○ Petite Martinique
   - ○ None of the above

* 6. What is your highest level of education?
   - ○ Primary
   - ○ Secondary
   - ○ College
   - ○ University
   - Other (please specify)

* 7. Is your livelihood dependent on any of the following?
   - ☐ Farming
   - ☐ Fishing
   - ☐ Tourism
   - ☐ Forestry/ Forest resources
   - Other (please specify)

* 8. Household income per month (in XCD)
   - ○ $999 and under
   - ○ $1000-4999
   - ○ $5000-99999
   - ○ $100000 and over

Section 2: Use of Nature

This section explores how people use and benefit from ecosystems in Grenada. Some examples of how people benefit from ecosystems include:

1. Food from plants and animals (including fish) that you grow/rear or harvest/hunt/fish in nature
2. Materials from plants and animals, e.g. building materials and medicine that you grow or harvest in nature (Everything that is not food or fuel.)
3. Fuel from plants for cooking or lighting that you grow or harvest in nature
4. Protection from disasters (e.g. wind and wave breaks from hurricanes)
5. Plants that clean the air, e.g. by removing dusts and pollutants
6. Plants and animals that clean the water (filtrate wastes)

7. Plants and animals that prevent soil erosion (e.g., plant roots that stabilise the soil) and protect the coast (e.g., by reducing waves)
8. Places for activities or to relax and have an enjoyable time (e.g., activities to come together, swimming, walking).
9. Culture, heritage and traditional knowledge associated with nature including stories, music, art, plants and animals
10. Opportunities for education and skill development
11. Protection or conservation of plants, animals and nature for their own value or for future generations

* 9. Rank the importance of ecosystems that occur within your parish (1 being the highest rank, 10 being the least rank)

- Agriculture
- Backyard/home garden
- Beach/coastline
- Coral reef
- Forest
- Grassland
- Mangrove
- Ocean
- River, stream, lake, spring
- Seagrass

* 10. How important are the following ecosystem services to your life and/or livelihood?

	Not important at all	Low importance	Neither here nor there	Important	Very important
Food	◉	○	○	○	○
Materials	◉	○	○	○	○
Charcoal	◉	○	○	○	○
Protect	◉	○	○	○	○
Clean air	◉	○	○	○	○
Clean water	◉	○	○	○	○
Erosion control	◉	○	○	○	○
Leisure/recreation	◉	○	○	○	○
Cultural	◉	○	○	○	○
Education	◉	○	○	○	○
Conservation	◉	○	○	○	○

* 11. What do you think is the most important threat affecting how you benefit from natural ecosystems?

- Climate change
- Pollution
- Crime/safety
- Gender/social issues
- Access
- Infrastructure

Other (please specify)

Section 3: Resilience

This section explores the effects of climate change and the resilience of ecosystems in Grenada to climate change. Resilience is defined as capacity of an ecosystem to absorb disturbance and return to its pre-disturbance state following a perturbation.

* 12. In your parish, what are your top concerns regarding climate change?

- Precipitation/flooding
- Hurricanes/storms
- Water quality
- Sea level rise
- Extreme temperatures
- Ocean acidification
- Air quality
- Impact on oceans and marine life
- Impact on ecosystems and wildlife
- Impact on agriculture and food supply
- Impact on coastal communities

* 13. Would you like to see more being done to improve the resilience (ability to resist and recover) of Grenada's ecosystems to climate change impacts?

- Yes
- No
- Neutral
- I don't know

* 14. Can you suggest what should be done to improve the resilience of Grenada's ecosystems to climate change impacts? [Open-ended question]

* 15. How important do you think the protection of ecosystems is to improving the resilience of Grenada to climate change impacts?

- Very important
- Somewhat important
- Neutral
- Not really important
- Not very important

Section 4: Protected areas and ecosystems

* 16. What do you think are the most significant threats to Grenada's major natural ecosystems (agroforestry, forests and coastal and marine ecosystems)? (check all that apply)

- Praedial larceny (agro)
- Climate change
- Water scarcity (agro and forest)
- Pest and invasive species
- Soil erosion (agro and forest)
- Fire (agro and forest)
- Overexploitation (all)
- Habitat degradation (all)
- Invasive species (forest, coastal and marine)
- Pollution (all)
- I don't know

Other (please specify)

* 17. Fill in the blank, Protected areas are having a ……… on protecting Grenada's ecosystem services

- Positive
- Neutral
- Negative
- I don't know

* 18. Would you like to see more protected areas and if so how much?

- Less than 10%
- 10-20%
- 20-30%
- More than 30%
- No
- I don't know
- I don't think there is need for any more protected areas
- I don't believe that protected areas work

* 19. Do you think increasing the amount protected areas will increase the resilience of Grenada to climate change impacts?

- (●) Yes
- ( ) No
- ( ) Maybe
- ( ) I don't know
- ( ) It depends

Section 5: Plant and animal species

The previous sections addressed ecosystem level information. Here we would like to probe the roles of different species, and plant and animal groups, within these ecosystems. In particular please consider the role and value of different plants and animals in terms of their cultural and social values and the importance of these plants and animals to ecosystem function and services.

* 20. This question probes the contribution of different species to ecosystem functions and services (e.g. their role as a food source for other species or their role in pollination, cycling nutrients, soil protection, coastal protection, carbon storage, etc.).

How important are the following species or groups to ecosystem function and services like the ones mentioned above?

	none	low	medium	high	critical
Marine fisheries- pelagic (e.g. tuna)					
Non-reef fisheries (shallow/coastal fisheries)					
Reef fisheries					
Shelled fisheries (Conch, lobster)					
Sea urchins					
Sea turtles					
Whales & krill (products = whale oil, krill oil)					
Titiree					
Freshwater crayfish, shrimp, crabs					
Land crabs					
Aquaculture species (e.g. tilapia, cascadoo)					
Mangrove oysters					
Sea moss					
Mangroves and seagrasses					
Grenada's unique (endemic) wildlife (e.g. Grenada dove, frogs)					
Grenada's unique (endemic) plant life					
Timber					
Medicinal plants (for health, restorative, curative, etc) (e.g. moringa, ginger)					
Pollinators (unmanaged areas) e.g bees, bats					
Pollinators (for agricultural crops) e.g, bees, bats					
Hunted wildlife					
Timber (e.g mahogany, cedar, teak, pine, bamboo)					
Grenada Spices					
Grenada Rum					

	none	low	medium	high	critical
Tree crops (e.g. cocoa, nutmeg, soursop)					
Spice tree crops (e.g. black pepper, cinnamon, tonka bean)					
Root crops (e.g. cassava, tannia, sweet potato)					
Non tree crops (e.g. corn, peas, cucumber, etc)					
Horticultural / ornamental plants					
Fruit trees					
Livestock (e.g. chicken, goats, cattle)					

* 21. This question probes the cultural and social value of different species e.g. traditional use, medicinal remedies, religious purposes, etc.

How important are the following species to cultural and social values like those mentioned above.

	none	low	medium	high	critical
Marine fisheries- pelagic (e.g. tuna)					
Non-reef fisheries (shallow/coastal fisheries)					
Reef fisheries					
Shelled fisheries (Conch, lobster)					
Sea urchins					
Sea turtles					
Whales and krill (products = whale oil, krill oil)					
Titiree					
Freshwater crayfish, shrimp, crabs					
Land crabs					
Aquaculture species (e.g. tilapia, cascadoo)					
Mangrove oysters					
Sea moss					
Mangroves and seagrasses					
Grenada's unique (endemic) wildlife (e.g. Grenada dove, frogs)					
Grenada's unique (endemic) plant life					
Timber					
Medicinal plants (for health, restorative, curative, etc) (e.g. moringa, ginger)					
Pollinators (unmanaged areas) e.g bees, bats					
Pollinators (for agricultural crops) e.g bees, bats					
Hunted wildlife					
Timber (e.g mahogany, cedar, teak, pine, bamboo)					
Grenada spices					
Grenada rum					
Tree crops (e.g. cocoa, nutmeg, soursop)					
Spice tree crops (e.g. black pepper, cinnamon, tonka bean)					

	none	low	medium	high	critical
Root crops (e.g. cassava, tannia, sweet potato)					
Non-tree crops (e.g. corn, peas, cucumber, etc)					
Horticultural / ornamental plants					
Fruit trees					
Livestock (e.g. chicken, goats, cattle)					

Appendix 4. Coastal and offshore marine ecosystems – DPSIR table

Ecosystem	Service/ Function	Pressure	State	Impact	Resilience
Sandy beach, rocky shore, dune	Coastal protection – buffering against storm waves and surge Important nesting habitat for sea turtles Important habitat for invertebrates Tourism resource Recreation Supports littoral forests Limited use in water filtration systems by NAWASA due to grain size Previously used as building material; limited beach sand exploitation (Dan Gavriletea, 2017); likely illegal and unregulated usage is ongoing (Birchenough, 2017) Provides important storage/landing areas for boats for fishers	Natural shoreline movement (i.e., natural erosion and accretion phases Decline in coral reef health Human interference with natural coastal processes (e.g. coastal engineering structures and beach sand mining) Climate change impacts, including SLR and increases in the magnitude and frequency of storms and hurricanes Restricted room to migrate inland due to permanent developments	Cambers (2009) details around 15 years of beach profiling data for Grenada to document coastal changes and beach erosion. One of the observations of that study was that 75% of beaches in Grenada are showing erosion, mainly from anthropogenic stresses such as sand mining and climate change. Andrews (2018) reviewed the past beach profiling done in Grenada. The study indicated that based on the existing beach profiling data there are persistent erosion trends on the west and south coasts. The north coast trends indicate a shift from accretion to erosion of sediment and the east coast trends show the opposite. Grenada's Sediment Transport Study conducted coastal modelling and compiled all available beach profiling data to better understand the movement of sediment related to the beaches and coastlines.	Increased coastal erosion Loss of coastal protection buffers Loss of ecotourism opportunities Loss of recreational and cultural use Loss of turtle nesting sites	Grenada passed an ICZM Coastal Policy and Legislation in 2016. The new legislation attempts to regulate beach sand mining. It also calls for the development of a coastal zone management plan. Such a plan would be instrumental in management of the entire coastline of the tri-island state and would be a major step in coastal planning for Grenada. This would allow for understanding of the sediment processes within individual coastal cells which influence the formation of beaches. It could also inform coastal setbacks which consider future SLR and better inform both EbA and hard engineering interventions. In the region, Barbados developed a coastal zone management plan and has developed extensive local capacity for management of the coast. Elsewhere, the Seychelles have also recently developed a coastal zone management plan with assistance from the World Bank with a specific focus on erosion mitigation (World Bank, 2019). Caribbean Ocean and Aquaculture Sustainability Facility (COAST) parametric insurance for fishers may help to provide reimbursement for lost fishing effort following storm surge and other related storm events which can affect landing sites and boat storage. This enhances community resilience to the effects of climate change.

Ecosystem	Service/ Function	Pressure	State	Impact	Resilience
Mudflat, estuary, salt pond, coastal aquifer	Important habitat and refuge for marine and freshwater species. Species of fish may spawn in estuaries Important birding habitat Estuaries are harvesting sites for important fish species such as the Sicydium plumieri (Titiree) Estuaries are popular recreation areas for swimming Source of freshwater Historically salt ponds were harvested for salt (e.g. ponds near Maurice Bishop Airport)	Land-based sources of pollution Coastal development (e.g. in areas with mudflats and salt ponds) SLR and saltwater infiltration Shifts of species to other habitat types (regarding mudflats)	Limited information available Grenada has 71 watersheds, each of which has a river that ends in a lagoon as it flows into the sea (Government of Grenada, 2014a). Estuaries help in regulating the flow of water and nutrients into the marine environment and provide tremendous opportunities for ecotourism and education (GoG, 2017a) Potential to use spatial analyses to identify and quantify locations, especially estuaries. Some areas such as mudflats may overlap with mangrove areas. Limited number of salt ponds including Saline Island, La Sagesse and salt ponds located in Point Salines. Coastal aquifers maintained by NAWASA. May be vulnerable to saltwater infiltration which will be exacerbated by SLR	Loss/gain in commercial fisheries income Loss of ecotourism opportunities Loss of recreation areas as estuaries are popular swimming areas Decreased wetland area and biodiversity Reduction in quality of groundwater sources	Most of these ecosystems are understudied and little is known about their status. Many are vulnerable to changes in SLR which can affect the chemical composition of salt ponds and coastal aquifers. Many are important sources and/or sinks for coastal sediment. Important mudflat areas such as in Mt. Hartman are important sites for birders, which can be a separate ecotourism product

Ecosystem	Service/ Function	Pressure	State	Impact	Resilience
Mangrove/ coastal forest	Mangrove species are important biodiversity hotspots for birds and act as important nursery habitat for juvenile fish species, including those of commercial importance. Red mangroves are important in buffering the coastline against storm surge and coastal erosion. Carbon sequestration Harvesting of species such as crabs Mangroves are used in charcoal production and for agricultural purposes (e.g. stakes)	Coastal development Unsustainable harvesting practices Hurricanes Storm surge SLR Storm damage (wind) Deforestation Litter/Pollution	Although there has been natural growth and recovery of mangroves, including after storms like Hurricane Ivan, overall mangrove cover has declined (Buckmire et al.2022) Centre for Environment, Fisheries and Aquaculture Science (CEFAS) is currently conducting a Blue Carbon Assessment to assess carbon sequestration UNDESA (2012) notes the importance of littoral forests in stabilising shorelines in sandy areas. These forests, which include trees like almonds and seagrapes, also reduce storm damage and surface runoff from inland areas.	Loss/gain in commercial fisheries income Loss of informal rural income (e.g. crabs) Increased coastal erosion Loss of coastal protection buffer Loss of ecotourism opportunities Decreased wetland area and biodiversity	A wetland management policy with strong legislation could give protection to both mudflat and mangrove areas. Grenada has one RAMSAR site but there is no overall management or protection of wetlands. The new ICZM legislation makes it a penalty to remove coastal vegetation, but management capacity and enforcement are lacking. Strong planning legislation/regulations are needed which speak to the EIA process and the assessment of mangroves and the impacts proposed developments may have on them, especially in the face of climate change Grenada has examples of successful mangrove restoration in the south of the country as well as co-management restoration pilot projects in the northeast. In Carriacou, mangrove restoration has been ongoing in the Petite Carenage area. Many of these projects focus on red mangroves due to the relative ease that they can be propagated. Developing capacity to propagate white and black species will also be important. Recent coastal and terrestrial LiDAR surveys conducted in Grenada in 2016/2017 provides an important dataset on mangrove spatial cover. This could be augmented by regular surveys with drones. Some ecotourism businesses focus closely on tours through mangroves, such as Conservation Kayak.

Ecosystem	Service/ Function	Pressure	State	Impact	Resilience
Seagrass	Primary producers Important nitrogen fixers Providing habitats, feeding, breeding, recruitment sites and nursery grounds for juvenile and adult reef organisms Reducing sediment movement in nearshore waters Removing sediments from the water column, decreasing turbidity of the water Stabilizing the coastline Carbon sequestration	Nutrient loading and increased turbidity from agricultural runoff, land clearance, construction, sewage disposal and trawling (Aucoin, 2013) SST increases SLR Storm damage Sand mining Sedimentation Ocean acidification	According to Eagleson, (2019), Grenada houses 29km^2 of seagrasses Aucoin (2013), lists these as turtle grass (*Thalassia testudinum*), manatee grass (*Syringodium filiforme*), shoal grass (*Halodule wrighti*), paddle grass (*Halophila decipiens*), halophila seagrass (*Halophila stipulacea*) and cover grass (*Halophila baillonii*). *H. stipulacea* is a more recent invasive seagrass which has been displacing native seagrass. Estimates of cover seem uncertain but GIS data may be used to help quantify. CEFAS is currently conducting a Blue Carbon Assessment to assess carbon sequestration (draft submitted for publication) Recent bathymetric data developed by the UK Hydrographic Office (UKHO) provides an indication of recent nearshore seagrass coverage in Grenada. TNC also developed benthic habitat maps in 2017.	Loss/gain in commercial fisheries income Increased coastal erosion Loss of coastal protection Buffer Loss of ecotourism opportunities Increased coastal erosion "Key economic sectors such as fisheries and dive tourism will likely suffer losses if seagrass ecosystems are degraded" (Simpson *et al.*, 2012) Loss of marine biodiversity	Recent studies have been conducted in Carriacou which focus on invasive seagrass species *H. stipulacea*. It will be important to improve island-wide monitoring to understand how this species may be outcompeting other native species in Grenada. The potential for seagrass to provide carbon sequestration benefits are promising and large amounts of seagrass beds still appear to be intact. Increasing capacity to monitor stocks to account for this will be important as well as investigating carbon trading mechanisms and other financial incentives which can incentivise keeping seagrass beds intact. Seagrasses are important habitat for the commercially important conch and local market for sea urchins. Linking the importance of these species to this ecosystem will be important for long term protection and management of seagrass. MPA establishment and enforcement will be an important tool to protect seagrass. Larger MPAs such as the proposed southeast corridor in the Protected Area Systems Plan would help conserve a large area of seagrass. Pilot studies focusing on seagrass restoration, especially native species would be a benefit Grenada has four legally established MPAs which offer some level of protection to coral and seagrass species.

Ecosystem	Service/ Function	Pressure	State	Impact	Resilience
Coral	Coastal protection Primary producer (zooxanthellae) Important habitat for reef fish and other important organisms Production of sand Dive ecotourism Historically used to produce 'lime' for building material On a small scale informally harvested for jewellery	Nutrient loading and increased turbidity from agricultural runoff, land clearance, construction, sewage disposal and trawling (Aucoin, 2013) SST increases – associated with coral bleaching events SLR Ocean acidification Yacht and anchor damage Coral harvesting Physical damage Disease Algal Overgrowth Sedimentation Storm damage Invasive species e.g. Lionfish Overfishing – e.g. of sea urchins and parrotfish Sandmining	GoG (2017a) noted that Grenada has experienced significant coral loss and the majority of the remaining reef systems are moderately stressed	Loss/gain in commercial fisheries income Increased coastal erosion Loss of coastal protection Buffer Loss of ecotourism opportunities Increased coastal erosion Key economic sectors such as fisheries and dive tourism will likely suffer losses if seagrass ecosystems are degraded (Simpson *et al.*, 2012) Loss of marine biodiversity	There have been multiple examples of coral restoration in Grenada. These include the UNEP EbA pilot project in Grand Anse and Carriacou (2015-2016), which focused on staghorn and elkhorn species using trained community members to propagate and maintain the corals using different methods. These include using both tree and table structures to grow corals. Biorock technology has been used to establish coral propagules in the Gouyave area (Global Coral Reef Alliance, 2018). This technology has been used in the Pacific and Jamaica and uses electrolysis to accrete calcium carbonate onto a cathode which is linked to a metal structure. The resulting surface provides a substrate for the attachment of corals which also seem to benefit from increased oxygen levels. This may help to mitigate future water quality issues under future climate regimes. In 2013 in the Grand Anse area, small concrete pyramids were constructed by a local dive shop; this has shown accretion of corals and increased fish habitat in the shallow nearshore area. In Grenville, a hybrid reef structure is being piloted by The Nature Conservancy (TNC) to enhance the coastal protection in the Bay. Small numbers of corals have been planted onto pyramid structures constructed of a coated rebar mesh which encloses either concrete or quarry rocks. These different methods should be monitored to gauge short to medium survival rates of coral species. Also, it will be important to understand which methods are most suited to particular species

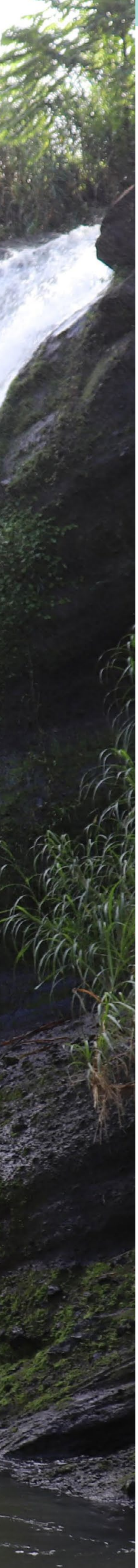
Ecosystem	Service/ Function	Pressure	State	Impact	Resilience
Coral					Upscaling of these initiatives and technologies will be important for Grenada as well as building local capacity for conducting these interventions All of these initiatives have involved in-water nurseries. The use of an on-land facility may allow for better selection of coral species which can survive different climate related stressors such as increased SST. Monitoring of pH levels related to ocean acidification in Grenada is at a very early stage. A Coral Reef Early Warning System (CREWS) buoy containing instrumentation to record parameters linked to ocean acidification was installed in the Grand Anse area. This instrument is linked to the NOAA Integrated Coral Observing Network. The installation of more stations such as this around the country would be important to gauge these conditions. TNC has produced a coral refugia dataset showing regional patterns and highlighting areas where coral resilience to the effects of climate change is likely to be strongest. These areas should be highlighted for future MPAs and research. COAST parametric insurance for fishers may help to provide reimbursement for lost fishing effort following bleaching events.

Ecosystem	Service/ Function	Pressure	State	Impact	Resilience
Sargassum	Can be composted for fertiliser if tested for heavy metals prior to use Houses unique species and may also act as floating refuge for species	Land based sources of pollution SST increases Nutrient loading Ocean acidification may impact Sargassum invertebrate communities	Limited data available News articles can be used to gauge incidence of Sargassum washing up on beaches Some economic estimates of cost from Ministry to remove Sargassum An updated draft of the Sargassum Adaptive Management Strategy was developed for Grenada in 2023, which contains some information (Centre for Resource Management and Environmental Studies [CERMES], 2023) In a study completed by the Japan International Cooperation Agency (2019) and areas listed in the Sargassum management strategy the primary locations where Sargassum has been accumulating in Grenada are Grenville, Bathway, Marquis, Soubise, Woburn, Petit Bacaye, Conference Bay and Sauteurs.	Loss/gain in commercial fisheries income (related to damage to vessel engines, hampering and entanglement of fishing equipment) Some commercial species may be affected–based on 2015 observations Can hamper seamoss production Impacts on human health (H_2S emissions) High cost to remove Sargassum from beaches Impacts on beach erosion–if heavy machinery is used to remove Impacts on turtles and other animals which are entangled Impacts on turtle nesting	Grenada has developed a draft Sargassum management strategy. This should be approved and implemented to manage Sargassum events in a more sustainable manner. Previous attempts to remove Sargassum from the beaches on the eastern side of Grenada (e.g. 2018) used heavy machinery which resulted in removal of beach sand and negative consequences to the beach, at a high financial cost. COAST parametric insurance for fishers can help to provide reimbursement for lost fishing effort following Sargassum events. Better monitoring of Sargassum on a regional level may help to predict events SST monitoring may assist with coral bleaching monitoring and prediction as well as Sargassum

Ecosystem	Service/ Function	Pressure	State	Impact	Resilience
Sargassum				Potential benefits to beach accretion if left on beaches Negative effects on human health Negative impacts on tourism Can be associated with eutrophication and fish kills Can introduce invasive species	
Offshore islands	Natural barrier against offshore waves e.g. islands off Bathway, Levera, Petite Bacaye, St. Andrews Bay, L'Esterre Bay Often near pristine – multiple ecosystems in one place Important nesting and breeding grounds for birds and turtles Many areas associated with pristine dive locations e.g. Isle de Rhone, The Sisters Cultural use – whaling sites in the past Used for hunting of birds and other animals by local persons Many offshore islands have little permanent human presence meaning less disturbance for wildlife	Invasive species – e.g. rats and goats Lack of coastal access to the public on private islands Coastal development Lack of protection/ management (Proposed Levera MPA aims to protect three offshore islands). Sugar Loaf Island is included as part of the Ramsar area. Sandy Island in Carriacou is also within the MPA area). Isle de Rhode and Southern Carriacou islands are proposed as future MPAs. Deforestation Temperature increases Storm surge SLR Drought	Limited information Studies done on invasive species GIS Maps can show locations Data showing bird usage – Environmental Protection in the Caribbean (EPIC). Monitoring data shows the importance of these islands as bird nesting habitat.	Loss of ecotourism opportunities Loss of biodiversity hotspots Loss of recreational and cultural use	Special designation should be given to these islands as internationally important bird habitat More emphasis could be placed on designation of large, offshore MPAs that can encompass some of these areas. The Isle de Rhone MPA may be an example as well as the proposals to merge the Levera and the Isle de Rhone MPAs. An additional opportunity may be to create an MPA encompassing the Kick-'em-Jenny exclusion area which is already restricted in terms of marine transportation The coral refugia data shows many areas in close vicinity to these islands as being important for coral resilience

Ecosystem	Service/ Function	Pressure	State	Impact	Resilience
Plankton	Base of food web Supports commercial fisheries Carbon sequestration/ Sink of CO_2 Emits dimethyl-sulfoniopropionate (needed for cloud formation)	Change in food resources for commercial fisheries SST increases Ocean acidification	Limited information International research vessels may have collected data	Loss/gain in commercial fisheries income Loss of light penetration Loss/gain food resources	Monitoring of SST and pH levels could give a better understanding of the potential impact to these organisms. Upscaling of initiatives such as CREWS could assist with this. International research vessels may be an important source of information
Pelagic/ open ocean fish	Basis of commercial fisheries and subsistence livelihoods Source of protein for locals Food source for marine mammals	SST increases Ocean acidification Changes in ocean currents	Studies conducted on commercial species—reduced Scad and tuna landings reported	Reduction in biodiversity (reduced abundance, shift in distribution and disruption of reproductive cycles) Loss in commercial and subsistence fisheries income Loss of food resources	Focus on large scale offshore MPAs could help to conserve marine areas for stocks MPA boundaries that can change/are seasonal to protect moving stocks could be an option e.g. southeast coast of Grenada at certain times of year Better monitoring and management of fishing methods such as Fish Aggregating Devices (FADs), trawling, long lining and national/international fishing vessels operating in Grenada's EEZ could assist with more data and information Development of a Caribbean wide certification scheme could help to certify catches with sustainable methods which reduce bycatch and prevent ecological damage
Coastal and marine megafauna	Cycling of nutrients (e.g. whale pump) Contributors to the top of the food web as both predators and prey Ecotourism: whale watching, sighting of large species such as sharks, manta rays and whale sharks during scuba diving	Commercial fisheries Climate change altering pineal responses (affecting migration and feeding)	Sea turtle populations under threat from illegal harvesting of adults and eggs during the closed season (Bräutigam and Eckert, 2006) Limited data on shark and manta ray populations	Loss of biodiversity Migration and reproductive cycles out of sync with food supplies	Potential for submarine ecotourism to promote the importance of these species, using examples from countries such as Barbados Ecotourism opportunities linked to these species could be upscaled/further investigated

Concord Waterfall, St. Johns, Grenada
Photo credit: Natalie Boodram



4. Towards the valuation of the genetic and ecosystem resources within Grenada

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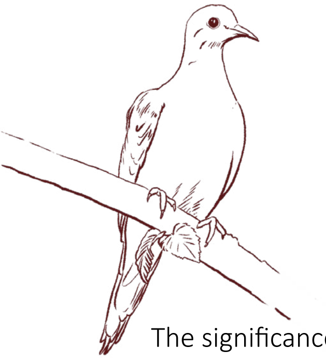

Summary

The significance of island biodiversity and associated marine biodiversity has been well recognised with over half of the tropical marine biodiversity found around islands (Olson and Dinerstein, 1998; Marin *et al.*, 2004). In addition, indigenous island cultural peculiarities are closely linked with nature and have, in many instances, enabled locals to sustainably manage valuable natural resources. The positive impact of policies and management approaches to managing ecosystems are always greatly enhanced when the relationship between people and nature in its local context are carefully considered, and how these can be used to lessen the negative impacts of anthropometric lifestyles and activities on ecosystems (Chan *et al.*, 2016). This is particularly crucial for island populations that often host lower levels of genetic diversity and higher levels of differentiation when compared with the mainland (Frankham, 1997). This puts species on islands such as Grenada at increased risk of extinction, especially given the likelihood of greater environmental and demographic stochasticity.

This chapter provides an overview of the process and mechanistic tool of ecosystem valuation, defining it, and where possible, providing conservative values. These are then used to demonstrate how Grenada's marine, terrestrial, agricultural, and genetic resources contribute to human well-being and quality of life by examining the instrumental, intrinsic, and relational values of these ecosystems. Lastly, this chapter assesses several emerging threats and issues based on a Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis.

Important conclusions and findings from this chapter are as follows.

Grenada's nature, that is its ecosystems, products and services it provides constitutes an essential part of the country's identity beyond the economic contribution these systems provide, particularly as it relates to food products and aesthetic beauty. Grenada's byname as the 'spice isle' reflects the vibrance and importance of its agriculture and is built upon the health and functioning of agricultural as well as forest and aquatic ecosystems. While tourism holds a significant importance to the Grenadian economy, other economic activities that are reliant on the island's ecosystems (commercial/recreational fishing, backyard/subsistence/commercial agriculture) arguably play a more important role in what it means to be 'Grenadian' and thus have important relational values well beyond the income and foreign exchange earned.

The economically-critical industry of tourism relies on healthy and unique aesthetic beauty of ecosystems, which are largely impossible to substitute with manmade alternatives. Natural capital assets such as beaches, waterfalls and forests are the primary draw of international tourists to Grenada, and replacing these assets with human-built alternatives would likely not be able to provide a similar economic benefit in scale. Charismatic and notable examples of important natural capital assets to tourism include the Grand Etang Lake, which generated a total revenue of US$585,613.17 in user fees and private tours between 2016 and 2020. Unfortunately, limited data on the indirect economic benefits generated by ecosystem-based tourism in Grenada (taxi/transportation fees, restaurant income, craft sales) under-estimates the true economic values of this ecosystem.

Recreation within natural environments continues to grow in importance to Grenadian people and is linked to providing mental and physical health benefits. Beyond international tourism, domestic tourism and recreation at beaches, rivers, waterfalls and activities within natural areas such as walking, hiking, and swimming have always been a part of Grenadians' relationship with the environment. In particular, morning 'sea baths' are thought to have significant mental and physical health benefits and are routinely practiced by many Grenadians. Prior to and following the global pandemic, there has been an increase in recreational activities in natural environments, particularly hiking and terrestrial recreation indicated by the proliferation of hiking groups and domestic social media accounts focused on content in the

natural environment. This reflects an increasing importance of relational values for Grenadians and potential demand for conservation of these natural resources from the indigenous population.

Grenada's terrestrial ecosystems are essential to the provision of freshwater, and in the face of increasing water demand due to economic growth and increasing rainfall unpredictability due to climate change, these water provisioning services will only become more important with time. Approximately US$23,986,622.54 of value in water supplies is generated every year by natural water resources. This estimate reflects market prices paid for water and likely under-estimates the total value of water to human well-being in Grenada. Recognising this importance of the water supply and the increasing threats to it in the form of climate change, the preserving of these watersheds will be critical to long term well-being, especially given the very high economic costs associated with water production alternatives such as desalination and importation.

Although there is a pressing need for further research, current evidence indicates that Grenada's genetic resources are extremely valuable and require protection. Bioprospecting or the exploration of biodiversity for new biological resources of social and economic value already occurs in Grenada. The presence of numerous herbal/bush medicines and remedies can lead to the identification of substances which have significant commercial value. The implications of having a strong genetic asset base should be considered in the context of the *Nagoya Protocol* and rules related to Access and Benefit-Sharing (ABS) implemented.

The genetic diversity of agricultural products is a major Grenadian asset which generates significant income but has the potential to generate much more. High quality cocoa and spice products are dependent on local agricultural and varietal diversity unique to Grenada. The example of soursop should be noted, as between 2012 and 2017, the export value of soursop grew over 20 times to US$2.67 million. This may prove true of many other underutilised agricultural products currently from Grenada. The genetic pool of the species that produce agricultural products and the species that produce Non-Timber Forest Products (NTFPs) should also all be considered as having a high potential value as global interest in unique natural products grows.

Highlighting the ways in which nature contributes to people, including narratives by Grenadians on relational values, is an important pathway to improving the management of Grenada's ecosystems. Nature's Contributions to People (NCP) focuses on recognising values that are relevant to local peoples in the local language and not only in monetary terms, which usually fail to capture some of the most important values. This is particularly important for assets that are scarce in nature (due to unique habitat/geography/species diversity) and are vulnerable to environmental change.

4.1. Introduction

As has been described in Chapter 2, Grenada hosts a wide variety of ecosystems such as forests, coastal, marine (offshore islands, deep sea), freshwater, and agricultural. These ecosystems contribute in a variety of ways to the Grenadian economy and human well-being, a concept known as NCP and ecosystem services (ES). Improving the understanding of these values to the Grenadian people and incorporating them into decision making are essential for the long-term well-being of Grenada's peoples and ecosystems. This was clearly recognised by Grenadian stakeholders in the scoping phase of this National Ecosystem Assessment (NEA) and articulated in the form of two policy questions that guide this chapter:

- what are the current and projected value of marine and terrestrial ecosystems to the Grenadian economy and human well-being; and

- what is the value of the genetic resources across the different ecosystem types, in particular, the agricultural landscapes of Grenada?

With these policy questions, this chapter aims to provide an overview of Grenada's biodiversity and genetic resources, with a special focus on those flora, fauna, and indigenous ecosystems that have significant major economic, ecological, and/or social importance. It outlines how Grenada's aquatic (marine and freshwater), terrestrial, medicinal and agricultural ecosystem resources contribute to human well-being. Each ecosystem and the genetic resources embedded within them are evaluated based on their instrumental, intrinsic, and relational values, with case studies provided where possible. As tourism is one of the major industries in Grenada and is heavily reliant on the existence of healthy ecosystems, a special note is made of this. Finally, this chapter outlines important policy tools and recommendations for policy makers that can be used to improve the incorporation of ecosystem values into decision making. With its focus on genetic resources, this chapter provides opportunities and challenges for the conservation, sustainable use and benefits of sharing of resources.

4.1.1. Guiding concepts

While there are a multitude of comprehensive overviews of Grenada's relatively rich range of ecosystems, species (>2,500 species) and genetic biodiversity (Food and Agriculture Organization [FAO] 2015) a comprehensive valuation of the contribution of genetic and ecosystem resources to human well-being has not yet been formally conducted. The existing studies are limited in their coverage and there is a significant absence of data that extends beyond monetary valuations.

Recognising the importance of capturing the value of ecosystem and genetic resources, this chapter is guided primarily by the concept of NCP and utilises the values assessment approach set out by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) on how to embed the value of nature into the decision making process. Thus, within the context of the NCP framework, this chapter recognises and aims to evaluate the plural values outlined by the IPBES values assessment protocol, including instrumental, intrinsic, and relational values.

Instrumental values, sometimes perceived as 'economic' values, are the easiest to determine in monetary terms (Arias-Arévalo *et al.*, 2017) since they are often traded in the market (e.g., export data or market price). Instrumental values relate to the direct use of goods and services by people, which can either be consumptive or non-consumptive. The type of value can be estimated using a combination of approaches (IPBES , 2016): 1) the market-based approach, based on the average selling/purchasing price over multiple years, 2) the substitution cost method, based on the cost of providing potential substitutes for a good, estimated by using average import and export cost per commodity over multiple years, and 3) conservative estimates, as percentages deduced from literature, based on willingness to pay for such kind of services. One common method of instrumental valuation involves assessing market prices and the volume that has been traded.

Unlike instrumental value, intrinsic value refers to nature's value irrespective of its use to mankind (Arias-Arévalo *et al.*, 2017) and as such is often perceived as 'ecological' value. Intrinsic value is the value that ecosystems and their complexity have in themselves, outside of its 'usefulness' to humans. Many people value ecosystems simply for their diversity, wildness, beauty and wondrousness.

Lastly, relational values are the most difficult to assign monetary values, as this aspect of value is important for the community and well-being of individuals and is not traded in the market or substitutable (Himes and Muraca, 2018). Both instrumental and relational values contribute to human society and its well-being; however, the difference lies in the substitutability. For example, in the case of consumers' values of nutmeg (instrumental value) the nutmeg does not have to come from a specific landscape or specific place. In contrast, in the case of indigenous people's sense of belonging created through their livelihood, hunting or agriculture (relational values), the landscape or the place cannot be easily substituted. Definitions and examples of genetic resources and each aspect of values are summarised in Table 4.1.

Recognising the limited availability of studies and information on NCP in Grenada and the relative novelty of this concept and widespread use of ES concepts currently available in the literature, this chapter relies on data and information garnered from more 'traditional' ES and ecosystem service valuation studies. A comparison of the concepts is presented in Table 4.2.

Across this chapter, valuation and data-gathering approaches were selected by balancing the robustness needed for current decision making processes, available resources for the assessment, and the relevance of the value to current and future decisions. By and large, this assessment relied on literature reviews and value transfer approaches using primary data on ecosystem extent in Grenada. Where original ecosystem valuation studies for Grenada were conducted, the primary methods used in those studies are described.

Table 4.1. Summary of defining genetic values

Type of Value	Definition of value	Example of values	Valuation methods
Instrumental value (also termed as economic or use value)	Value that contributes to human society, e.g. to livelihoods, food security, or resilience to disasters or risks Value to which a dollar sign can be attached Value of an entity as a means to an end	Value of genetic diversity that can be used to develop new varieties of crop or medicine Value of genetic diversity that contributes to landscapes, e.g. forest that can be used for ecotourism	Cost-benefit analysis for bioprospecting Replacement cost Hedonic cost Travel cost
Intrinsic value (also termed as ecological value)	Value of nature, ecosystem, or life irrespective of human needs and wants Value that we cannot attach dollar sign to, but they are important in maintaining ecosystem function	Value of genetic diversity that contributes to maintaining the function or structure of ecosystems	Replacement cost
Relational value (also termed as cultural and social value)	Value that contributes to meaningful relations and responsibility amongst humans and between humans and nature Value that we cannot easily attach a dollar sign to but are important in maintaining human society	Value of genetic diversity that contributes to the creation and maintenance of indigenous knowledge (knowledge is passed on from one generation to another creating relationships, or knowledge is used by the practitioner to the patient)	Ethnography Participant observation Participatory mapping Art-led method

Table 4.2. Comparison of Ecosystem Services (ES) and Nature's Contributions to People (NCP) value assessment

	Ecosystem Services (ES)	Nature's Contributions to People (NCP)
Definitions	The benefits humans derive from ecosystems – the support of sustainable human well-being that ecosystems provide (Costanza *et al.*, 2014)	The contributions, both positive and negative, of living nature (diversity of organisms, ecosystems, and their associated ecological and evolutionary processes) to people's quality of life (Díaz *et al.*, 2018)
Type of values assessed	Instrumental values Intrinsic values	Relational values Instrumental values Intrinsic value

	Ecosystem Services (ES)	Nature's Contributions to People (NCP)
Unit of valuation (possibility of aggregation)	Value monism – Single monetary unit, often monetary unit, enabling values to be aggregated into one unit	Value pluralism – Plural unit of valuation, including both scientific knowledge as well as indigenous ecological knowledge; not allowing values to be aggregated into one unit
Main purpose of assessment	To convey the significance of the value of ecosystems to policy makers	To incorporate the central and pervasive role played by culture in determining our relationship with ecosystems and to incorporate indigenous ecological knowledge held by various stakeholders in the policy making process

It is important to note that not all values instrumental, intrinsic, and relational) were captured in this chapter due to a lack of information and limited access to information. Sale values of products derived from nature often do not consider production costs or other factors influencing selling and purchasing prices and behaviour (e.g., inflation, competition, supply or demand). As much as possible, information and data were solicited from local persons for traditional based local knowledge, as well as through field visits, consultations and dialogues with stakeholders. However, primary data collection was limited and outside the scope of this assessment. Thus, in order to determine a conservative value for genetic resources, the variety of species, their roles, functions and utilisations within Grenada must be understood and quantified. In this chapter, the values of selected species were used to demonstrate the extent and importance of the value of Grenada's ES and cultural and social linkages.

4.1.2. Relationship between genetic, species and ecosystem values

Genetic resources refer to "any material plants, animal, microbial or other origin containing functional unit of heredity" of actual or potential value according to Article 2 of the Convention on Biological Diversity (CBD). FAO (2019a) divides genetic resources into four categories: 1) plant, 2) animal, 3) forest, and 4) aquatic. Plant genetic resources include varieties and landraces managed on-farm, improved materials, breeding materials, accessions conserved ex situ (i.e. gene banks, or other collections), wild plants that may be related to crops (i.e. crop wild relatives) or those wild species harvested for human consumption (FAO, 2019a). Similarly, animal genetic resources can refer to genetic resources of both wildlife species as well as domesticated avian and other megafauna used for food and agriculture (FAO, 2019a). Forest genetic resources are heritable materials maintained within and among trees and other woody plant species (FAO, 2019a). Finally, aquatic genetic resources include those organisms (or parts hereof) that have the potential to provide food and agriculture for human benefits (FAO, 2019a).

As depicted in Figure 4.1, while ecosystems are massive in comparison to the area occupied, it is the genetic and species variation that increases the value of the resource. In other words, at the organismal level, genetic traits allow for the expression of different traits, where these varied traits (i.e. landraces or varieties) contribute towards the value of a resource. For example, plants can be bred for the flavour of their fruit, and animals for their ability to produce milk. In the wild, genotypic variation allows organisms to survive environmental changes. If properly managed, the potential to earn revenue at the ecosystem level as their stability and resilience against change increases. An example of such linkages is illustrated in Figure 4.2.

As described in Chapter 2, Grenada can be divided into six different types of ecosystems: 1) agriculture and agrosystems, 2) forest, 3) coastal, 4) freshwater, 5) offshore islands, and 6) deep ocean. Each of these provides a variety of provisioning, regulating, supporting and cultural services (Figure 4.3). In this chapter, however, we have opted to class coastal, deep ocean and offshore island ecosystems as marine ecosystems, whilst the remaining types (agriculture

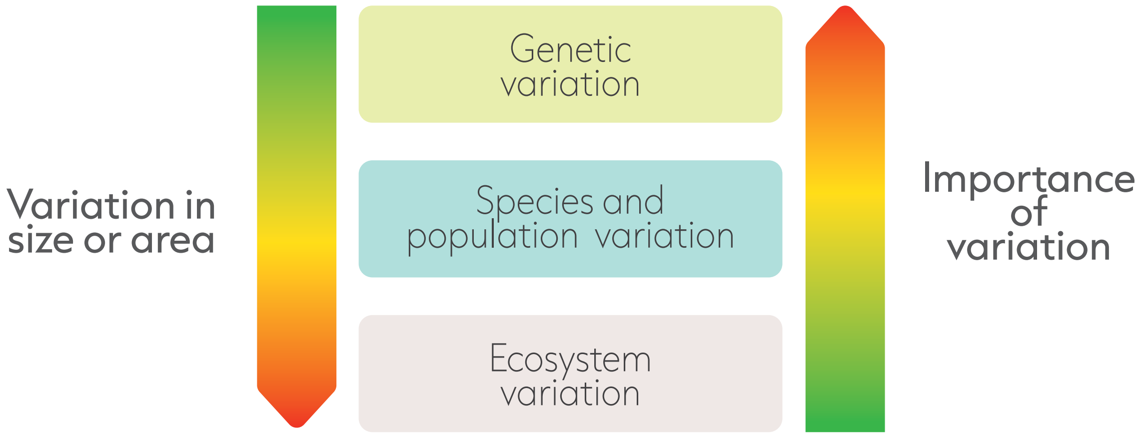

Figure 4.1. *Linkages from the micro scale (genetic and species variation) to the macroscale (communities and ecosystems)*

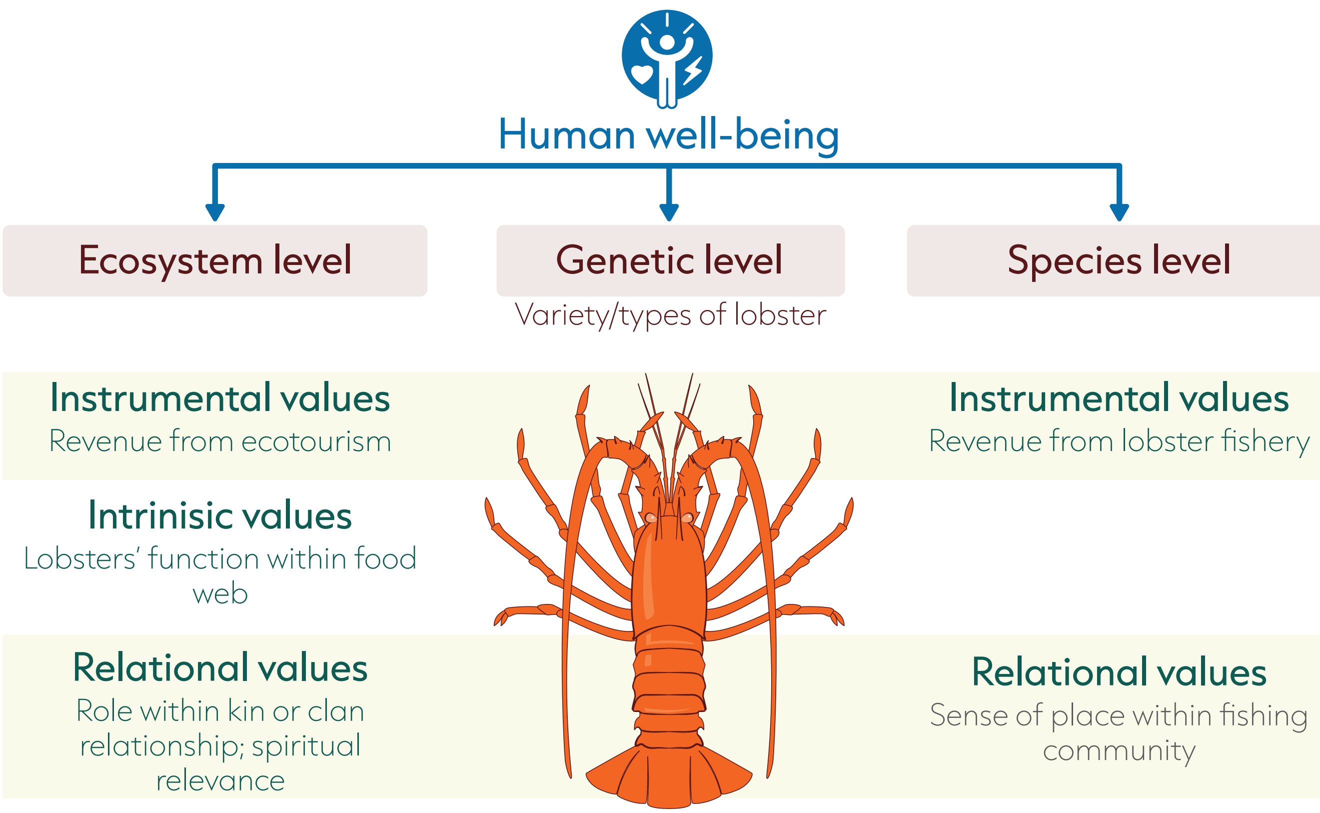

Figure 4.2. *Demonstration of genetic, species and ecosystem level value linkages*

and agrosystems, forest, and freshwater) as terrestrial ecosystems. In this chapter, the value or 'worth' of genetic/species and ecosystem resources are classified into instrumental, intrinsic, and relational values (Tables 4.1 and 4.2 on page 267) and can change based on spatiotemporal and/or sociocultural variations.

Emphasis is placed on genetic resources, both as realised and unrealised contributions by nature, to the well-being of the Grenadian people, and where appropriate to the global community. It is noted that a valuation of genetic resources contained in the tri-island state would be useful as part of a framework for implementation of the *Nagoya Protocol* on ABS. Therefore, focus on selected key species of interest and trends that could likely impact the value of the island's genetic resources is given in this chapter.

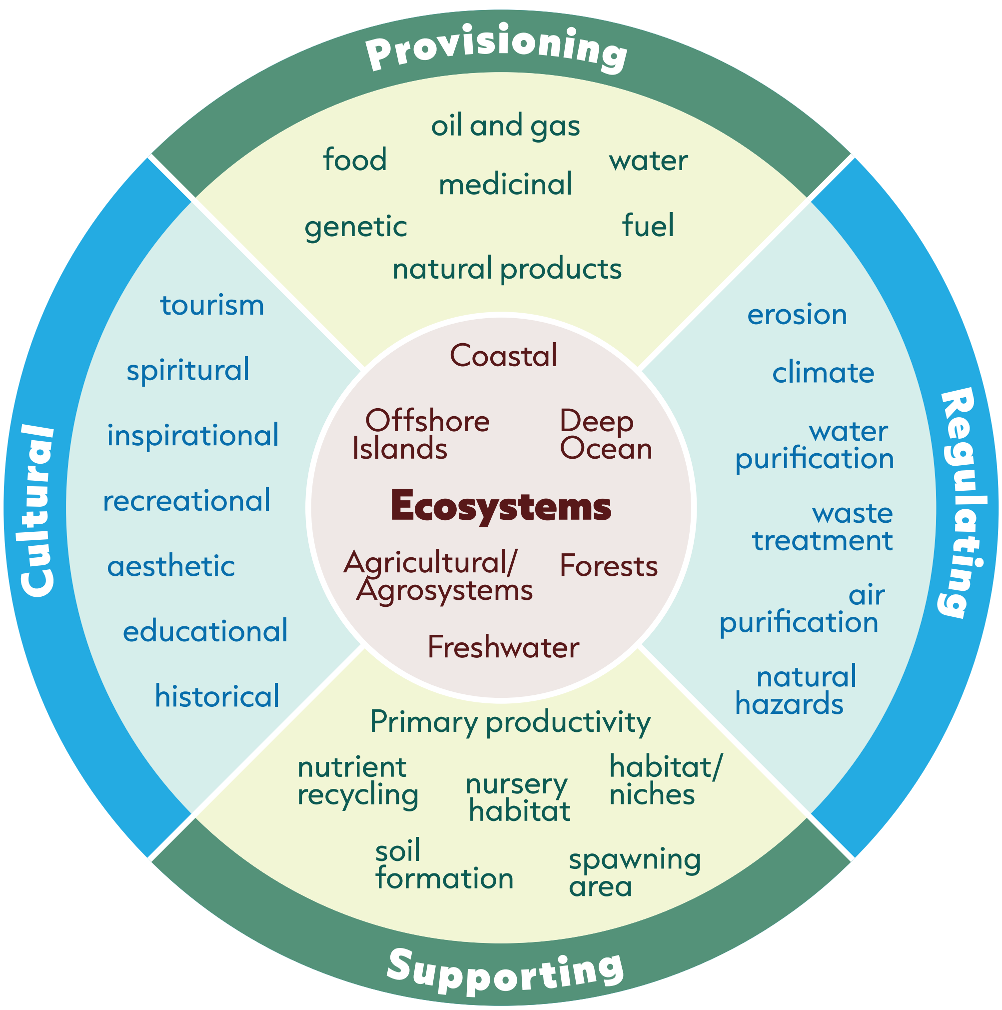

Figure 4.3. Example of services (provisioning, regulating, supporting, cultural) provided by ecosystems

4.2. Valuation of marine ecosystem resources

Marine instrumental or economic values were attained from direct sources such as data collected and collated from organisations like the Fisheries Division in Grenada, and the Fishing Cooperative. In contrast, intrinsic and relational values were anecdotal and more difficult to ascribe a monetary value, however, their contribution to the overall value of the species is nonetheless important. As in many other Caribbean islands, Grenada has a historical dependence on its marine resources, with some species having been harvested for the past five millennia like the queen conch (*Aliger gigas*) (Lawrence and Phillips, 2013). Species such as mangroves, are known for their contribution to ecosystem goods and services though this contribution has yet to be properly monetarily valued. Conservative estimates, however, can be made using existing information on select species with the understanding that similar trends may exist for the remaining species. A breakdown of emerging SWOT is provided in Appendix 1, to ensure that as many gaps are identified.

The relationships between genetic components on characters and the non-genetic responses of traits to changes in population density and environmental parameters (transboundary considerations) is complex and poorly understood (Smith, 1994). Thus, this makes it difficult to separate the genetic and non-genetic impact of fishing on natural populations. Therefore, it is important to highlight measurable values of the related species and ecosystem biodiversity. It is further essential to outline the major factors producing changes in fish stocks before making inferences of the genetic impact of fishing (Smith, 1994; Naish and Hard, 2008), which this section aims to do.

4.2.1. Marine fisheries

There is a high dependency on Grenada's marine ecosystem and thus an ensuing high economic value. Of the estimated 233 marine fish species in Grenada's marine waters (FAO, 2016) 60 pelagic, coastal and non-fish reef species were harvested over the 40-year period 1978 to 2017, representing a total of 78.7kt (kilotonnes) valued at US$681.34 million. There were four distinct time periods that shared similar harvests: 1978 to 1984, 1985 to 1994, 1995 to 2001, and 2002 to 2017 with an overall increasing trend from 1978 to 2017 (1.9kt valued at US$2 million to 2.7kt valued at US$13.81 million). The average cost per pound of fish also increased from US$0.90 (US$0.19–$2.96) in 1978, steadily increasing to US$2.22 (US$2.96–$5.10) in 2017 (Fisheries Division, 2021). This highlights the increasing revenue from marine fisheries caught in Grenada's waters over the past four decades, as well as an increasing economic or instrumental value, given the 150% increase in production compared to a nearly 700% in revenue generated.

Of all the species harvested, the yellowfin tuna (*Thunnus albacares*) accounts for 30% of the total harvest and 38% of the revenue generated during the 40-year period making this the most valuable species for this fishery based on abundance of catch, and arguably the most at risk if stocks remain unmanaged and catches unchecked. Despite representing the most abundant species caught with the greatest revenue, the yellowfin tuna has only an average value (range) of US$2.63/kg (US$1.76–$7.19) over the last 40 years, making it the 24th most expensive species/kg caught. In comparison, the Caribbean spiny lobster (*Panulirus argus*) landed the highest price per kilogramme, with an average (range) value of US$8.12/kg (US$6.47–$13.99), and a total landing of 822,727kg; a much smaller catch than the yellowfin tuna. In contrast, the false herring (*Harengula clupeola*) and Atlantic thread herring (*Opisthonema oglinum*) were the least expensive per weight, at US$0.15–$0.95/kg and US$0.42–$0.95/kg respectively.

The average value of the fisheries stock over the last four decades has increased (Figure 4.4). The yellowfin tuna was the key contributing species, based on both abundance of landing and revenue generated. Other top catch species include the blackfin tuna (*Thunnus atlanticus*), big eye scad (*Selar crumenophthalmus*),

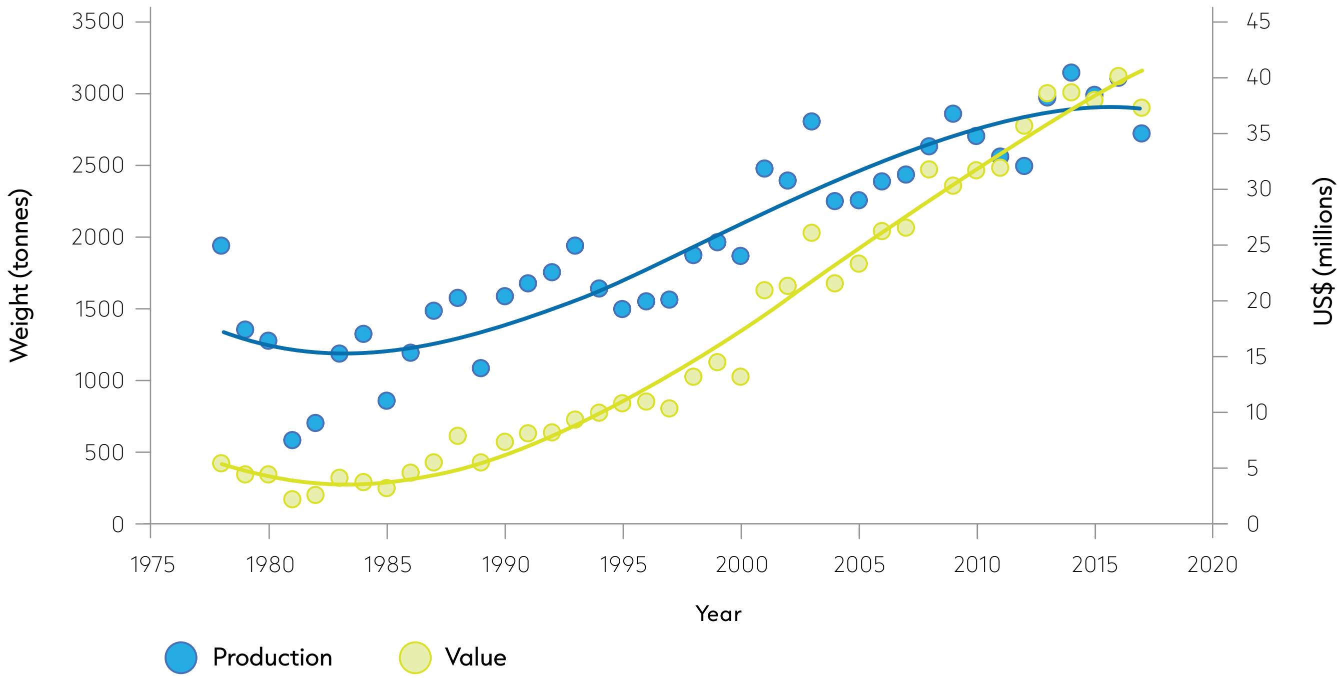

Figure 4.4. The change in value for fisheries stock in Grenada for the period 1978-2017 (Data from Fisheries Division, 2021)

round eye scad (*Decapterus tabl*), common dolphinfish (*Coryphaena hippurus*), Atlantic sailfish (*Istiophorus albicans*), redhind (*Epinephelus guttatus*), and parrotfish (Scaridae) (Appendix 2).

A total of 39 pelagic species (16.7%) were landed for production and 24 species (10.3%) for export during the period 1978 and 2017 (Fisheries Division, 2021). Of these, 19 species (8.2%) are common between the production and export fisheries (Appendix 3). Both large pelagic species (n=28 spp.) and small pelagic species (n=11 spp.) are caught with a total estimated revenue of US$204.81 million between 1978 and 2017. Grenada's export fishery is 27% of the size of the production fishery (total fish landed) (~ 3.77 million kg) bringing in approximately US$5.41 million in revenue within the same period.

Unlike the overall production fishery, the export fishery has been declining since 2015 and coincides with markedly lower catches, with price per kg varying little over the last 5-year period (2013-2017). However, in 1988 the fishery value accounted for US$2.44 million for Grenada (Tabor, 1990) representing a reduced catch compared to recent years; the average cost per kg of fish caught between 1979 and 1988 was US$4.31.

Between the period 2013 and 2017, the key species exported in order of total revenue were the yellowfin tuna, parrotfish, red hind, lobster and conch. These five species generated an estimated US$2.96 million during the same 5-year period. With the exception of the yellowfin tuna, all the export species are caught from coral reefs or nearshore marine areas. It should be noted that the total 40-year revenue generated from coral reef fisheries was second to the large pelagic species (US$41.20 million and US$188.50 million respectively). This suggests that the reef fisheries are a key revenue generator within the marine fisheries. This is largely due to the higher cost per pound given that the catch size is much smaller, such as the Caribbean spiny lobster.

Recreational fishing is also another revenue source for Grenada. Some of the species targeted in the sport fishing industry include offshore species such as marlin, tuna, and wahoo. The associated recreational values (e.g., joy for the sport, lowered stress, appreciation for the environment) are difficult to provide a monetised valuation.

Fish landing estimates are available from 10 primary landing sites in Grenada (Harvey, 2018). There are, however, 36 secondary landing sites (including beaches or bays) where no data are collected (Harvey, 2018). This affects estimates of landings and estimates of local consumption rates of important species such as sea urchins (Figure 4.5), lobster, and conch (Harvey, 2018). Overall, the landing of several species have shown declines in recent years: black fin tuna, wahoo, Atlantic bonito, snapper and conch. It is uncertain if this may be due to declining stock, effort, or target, coupled with improper wild stock management (Figure 4.6). In contrast, given the high cost per pound, landings in lobster have significantly increased over a similar period.

Grenada's fisheries sector is the largest exporter nationally, exporting high value species like tuna, lobster, and conch (The World Bank, 2019). Grenada is relatively small in size (348 km^2), but has an exclusive economic zone (EEZ) that is roughly 69 times its land area (24,153km^2) (Mohammed and Rennie, 2003). In 2016, Grenada reported that roughly 87% of its fishery exports went to the USA (mainly yellowfin tuna), with European Union coming in second, accounting for 9.8% (Van Anrooy *et al.*, 2018). The total export earnings peaked in 2016, valued at US$7.30 million earnings then declined in 2017 to US$6 million (Van Anrooy *et al.*, 2018).

A market analysis exploring the potential to increase exports of yellowfin tuna, was completed in 2018 (FAO, 2019b). This analysis indicated found that with just a proposed investment of US$362,500 into primarily the yellowfin tuna fleets, investors could earn an internal rate of return (IRR) of up to 28% (FAO, 2019b). Over a 5-year period, this would translate into an increase of fisherfolk income by US$1.1 million (FAO, 2019b). The status of this proposal is currently unknown. Finally, with no quotas having been allocated due to the historically low landings and exports and landings, this expansion if implemented may compel the International Commission for the Conservation of Atlantic Tunas (ICCAT) to implement such a quota for Grenada.

Figure 4.5. Harvesting of eggs from sea urchins in Bacolet, St. David (Photo credit: Jonathan Hanna)

4.2.2. Queen conch

The queen conch, (*Aliger gigus*) is a small-scale coastal fishery for Grenada, with the potential for decline (Figure 4.6). In 2017, close to 24 tonnes of conch (lambi) product were harvested from 90 – 105 fishers (United Nations Conference on Trade and Development [UNCTAD], 2021). Price ranges of the different conch products vary including 100% cleaned meat (US$24-66/kg) operculum (US$35/kg), US$30–$45/shell (retail), and the rare conch pearls (US$2,000 –$7,000/carat) (see Box 4.1 for more information) (UNCTAD, 2021). While there is great potential for the conch industry, there is a recommendation to suspend its trade due to non-reporting, that can lead to the risk of species depletion (Figure 4.6).

The queen conch is a marine species that also contributes towards a relational value of marine species. In Grenada, the queen conch is of

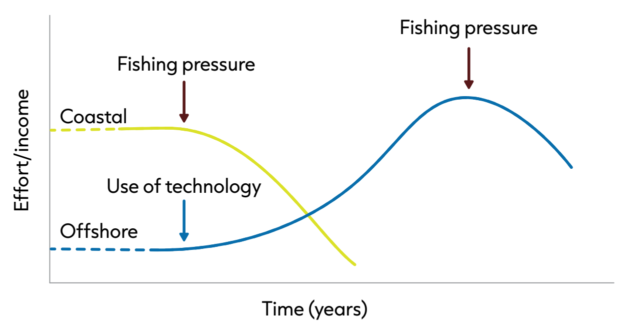

Figure 4.6. Forecasting map of the conch fishery, indicating the possible impact of fishing pressure and associated loss of biodiversity

Box 4.1. Queen Conch and CITES: Economic justification for data collection and science based management

Queen conch (*Aliger gigas*) is an important commercial species regionally and globally. Grenada, particularly in the areas surrounding Carriacou and Petite Martinique have significant habitat appropriate for queen conch, and historically are commercial harvest sites by fishers.

Between 2013 and 2017, a total of 143 tonnes of conch meat were harvested in Grenada, according to landing data (Fisheries Division, 2021). During this period, an average value of US$60,660 of dirty conch was landed annually. This is relatively low when compared to neighbouring St. Vincent and the Grenadines, which has larger but comparable queen conch habitats where their harvest was 386 tonnes, with an estimated value of US$2.96–8.89 million.

Grenada's queen conch harvest is particularly low due to multiple recommendations of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) to suspend trade which affect its legal export, and the absence of key environmental information for effective management. Through the work of the Organisation of Eastern Caribbean States (OECS), in collaboration with UNCTAD, and the Government of Grenada, funds will be allocated to address recommendations to suspend trade through science based management of the fishery. Stock assessments can then be conducted to establish maximum sustainable yields.

Efforts to maximise value extracted from the resource in a sustainable way will be supported by the development of sustainable value chains, which increase value from scientifically established quotas through the commercialization of by-products such as conch trimmings, shells and operculum, but also by seeking high value export markets for value added products.

These investments in science for effective management and regulatory compliance will assist in unlocking additional financial, economic, and social value from biodiversity. This would demonstrate the need for comparable investments in research and data management in other sectors. Fisheries stock assessments are particularly important due to the risk of biological overfishing and fisheries stock collapse.

cultural importance to the island, like many other Caribbean islands for nearly 5,000 years. Conch is used extensively by Grenadians, and is considered a delicacy. Most fishermen harvest conch using SCUBA and free diving from small wooden boats with outboard engines. The catch is landed at many landing sites throughout the island. On occasion, the fishermen save their catches in 'crawls' until ready for market (in the Grenadines) where only the meat is landed. As with oysters, the consumption of raw conch meat is considered by some as an aphrodisiac.

4.2.3. Sea urchins

Another delicacy within local coastal communities in Grenada are sea urchins (*Tripneustes ventricosus*). However, due to overfishing and poor stock management, this industry collapsed in 1994, and subsequently closed in 1995 (Nayar *et al.*, 2009). Prior to the collapse, harvesting occurred in nearshore coastal areas primarily between River Antoine to Calliste (Nayar *et al.*, 2009).

4.2.4. Sea turtles

Another important genetic marine resource are the sea turtles including leatherbacks (*Dermochelys coriacea*) (Figure 4.7), loggerheads (*Caretta caretta*), hawksbills (*Eretmochelys imbricata*), olive ridleys (*Lepidochelys olivacea*), and greens (*Chelonia mydas*). Sea turtles are hunted and poached for their shells, particularly the hawksbill turtles and greens (Grazette *et al.*, 2007). While shells are used for decorations and jewellery, their meat and eggs are also taken for consumption.

Fishing for marine turtles in Grenada has been an important activity since the island nation was first inhabited (Meylan and Mack, 1983). The eggs of all nesting species are traditionally a delicacy (Grazette *et al.*, 2007). Grazette *et al.* (2007) reported an estimated 782 sea turtles per year are caught, the majority of which were green and hawksbill turtles. Despite not being a lucrative trade, turtle meat and its products are reportedly used in some christenings, weddings or work parties (Grazette *et al.*, 2007).

Although there is a paucity of information on the value of sea turtles in Grenada, some information on turtle tours was provided by turtle tour operators on the island. In 2016, US$19,896 was generated from tours alone. A similar revenue was estimated for 2017 (US$19,764), with a slight decline by 8.5% in 2019 (US$18,072). While total tours for 2022 was unavailable, it was noted that cost of tours increased by US$10 in 2022 (Table 4.3), and therefore the anticipated revenue is expected to be higher than previously calculated. At the time when the tour operators were interviewed in 2022, 711 tours were conducted for the year, with an estimated revenue of US$18,725 thus far. In contrast, salaries for tour guides and associated staff did not vary from 2018 to 2022. Tour guides typically generate between US$37–$56/tour depending on years of experience, while tour guide trainees make US$28/night. Wardens similarly earn between US$19–$28 per night.

Table 4.3. Conservative comparison of revenue generated from sea turtles in various Caribbean islands (Godley et al. 2004)

Trade	Unit Cost (US$)
Grenada (2022)	
Tours- visitors	$30/ person
St. George's University's students	$20/person
Local	$30/person
St. Patrick	$20/person
Anguilla	
Whole turtle	$1.65–3.17/kg
Butchered turtle meat	$4.55/kg
Turtle meat (served)	$7.46–18/serving
Shell only	$4.93/kg
Scutes (from shell)	$6.58–33/kg
Egg	$0.28/egg
Jewelry	$25/bracelet
Stamps	$0.75–10 /stamp

Figure 4.7. Post-nesting leatherback in Carriacou (Photo credit: Kido Foundation)

While no information on values derived from turtles are directly available for Grenada, comparison revenue from other nearby Caribbean islands is provided in Table 4.3. Whole turtle, meat, eggs, and shell (or parts thereof) are also sold. Revenue from such in Anguilla was estimated to be US$1,350–$2,593. In the early 2000s, up to 1,801 whole turtles were estimated to be sold as well as 3,222 butchered turtles.

4.2.5. Other marine natural resources and bioprospecting

In the context of Grenada's coastal and marine ES, there is potential to utilise marine natural products (MNPs) such as bioactive compounds, in pharmaceuticals (medicinal drugs), nutraceuticals (food with health benefits), and cosmeceuticals (cosmetic products with health benefits). Secondary metabolites are frequent compounds of choice, with over 16,000 marine compounds from 15 phyla having been identified. Marine organisms such as algae, sponges and molluscs are key in the research and development of drugs. With over 2,500 marine species, natural harvest, mariculture or aquaculture, Grenada presents an untapped potential.

Although an understudied revenue for the country, Grenada already produces nutraceuticals, made from compounds such as seamoss (*Gracilaria* sp.). Seamoss farming within Grenada occurs on a small scale in areas such as La Baye, Carriacou, Isle de Ronde, and the sand-mud locations of Calliste, Conference, Pearls and Telescope. Grenadian processing facilities package and bottle seamoss products (Figure 4.8), both from local and imported harvests. While the revenue generated from this industry is currently unknown for Grenada, in 2005 the seamoss industry in Saint Lucia generated an estimated US$1 million (Lovelace, 2005). In 1986, the cost of dried seamoss was US$7.32/kg (Smith *et al.*, 1986), compared to recent times where it sells at US$88/kg. This represents an 1100% increase, indicating the potential for industry. Other seamoss revenue generating products include thickening alginates, extracts for soaps, gels, and supplement capsules, and drink products. Other marine nutraceutical products available from Grenada

Figure 4.8. Examples of nutraceutical products from seamoss (a. dried seamoss, b. soap, c. drinks, d. health supplements, e. gels) and f. whale oil

(Photo credits: a. Pure Seamoss company, b. Unknown, c. Sharine Joseph, LoopNews, d. NutreeVIt, e. Gordon Watkins and f. Aria St. Louis)

include whale and krill oil (Figure 4.8). As the case for seamoss, the revenue generated from its products is underreported, however prices in Carriacou (off-the-shelf costing in August 2021) can range between US$5.56 (small bottle ~250ml) and US$16.67 (large bottle ~750ml).

There are also lesser known Grenadian products extracted from a marine cyanobacterium, *Lyngbya majuscula*. Fatty acid amides were isolated from *L.*

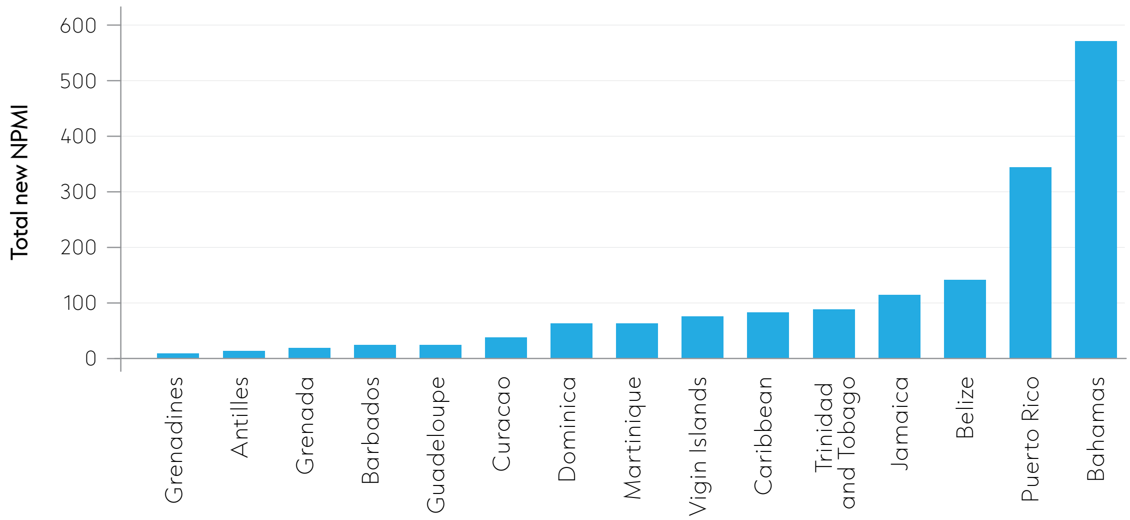

Figure 4.9. New natural products from marine invertebrates (NPMI) (MarinLit database, 2021)

majuscula, and converted into a biofertiliser called Grenamides. On record, Grenada has already 11 natural products from marine organisms (Figure 4.9). However, the revenue generated from these products is currently unreported.

Shells found on beaches as well as lionfish spines also have value for Grenadian entrepreneurs. Both are used to make a variety of jewellery such as chains, earrings and bracelets, ranging in price from US$3.70–$10.00/piece. Shells are also used to make wind chimes (US$7.41–$11.11 each), and as decorative pieces in arts and crafts.

4.2.6. Mangroves and seagrasses

Genetic resources contained within mangrove and seagrass ecosystems are extremely valuable particularly based on the provision of ecological goods and services. There are four main species of mangroves including red mangrove (*Rhizophora mangle*), black mangrove (*Avicennia germinans*), white mangrove (*Laguncularia racemosa*), and buttonwood (*Conocarpus erectus*). There are two main seagrass species including turtle grass (*Thalassia testudinum*) and manatee grass (*Syringodium filiforme*).

Mangroves and seagrasses are able to sequester carbon, nearly 40 times more than terrestrial systems. Other functions include nutrient recycling and filtration, soil retention, provision of critical habitats for feeding and breeding, and the provision of nursery areas for commercially important fish and crabs. The root systems also allow crab larvae to develop. Furthermore, mangroves are also associated with climate resilience protecting shorelines during storm and hurricane events. Mangrove species are also important sources of food for pollinating species such as bees and bats. They are also used within some communities for sources of timber, firewood, charcoal, dyes, and in some cases traditional medicine. Farming, fishing, crab hunting, bee keeping, and cattle grazing are indirect livelihoods dependent on the ES provided by the existence of healthy mangroves (Watts, 2011). Black mangroves in particular are noted for their role in charcoal production and bee keeping. Dark honey is produced from black mangroves and is valued by the community for its high quality (Watts, 2011).

Seagrasses such as *Thalassia* can provide 10L/day of oxygen and are major contributors to aquatic oxygen. Aside from this, a variety of seaweeds are also consumed. The most notable is seamoss (*Gracilaria* sp). Seamoss, which is believed to boost the immune system, contains 92 minerals and is rich in vitamins and amino acids. Besides being considered as a super food, in the Caribbean it is thought to be an aphrodisiac.

The genetic variation within mangrove and seagrass species contributes to species divergence related to physiological, morphological and/or taxonomic changes, otherwise known as phenotypic plasticity. Such changes are instrumental for resilience against climate change and disease. Although these species are considered invaluable, their value contribution to Grenada ecosystem function and services needs further research. However, Grenada has approximately 178.65ha of mangroves, and global estimates by Getzner and Islam (2020) indicate median total economic value of ES provided by mangroves, which are worth on average US$21,071/ha/year (based on 2018 prices). Scaling this median value up, Grenada receives at least US$3,764,334 in service values annually from mangroves. This value is however likely an underestimate of the economic importance of this ecosystem as this review of global studies was skewed towards countries with larger populations and higher mangrove abundance, which through scale and connectivity can reduce per hectare values.

4.2.7. Marine Protected Areas

Protected Areas (PAs) such as the Sandy Island/Oyster Bed Marine Protected Area (SIOBMPA) located on the southwest coast of Carriacou, also contribute significantly to well-being through ES. Net benefits generated by this MPA were estimated to be between US$1.07 and US$2.52 million each year (Blommestein and Associates, 2012). These benefits include direct use and indirect use values provided by the PA. What is notable is that while being protected and earmarked primarily for conservation purposes, these PAs still generate numerous and valuable net benefits.

4.2.8. Coastal protection services

Large areas of the Caribbean coast are highly susceptible to erosion, with Grenada being no exception. It is estimated that with a 1m sea level rise, and a conservative estimate of associated erosion, 49% of major tourism resorts in the Caribbean Community (CARICOM) countries would be damaged or destroyed. With projected 50m erosion, 95% of the resorts in Grenada will be at risk, with all (100%) at risk with a 100m erosion scenario. All of the sea turtle nesting sites in Grenada will be impacted with 50m erosion. With this reality, the value of coastal protection, natural hazard protection, erosion control services provided by existing coastal assets will only increase. Coastal protection services provided by coral reefs, seagrass beds and other natural protection structures are essential to the preservation of key Grenadian infrastructure. Maps of key coastal infrastructure and associated ecosystems providing protection services are provided in Chapter 2.

A recent compilation of Natural Capital Accounts for Grenada estimated the value of natural hazard protection provided by coastal reefs to be approximately US$485.47 million/yr in 2016 using a 'damage-cost avoided' valuation approach. This approach estimates the damage that would be caused by extreme event induced coastal flooding in the absence of coral reefs. Additionally, studies have indicated that the estimated cost of restoring a hectare of mangroves in Grenada to be US$14,000, while constructing similar replacements such as seawalls and artificial breakwaters cost a comparative US$3.6 million and US$17.8 million respectively per hectare (Beck *et al.*, 2020). Globally, seagrass beds are even less understood than mangroves yet are thought to be equally important in ES provision.

4.2.9. Recreation services

Beaches, bays, coves, coral reefs, seagrasses and mangroves are all essential assets to traditional livelihoods and national tourism and associated cultural expressions. An attractive tourism product (Figure 4.10) relies on healthy functioning marine ecosystems and yet has significant impacts on these very ecosystems. Pre-pandemic, 2019 tourism represented 10.3% of Grenada's Gross Domestic Product (GDP) and 40.7% of employment, whereby Grenada receives close to 500,000 tourists annually (close to 4.5 times its population) (UNDP, 2022).

The majority of Grenada's major resorts are coastal and rely on coastal amenities such as beaches, and their associated regulating services (e.g. coastal protection; see also Figure 4.3 on page 270). Additionally, the importance of tourism to the Grenadian economy is highlighted where travel tourism (import) accounts for approximately 10% of total trade in services and as an export, up to 2019, accounted for approximately 90% of total trade in services. Imports of trade in services are mainly accounted for by business services, transportation and financial services. During the 2019-2020 periods, due to the onset of the COVID-19 pandemic, these figures were reduced to 3% (imports) and 51% (exports). This highlights the importance/value of trade in travel as an export commodity of Grenada.

Amongst coastal ecosystems, coral reefs play a particularly charismatic and important role to Grenadian tourism, as coral reefs attract visitors who come to Grenada specifically for snorkelling, diving and boating activities directly related to these ecosystems. These tourists spend significant funds in accommodation, dive certification, equipment rental, boat rental and guide fees. Mitchell (2010) estimated the total value of coral reef associated tourism along the south coast of Grenada to be approximately US$20,112,457 per year. This figure is believed to be an underestimate of the overall value of these reefs, largely due to the lack of necessary data to conduct extensive valuations. This estimate produced a value of US$2,600 per hectare of coral reefs in Grenada that could be used as a conservative estimate to value other Grenadian reefs.

It should be noted, that while not as important in a direct way to the Grenadian tourism product as coral reefs, seagrass beds and mangroves play a critical role in supporting the functioning of coastal ecosystems and thus associated tourism activities. Mangroves and seagrasses are critical to maintaining water quality through nutrient cycling and sediment retention and control. Further, these ecosystems play an important role in local sediment cycles, enabling the maintenance of numerous beaches that are fundamental to local and touristic recreation.

The world's coastal ecosystems, and the people who depend upon them, are at risk due to global scale threats. These global level factors are largely

Figure 4.10. Tourists at Grand Anse Bay (Photo credit: Natalie Boodram)

beyond the control of island nations like Grenada. Top threats include hurricanes that damage reefs and threaten coastal residents and coral bleaching caused by increasing sea surface temperatures and ocean acidification. This is compounded by the fact that coastal ecosystems also are threatened by local factors, including overfishing, disease and predators, pollution, eutrophication, sedimentation, and de-oxygenation. Countries that rely on key coastal resources have three primary options to deal with the impacts of these global threats: 1) reduce other environmental stressors that can make these problems worse, 2) adapt to a world with greatly diminished genetic and ecological diversity, and 3) push to reduce carbon emissions that cause both climate change and ocean acidification (Pendleton *et al.*, 2016). Given that the majority of respondents from stakeholder perception survey (conducted in 2021 by Grenada NEA authors) supported a medium-high importance of intrinsic and relational value for a range of ecosystems and species (Figure 4.11) it is important that Grenada reduces these impacts in order to preserve or improve their natural marine resource values. More details of the *Perception of Ecosystem and Ecosystem Services* survey are available in Box 3.2 and Appendix 3 of Chapter 3.

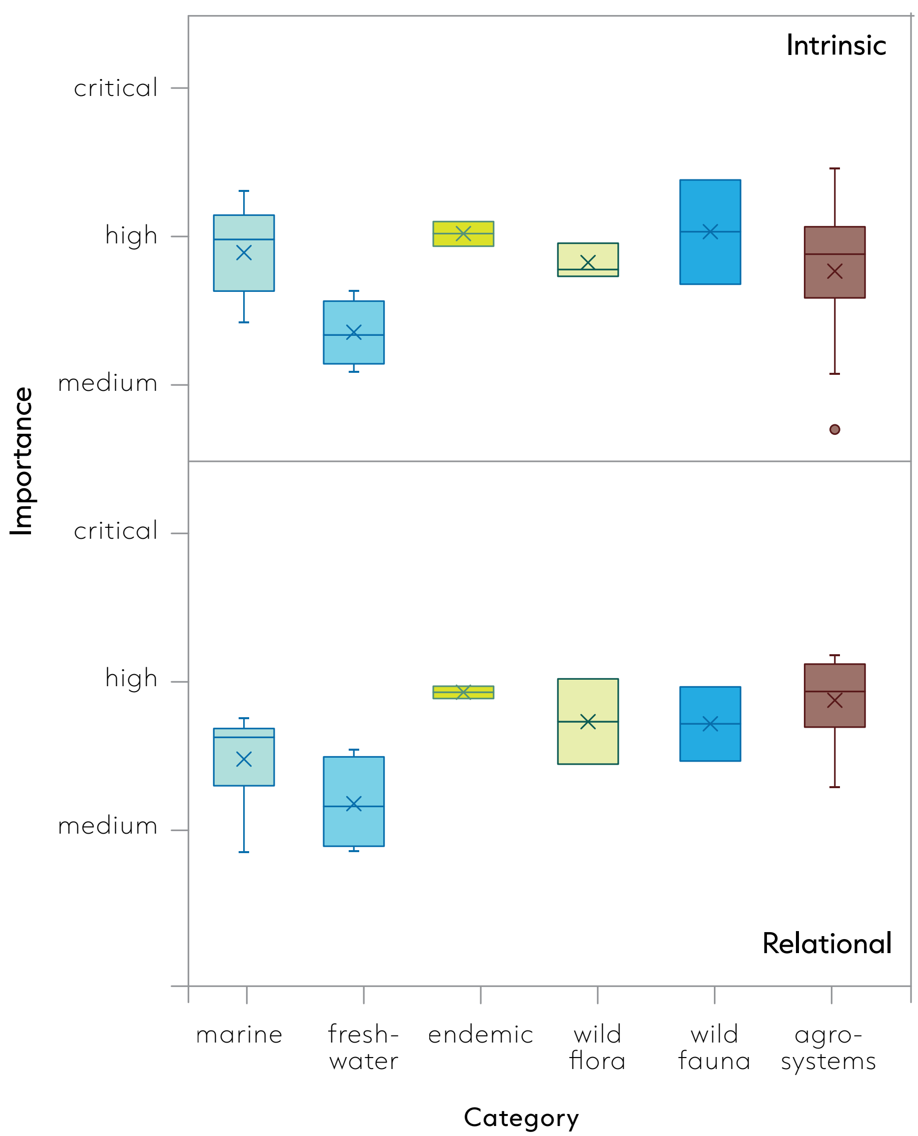

Figure 4.11. Boxplot of results from a survey conducted by NEA authors on Grenadian residents' perception of the importance of various resources, based on intrinsic and relational values (see Chapter 3 for more information on the survey).

4.3. Valuation of terrestrial ecosystem resources

4.3.1. Freshwater

In Grenada, there are 71 watersheds and several lakes and ponds which support a wide range of invertebrate and vertebrate species (Appendix 4). Unlike marine species, there is minimal direct value (instrumental) data currently available for freshwater species. However, several organisms within Grenada's freshwater systems have been identified as having either a direct contribution to livelihoods (instrumental), ecological (intrinsic), or cultural (relational) value. Much of the measurable genetic value for freshwater organisms are associated with trade, ecotourism, and the potential for bioprospecting.

According to FAO (2016), not many studies have been done on the population dynamics of freshwater species. Besides a wide variety of under defined invertebrates, such as snails, shrimp and insects, there are 17 known or described species on Grenada's main island. These include fish such as crevalle jack (*Caranx hippos*), mullet (*Dajaus monticola*), tilapia, guppy, sword tail, zandomay (*Eleotris* sp.), yoca (*Synbranchus marmoratus*), titiree (*Sicydium punctatum* and *S. antillarum*) as well as crayfish (*Macrobrachium* spp.), and river coco (*Centropomus ensiferus*). Although not much is known, there seems to be some level of indication that these populations are declining (FAO, 2016). Given the limited information available, specific species will be discussed from instrumental, intrinsic and relational perspectives.

Titiree

One of the best examples of freshwater instrumental value is the local artisanal Titiree industry, sometimes known as Tri Tri. Titiree are early larvae of a goby species complex composed of *S. punctatum* and *S. antillarum* (Bell *et al.*, 1994). These goby species are diadromous, where part of their life cycle is in marine environment, and other part in freshwater environment such as river mouths. In Grenada, Titiree is harvested from goby nests at river mouths on both the eastern and western side of the island, in locations called 'busheries' or estuaries. Harvesting of Titiree is seasonal, occurring only two to three times a year between the months of July to September and again from March to May.

In Grenada, there are multiple estuaries where Titiree can be harvested, however, Titiree yields vary, and high-yield estuaries are targeted by the Titiree fishers. Through interviews, Titiree fishers are generational, and families return to the same busheries generation after generation so that there is site fidelity for those who use specific busheries on island. However, key issues like the water quality of the river including anoxic conditions due to fertilisers, and output from rum distilleries, as well as plastic pollution ranked highly amongst the Titiree fishers with respect to factors which they think negatively impact not only the Titiree life cycle, but also the opportunity to harvest Titiree.

The Titiree industry is one where there is clear gender bias towards females. Traditionally, the Titiree is harvested and sold fresh in markets by local women at US$0.37 for a small tin (approximately 130g) and an estimated US$111.11 for a 10 gallon bucket (approximately 3.8kg). Within a season, Titiree fishers could generate around US$1,111.11 (M. Mathews, 2022, personal communication). Revenue from this industry within the July-August period enables families to afford schooling supplies (e.g. books, uniforms, school fees and other supplies).

The Titiree are made into patties or fishcakes for consumption (Figure 4.12). However, the revenue generated from such sales are unreported. Versions of this trade exist on other islands in the Caribbean (e.g. Dominica, Puerto Rico, Jamaica), Indian Ocean (e.g. Madagascar, Reunion, Mauritius), and Pacific (e.g. Hawaii, Phillippines) (Bell, 1999).

S. punctatum and *S. antillarum* post larvae harvests have been estimated to be 20,000 tonnes/year (Bell, 1999). Such large quantities of larvae provide a rich source of food for a variety of aquatic organisms. This is due to the rich nutrition provided by the yolk sack. Adults are herbivorous and feed on algae; this is a key ecological function. For Grenada, there are no known population studies of these species, and no studies on the full intrinsic value that these species have in Grenada. There is a need for an ecological assessment of the freshwater communities and assessments on the role of the *Sicydium* spp. In supporting commercially important fisheries. Given that declines in harvests have already been observed, intervention may be necessary before this revenue is lost.

Other edible freshwater species

Other species of potential genetic value include crustaceans e.g. cray fish (*Macrobrachium* spp.), Caca dos shrimp (*Atya* spp.), land crabs and manicou crabs (Gecarcinidae, Potamonidae), oysters (*Crassostrea* spp.), mullet (*Mugil cephalus*), tilapia (*Oreochromis mossambicus* and *O. niloticus*), and river snapper (*Lutjanus argentimaculatus*). While no information specific for Grenada is currently available, these organisms are either already utilised or can be important edible species as they are popular in other countries.

Cascadura (*Hoplosternum* spp.) (also *cascadoo, cascadeux, acemos*) is a popular freshwater fish that is caught in rivers and brackish water. It is an armoured catfish native to Central and South America, and was traditionally eaten only by the indentured labourers in the 1800's (Selvon, 1972). Commonly eaten with provisions, this fishery is largely unmanaged and unregulated in Grenada, though it provides a valuable genetic resource.

Species such as the cray fish (*Macrobrachium* spp.) are known in other parts of the world for its potential in aquaculture. FAO (1986) anticipated a gross profit (before tax) of US$12.23/kg and US$13.86/kg. Prices today are much higher (US$20.40–$24.50/kg) although the annual income generated is unknown. Additionally, several species of carp–common carp (*Cyprinus carpio*) and grass carp (C*tenopharyngodon acemo*), silver carp (*Hypophthalmichthys molitrix*) all have potential for aquaculture which can support restocking of Grand Etang and Lake Antoine.

Aquaria trade and ecotourism freshwater species

Other species such as guppies or millions (*Poecillia reticulata*, *Gambusia* sp.,) and sword tail (*Xiphophorus helleri*) among others can play a role in the aquaria trade. Again, there is a lack of data for this aspect of Grenada's economy, but it is no less valuable.

Grand Etang Lake is home to a number of genetic resources, including economically-important introduced species such as koi and red swordtails, both of which are highlighted in the ecotourism marketing of the lake. The revenue generated from visits to the lake is estimated at US$0.44 million (Ministry of Tourism, 2023, personal communication). Introduction of carp in Grenada's lakes is important for the aerobic decomposition of organic matter and nutrient availability in the water column. These species allow for bioturbation of benthic sediment

Figure 4.12. Titiree in Grenada (a. example of busherie where Titiree is harvested, b. freshly caught Titiree,c. Titiree cake)
(Photo credit: Teddy St. Louis Sr.)

whilst feeding on benthic organisms. The turbidity caused from the foraging behaviour of the koi supports growth of floating mats of freshwater species which reduces the total area of the lake, which is an important source/reservoir of potable water for the arid south of the island.

Waterfowl

According to the Ministry of Agriculture (Daniel Lewis, 2021, personal communication), Grenada's genetic resources also include the over wintering migrant waterfowl. This includes a variety of ducks e.g. northern shoveler (*Spatula clypeata*) and white-cheeked pintail (*Anas bahamensis*) that contribute to the nutrient loading in the lake and the growth of floating mats of vegetation. The Levera Pond has a snail that the endangered, endemic hook billed kite (*Chondrohierax uncinatus mirus*) feeds upon which accounts for the limited range of the endemic kite.

Endemic species

Frogs are ecologically important as they consume billions of insects each year, including those considered pests (e.g. ants and aphids), and, therefore, frogs are economically valuable to agriculture. They also provide a critical food source for a variety of animals (e.g. birds, fish, snakes, and other wildlife). Frogs are also considered important bioindicators of environmental health. There is an endemic frog in Grenada (*Pristimantis euphronides*) (Harrison, 2021). Other Grenadian endemic species are listed in Appendix 5.

4.3.2. Wild flora

Wild flora or plant species are those that need no human intervention for propagation or survival in a habitat or an ecosystem. Much of the economic value of these species is generated from the sale of timber and related industries, or from the use of edible and medicinal plants. These unmanaged plant species play a pivotal role in the livelihoods of those persons involved in timber production, charcoal production and home-based, small-scale value-added industries e.g. making handicrafts, food products, bush medicines and ecotourism. However, given the lack of available published data, it is difficult to assign monetary economic value for specific species sourced from the wild forest areas of Grenada.

Timber

Grenada's forests provide a wealth of raw materials, providing both round wood and fuelwood. Round wood timber is typically used for furniture, posts, poles, and split fencing. Popular species harvested for lumber include mahogany (*Swietenia mahagoni*), white cedar (*Tabebuia pallida*), galba (*Calophyllum* sp.), maruba (*Simarouba amara*) and bullet (*Manilkara bidentata*). Although there is a major gap in record keeping, these species are typically sold to individuals with mobile saws. It was estimated in 2014, that two persons using a chainsaw can produce at least 300 feet board of lumber with a then estimated income of US$140 per person per day (FAO, 2014).

Cuttings are eventually converted into usable wood raw materials that are sold to small furniture manufacturers and woodworkers, boat-builders and others (Figure 4.13). Mahogany is on average sold at US$3.33/ft, compared to white cedar, blue mahoe and pine which are each sold at US$2.59/ft. Materials (logs, panels, boards) and products (e.g. doors, windows, furniture, decking, flooring, pallet wood) from timber are used both locally and for export. Although the annual revenue from timber is not recorded, small tables can cost up to US$185, dining sets (tables and chairs) between US$304–$1,296, and beds between US$331–$741.

Some important timber species (Table 4.4, Appendix 6) are sourced from the three elfin thickets in Grenada. At least 19 species of trees from Grand Etang have been linked to the timber industry on island (FAO, 2016). Today, additional species include red cedar (*Cedrela odorata*), white cedar (*Tabebuia pallida*), blue mahoe (*Hibiscus elatus*), teak (*Tectona grandis*) and pine (*Pinus caribaea*). Within the Grand Etang Forest Reserve, the Forest Department facilitates the harvest of wood within plantations; the main harvested species are blue mahoe (75%) and pines (20%) (FAO, 2004). In 1992, a reported 2,500m^3

of round wood was harvested for timber; the quantity harvested presently is unknown (FAO, 2004).

Ormosia monosperma had also been recorded as being a desirable timber species (FAO, 2004) but is under threat and speculated to be pushed to local extinction due to extensive logging. Mahogany, red cedar and blue mahoe are the most valuable species in terms of furniture making.

Table 4.4. Tree species used for furniture, and estimated quantity of board feet (b.ft) of lumber and % contribution from 1997 (Frederick, 1997)

Species *commonly used	Estimated quantity (b.ft)
Mahogany*	155,580 (50.0%)
Red cedar*	61,370 (19.7%)
Blue mahoe*	37,300 (12.0%)
White cedar*	30,600 (9.8%)
Teak*	11,150 (3.6%)
Maruba	7,200 (2.3%)
Samaan*	6,400 (2.1%)
Galba	1,200 (0.4%)
Gommier	300 (0.09%)
Almond	200 (0.06%)

Fuelwood on the other hand, was reported to have had 40,000m^3 of harvest in 1992 (FAO, 2004). Fuelwood and charcoal are utilised for food preparation in rural poor communities. Fuelwood is collected from farm clearance for agricultural purposes and from dry fallen trees in wooded, mangrove and forested areas. Currently, no data has been compiled on the economic value of charcoal and fuelwood.

Timber species *Pouteria multiflora* (common name: 'penny piece') has edible fruits that also have relational value for hunters because Mona monkeys commune to feed on those trees, possibly making them easy targets for hunters. Since the species is also food for the monkeys, it plays a role in the

Figure 4.13. Sawmill after harvesting of timber
(Photo credit: Aria St. Louis)

local ecology as well as special value for the people; however, it has a declining population and thus may require a different level of management. Another timber species, *Inga laurina* (cacoley) has edible fruits that were once sold in markets in Grenada representing two overlapping economic uses from one species, but one economic use or relational value is being lost/changing.

Non-Timber Forest Products

Non-Timber Forest Products or NTFPs consist of goods of biological origin–other than wood–extracted for use by humans. NTFPs are used for food, fodder, medicines, perfumes and cosmetics, utensils, handicrafts and construction materials for example. (FAO, 1995). They are important for livelihoods within local communities, as they allow for both direct and indirect employment. For example, the red mangrove (*Rhizophora mangle*) is commonly used for firewood, charcoal, and tannin extracts (Dottin, 2008). In the late 1990's, the Guyana Forestry Commission reported 10,886.4kg (1996) and 90,956.8kg (1999) of mangrove bark was extracted for tannin for use by the local leather industry, however this has since been reduced with only a production of 12,619kg and 27,697kg in 2008 and 2009 respectively.

Screwpine (*Pandanus utilis*) leaves, once dried are used in crafting baskets, mats, hats and bags. They grow on farms and around communities but are not managed. Bamboo on the other hand, is classified as an invasive species, and while it is used in house construction, fisheries to make crab traps, and crafts (such as lampshades, tablemats, baskets, and soap dishes) (Table 4.5), it may have a negative impact on native plants due to fast growth rates. Some other species used for making necklaces and craft products include wild coffee (*Colubrina arborescens*), hoopvine (*Trichostigma octandrum*), the mimosa (*Vachellian macracantha*), and guaba (*Inga edulis*), like several mangrove species, are used for charcoal production.

Table 4.5. Example of crafts made from forest tree leaves (Data captured from four vendors in Grand Anse, St. George's Parish, July 2021)

Genetic resource	Use	General price range
Bamboo	Cups, baskets	US$6–$28
Dry cocoa pods	Earrings and chains	US$4–$6
Palm leaves, dry	Basket weaving	US$6–$17
Calabash (*Crescentia cujute*)	Bowls/cups	US$6–$9
Donkey eye (*Mucuna* sp.)	Chains, bracelets, earrings	US$6–$28

Non-timber species similarly are also important for handicraft production e.g. baskets, mats, hats, bags, earrings and brooms. Screwpine leaves (*Pandanus utilis*), larouman grass stem (*Ischnosiphon arouma*), latanye leaves (*Coccothrinax barbadensis*) are used in crafting baskets, mats, and brooms respectively once dried. While data from Grenada is absent, a 2006 report from Saint Lucia reported a monthly average income of US$369 from 2,080 to 2,300 Latanye brooms (Gustave *et al.*, 2006). Screwpines are unmanaged but are grown in inhabited areas around farms and homes.

According to both Ministry of Tourism and Ministry of Agriculture (2022, personal communication), value-added edible goods from forest resources have increased in interest and supply within the tourism sector. Examples of the edible goods are fruits of the jamun *Syzygium* sp. (*S. cumini*, *S. jambos*, *S. malaccense*) that are used for making pies, preserves, jams and drinks. Mammee apple (*Mammea americana*) flowers are used to make local liquor.

The intrinsic or indirect values associated with wild forest ecosystems are important in valuation processes. Ecosystem services provided by forests and trees include climate regulation, erosion control, crop protection, water supply, carbon sequestration, and shade, aesthetics and habitat provision for food and wildlife. There are no reports that have attempted to place a value to these key functions. However, the intrinsic importance of these genetic resources is potentially millions of US dollars.

Contribution of endemic species to ecosystem maintenance is not well understood. However, since they form a unique ecological identity of Grenada, endemic species as genetic resources provide an intrinsic value. There are four plant species that are endemic to Grenada (*Maytenus grenadensis*, *Rhytidophyllum caribaeum*, *Lonchocarpus broadwayi* and *Cyathea elliotii*) (Hawthorne, 2004).

Medicinal plants

Medicinal plants and plants of economic value generate income by sales of plant saplings for cultivation in home gardens, plant parts in crude form as crude medicines or value-added products like necklaces, soaps or essential oils generated from plant parts. A desktop review of Pavy (1987) and a July 2021 field visit at Pure Healing Herbs by the chapter authors revealed that each sapling of medicinal plants is sold at US$0.83 (Maureen M. Charles, Rastafarian Heritage Society, 2021, personal communication, 30 July). Medicinal plants are also economically important for sale of bush teas and medicines. However, due to the informal form of the bush medicine trade, the economic value of these plant species is undetermined and likely undervalued by a large sum. Handmade soaps from plants such as Noni (*Morinda citrifolia*) and Neem (*Azadirachta indica*) that retail from US$2.59–$6.30 have also contributed to the instrumental value from forest resources. Ms. Charles also suggested that there is also great potential for extraction of eugenol and essential oils from *Pimenta dioica*, *P. racemosa*, and *Syzygium aromaticum*.

The plant species used in the 'bush' medicine system hold an important cultural value and importance for Grenadians (Appendix 7). In addition to the functional value as medicines, the bush medicine system has Carib, Arawak, African and European influences which form a major part of Grenadian cultural identity. Skaff (1997) conducted a study on the usage of medicinal plants in Grenada, where 138 interviews were held with long term residents across the island (persons who did not migrate to Grenada within the last ten years). The study revealed that a significant majority, over 80% of the interviewees, reported using medicinal plants or 'bush' medicine to address various health issues. Interestingly, approximately 84% of the individuals who used bush medicine stated that they personally obtained the plants. Furthermore, 95% of the respondents reported possessing knowledge about the specific plants they utilised, indicating a widespread informal usage and a wealth of traditional knowledge within the Grenadian population.

This interaction with the local flora represents the cultural value of the genetic resources that are not fully captured by an economic analysis. About 150 medicinal plant species have been recorded from Grenada so far (Hawthorne *et al.*, 2004). The system of getting medicines or recipes from 'bush' doctors forms an important cultural relationship that is important which encourages the exchange of knowledge and maintenance of community linkages.

Ecotourism and recreation

Trees and forests in Grenada are economically important for their role in ecotourism and recreation. Hunting is an important recreational and subsistence activity. The economic value of forest genetic resources as an entire ecosystem (not species based) can also be indirectly estimated from the willingness to pay, and income generated from tourism.

The cost of tours conducted in Grenada ranges between US$7.41 and US$22.22 per person. Tours generate income for local guides and contribute significantly to Grenada's GDP. While this economic value of forest resources is not attributed to the value of its genetic resources in usual economic valuation, its characteristic features that form the identity of the landscape hold important economic value. Between the period 2016 and 2020, popular tourism sites such as Grand Etang and Annandale generated a total revenue of US$586,166.26 through the sales of visitor entrance fees, not inclusive of private tours. As expected, during the start of the COVID-19 pandemic, such sales declined.

Edible plants (Appendices 7 and 8) used in Grenadian cuisine form a part of its cultural identity and hold higher value for the community than just economic potential. Species that are collected as an activity together (e.g. family picking edible fruits together) contribute to maintenance of relationships through shared recreational activities, a value that is difficult to put a dollar value on. There are also species with important cultural value including donkey eye (*Mucuna* sp.) which is used in the spice necklaces offered to tourists in Grenada. Folklore practices hold an important cultural value; examples include: 1) putting seeds of *Abrus precatorius* (crab eye) in lamps for good luck, 2) using seeds of the balloon vine *Cardiospermum microcarpum* to ward off snakebites, and 3) using leaves of *Petrea volubilis* for diarrhoea and as abortifacient.

In addition, plants such as chadon beni (*Eryngium foetidum*) and dasheen (*Colocasia esculenta*) are both used in cuisines like the national dish of Grenada, 'oil-down', and cannot be properly captured by instrumental or relational valuation. Other examples include *Pimenta* spp. That are used in seasoning, as well as the edible fruits of *Syzygium* spp. (*S. cumini*, *S. jambos*, *S. malaccense*) that are used for making pies, preserves, jams and drinks.

Forest carbon sequestration

Terrestrial forests, including mangroves, are important for carbon sequestration. Estimates of carbon accumulation suggest that total carbon (tC) fixation for Grenada exceeds 8,000tC/ha per year, where Annadale and Grand Etang Forest Reserve contribute the most (4406tC/ha/yr) followed by mangroves (2850tC/ha/yr). This suggests that these forested areas are the most valuable, considering that valuation estimates of US$20 per metric tonne result in net carbon fixation benefits of US$88,120 per year (Blommestein and Associates, 2012).

Erosion control

The Gouyave and St. John's watersheds are susceptible to flooding each year during storms and hurricanes. The more urbanised characteristic of St. John's results in a more severe flooding event as more built-up areas and high per unit area of non-permeable surfaces reduce water infiltration into the soil and thus increase run-off. As urbanisation increases, susceptibility to flooding increases. The more natural land cover in the upper regions of Gouyave has a lower response to flooding than the urbanised areas in the lower areas. Aggressive debushing along roadsides (vegetation clearing) also leads to higher levels of soil erosion and surface runoff (Figure 4.14).

Figure 4.14. Debushing along roadsides in St. David
(Photo credit: Kriss Davies)

Watersheds and water provision services

Forest ecosystems play a critical role as watersheds in Grenada in the generation of water supply (through orographic precipitation process) and water supply management through moisture retention and management. Most watercourses in Grenada start in upper forested watersheds and have significant riparian nutrient input, making forest ecosystems inseparable from water freshwater supply and its associated ES.

In Grenada, freshwater supply supports the maintenance of genetic resources, fisheries resources, irrigation for agriculture and drinking water (both abstraction and direct consumption by communities). Non-consumptive services provided by freshwater supply include dilution and transport of waste, nutrient cycling, biodiversity, aquatic habitat, transportation corridor, and aesthetics and recreation. Ninety percent of the island's water supply come from surface water with distribution through gravity.

Water demand increases in the dry season because of tourism and irrigation. Water demand is approximately 45,500m^3 per day in the rainy season and 54,600m^3 per day in the dry season (Caribbean Environmental Health Institute [CEHI],

2006). Water is primarily supplied by the National Water and Sewerage Authority (NAWASA). There are approximately 29 water supply facilities, of which 23 are surface abstraction points and six ground water boreholes. Mean water production ranges from 31,800m^3 per day in the dry season to 54,600m^3 per day in the wet season (CEHI, 2006). The Annandale water production plant has a mean water production of 10,000m^3 per day and is the largest plant. Groundwater is used in the dry season; the three main boreholes (Woodlands, Chemin Valley and Baillie's Bacolet) produce approximately 3,013m^3 per day. Some hotels in the tourism sector use reverse osmosis desalination plants and a few companies, such as Grenada Breweries, abstract water directly through boreholes.

Limited information on the value of freshwater supplied by forest ecosystems exists, however one study (Ravnal, 2019) estimated the value of the water benefits provided by the Annandale/ Grand Etang Forest Reserve using an estimation of net benefits. The annual net benefit of water production in Grand Etang in 2010 was determined to be US$1,209,794 from a production of 1,033.69 million gallons. Direct use benefits to residents of Grenada through recreation and livelihoods were estimated at US$232,091. Beyond the value of Grand Etang Forest Reserve, using an estimate of total annual water demand as 4,801,855,395.7m^3 per year (Ravnal, 2019), and attributing 90% of this demand being supplied by forest managed ecosystems, sold at the median price charged by NAWASA to domestic customers (US$3.51/1000 gallons) results in US$24,009,276.98 of value per year generated by natural water resources. Here it is important to highlight a number of limitations of this estimation, but also the limits of placing an economic value on water. Water price rarely reflects the cost of producing this water, in terms of the services provided by ecosystems, and the investments necessary in those ecosystems to maintain this water supply. Forest watersheds in the islands of Carriacou and Petite Martinique by and large are not important sources of water, with rainwater harvesting providing the majority of water supply needs (see Box 4.2 for more information).

Box 4.2. Water supply in Carriacou and Petite Martinique

While there are eight major watersheds on Carriacou and Petite Martinique, none are subdivided, nor are they considered as important permanent streams or springs. Household water supplies in these islands depend upon catching rainwater and storing it in cisterns, while water for agriculture and livestock comes mainly from withdrawal of groundwater and surface water (run-off) stored in ponds at Grand Etang on Grenada (enlarged to 3,771 acres in 1963) and High North (336 acres) in Carriacou.

Rainwater harvesting in Carriacou (Figure 4.15) and Petite Martinique was facilitated by the construction of water cisterns with a capacity of 57m^3 to improve subsistence agriculture and livestock rearing. These cisterns cost US$11,200 and distributing rainwater storage tanks with capacities of 1.7m^3 and 3.8m^3 were also constructed at a cost of US$280 and US$852 respectively (Peters, 2017). The cisterns were subsidised for the residents and costs to the residents was US$936 for the concrete cisterns, US$150 for the 3.8m^3 tanks and nothing for the 1.7m^3 tanks.

Figure 4.15. Rainwater harvesting in Carriacou
(Photo credit: Adrian Cashman)

4.3.3. Wildlife (fauna)

Wild meat and game

Culturally there is a specific niche market for wild meat, where it represents more of a relational value. Despite this, stakeholder perception survey indicated that fauna wildlife was perceived to have a high importance for both intrinsic and relational value (Figure 4.11 on page 280). In Grenada, 'wild meat' is consumed at community events such as village card games. People who have come to play and to drink alcoholic beverages will also eat the cooked wild meat. Specialised fetes or specialised shops, which have legally caught wild meat for sale, are found in Byelands, Balthazar, Birchgrove, Clozier and Mirabeau.

The manicou or opossum (*Didelphis marsupialis*) is the most popular wild meat consumed. There are professional hunters who have hunting dogs trained to help find manicou and other hunted species. They use traditional methods including 'bangor' nets. Depending on size, a single manicou animal is worth US$11.11–$22.22, or up to US$8.14/kg. Tattoos (*Dasypus novemcinctus*) are the most expensive wild meat at US$20.37/kg (~US$29.63–$37.04/animal). Tattoo is more difficult to catch and as a result, scarcer in supply. Although more expensive, tattoo tends to taste very 'fresh' or 'gamey' if not prepared well, thus it is not as popular as the manicou.

Iguana (*Iguana iguana*) is also a popular game species in Grenada (Government of Grenada, 2000), especially in the countryside. Whole animals are typically sold at US$9.26–$12.96, with a unit cost of approximately US$5.08–$7.13/kg. Consumption of iguana is more common among friends or as part of a specialised event, such as a 'wild meat' fete. Due to hunting restrictions on other islands, juvenile iguana has been known to be taken from the Grenadines and sold as bushmeat in islands such as Saint Lucia (Breuil *et al.*, 2019). Iguana are listed under CITES Appendix 2, and, therefore, export of these animals requires special permits. A rise in smuggling of juveniles has been observed, along with attempts to sell the animal under varying trade names (Breuil *et al.*, 2019). Iguana eggs are also an important source of nutrients for other species, often fed upon by snakes, mongoose, cats, dogs, pigs and rats (Alberts, 1999). Additionally, iguanas are impacted by habitat destruction due to livestock grazing (Alberts, 1999). The estimated loss of revenue, as well as the effect on the population, is under studied. However, the iguana hybrid species are currently considered unique to Saint Lucia, St. Vincent and the Grenadines, and Grenada (Breuil *et al.*, 2019), and, therefore, it is important that measures are put in place to protect this rare genetic resource.

Ramier, or scaly-naped pigeon (*Patagioenas squamosa*) are also hunted. This species is not commercially hunted however, and therefore there is no known instrumental value. However, it has cultural value, as it is hunted by friends and by male family members. When caught, it is cleaned and cooked and either eaten or shared up among those who hunted for consumption later.

Mona monkeys (*Cercopithecus mona*) are an introduced species to Grenada and are considered good candidates for the study of ecological flexibility in fragmented habitats and speciation processes (Glenn and Bensen, 2013). Mona monkey populations are, however, under threat due to pressures related to hunting for bushmeat, pet trade (of live young), and loss of forested habitat (Glenn and Bensen, 2013). No associated costs are available for this species. If genetic diversity of the species is low enough, this population will be less able to adapt to environmental changes and hunting pressures.

Other income related to game and other hunted species include revenue generated from permits and legal trade, as well as loss of potential national revenue due to poaching and illegal trade. Such contributions, either holistically or by species, is generally unreported.

Endemic species

Grenada, like many island nations, supports significant endemic genetic resources. Although not well studied, several terrestrial endemic faunal species have been identified (Appendix 5) (Hailey *et al.*, 2011). Although there is a paucity of information on many of these species, the maintenance of genetic variability of Grenada's endemic genetic resources is essential to support resilience of populations, sub-species and species genomes to current and future impacts and hazards.

The intrinsic values offered by these species are further increased as they offer unique opportunities for study of theoretical principles governing natural selection, extinction and recolonisation, punctuated evolution etc. It also affords the opportunity to address empirical questions and challenges and to design, test and implement biodiversity conservation programmes. Endemic species also offer potential instrumental value given that globally, plant and marine genetic resources are known to be economically important as they harbour new and novel chemicals with potential downstream uses in the pharmaceutical, cosmeceutical and nutraceutical industries. For example, venom from local ants may contain novel biochemical compounds that can be utilised in the pharmaceutical industry. Grenada can therefore capitalise on especially endemic species as these may possess unique compounds. This is also reflected in the national stakeholder perception survey conducted, as endemic species are considered to be of high importance (Figure 4.11 on page 280), both for intrinsic and relational value.

Invasive alien species

There has been both positive and negative contribution of invasive alien species (IAS) in Grenada. These species are utilised as a means of biological (pest) control (e.g. the Indian mongoose), hunted game species (e.g. feral pigs and iguana) and trade (e.g. Amazon and macaw parrots, anole lizards, chicken). While the specific instrumental value for such species has never been reported, the detrimental impact to the native species and habitat has been noted. IAS have been shown to outcompete wildlife organisms for food and space.

Pollinators

Pollinators, such as bats, bees, beetles, wasps and flies have intrinsic value and play integral ecological roles especially within plant reproductive cycles (Figure 4.16). While such roles are generally under studied in terms of genetic value, pollinators support production in crops such as pumpkins, squashes and cucumbers.

In fact, diverse forest herbs, shrubs and trees depend on honeybees, carpenter bees, wasps and other pollinators such as butterflies, flies, ants, beetles, hummingbirds, zenaida doves, and bats. For example, the fruiting of guava, bananas and plantains rely on native nectar-seeking bats for pollination (Tremlett *et al.*, 2020). Without such organisms, plants such as timber trees (blue mahoe, white cedar), mangroves, fruit trees and crop successes could be at risk.

Natural products and bioprospecting

As is the case for many Caribbean islands, there is a wealth of possible entrepreneurship opportunities based on the utilisation and/or extraction of natural products from particular species. Products from fruits and seeds such as calabash and brooms from coconut leaves are commonly known and popularly sold but generally not recorded in terms of annual income streams for Grenada, both in the local and international market. In comparison, bioprospecting, or the isolation of compounds and products that can be used within the pharmaceutical, nutraceutical or cosmeceutical industry, is even less known, even though potentially much more lucrative in terms of national revenue sources.

Besides such instrumental values, genetic value should also include those revenues that are gained through the symbolic use or marketing strategies that use national icons, and generate commerce through various cultural and artistic expressions. Examples include imagery of iconic or endemic species such as nutmeg and the Grenada dove on clothing, stamps, local money, and billboards.

Other useful genetic resources include use of the invasive bamboo to make cups and baskets and palm leaves for woven baskets. Such products are estimated at US$16.67/item. Donkeyeye (*Mucuna* sp.), is also used for jewellery, with products ranging between US$5.56 and US$7.41/item. Estimated annual value of such species is largely unknown.

Other wildlife incentivised products include snake and centipede wine or rum (Figure 4.17). Both are

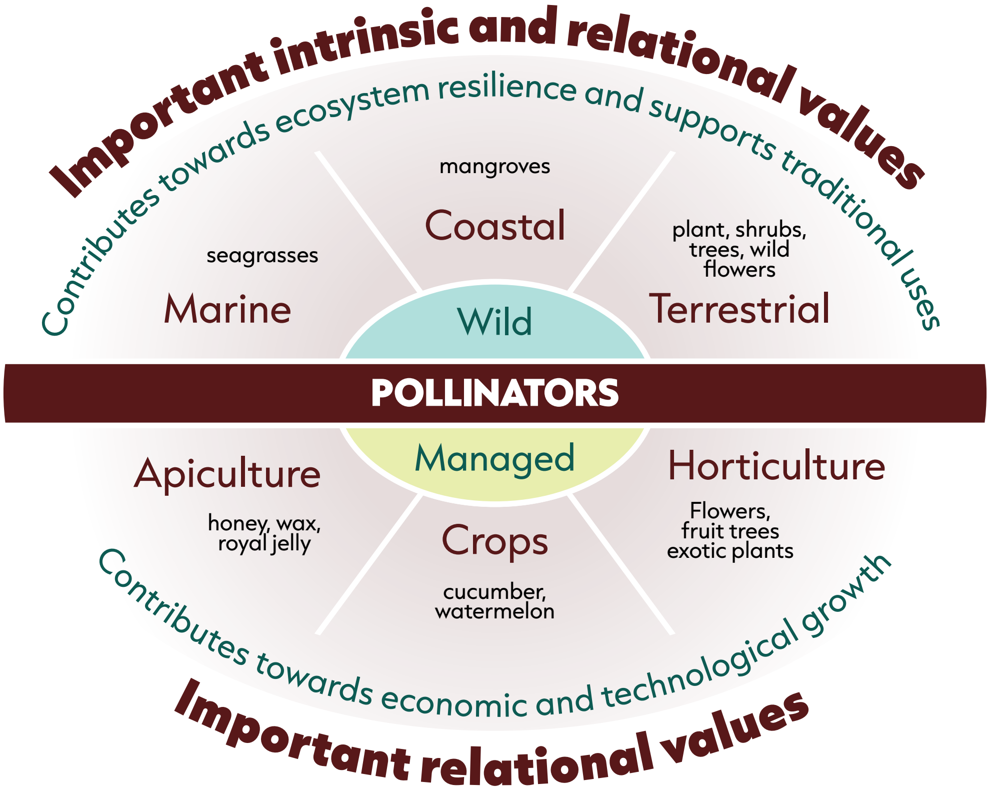

Figure 4.16. Interlinkage of pollinators to wild and managed ecosystems

considered to be powerful aphrodisiacs with similar function to Viagra and are mainly prepared in country or rural areas. The stakeholder perception survey conducted by the Grenada NEA authors indicated a medium to high importance for both intrinsic and relational perspectives for faunal wildlife (Figure 4.11 on page 280).

4.3.4. Agriculture and agrosystems

Genetic resources in managed or agroecosystems are essential to sustainable food security. These resources include the variety and variability of domesticated plants and animals, aquatic organisms and micro-organisms at the genetic, species and ecosystem levels in and around production systems for food, and non-food agriculture products and services (FAO, 2019a). The Government of Grenada identifies agroecosystem products as goods for food, and as genetic resources for exploration and benefit sharing (Blommestein and Associates, 2012; Thomas, 2016).

Figure 4.17. Example of centipede wine available for consumption (Photo credit: Food and Wine magazine)

Hence, apart from the direct consumptive benefits commonly associated with agro-goods, conservation of bio-resources, usually *in situ* and *ex situ* managed facilities, are also valued. They are also valued in plant and animal breeding programmes. This section focuses on the value of major agroecosystems in the island, small-scale farming, and, on a lesser scale, poultry and livestock rearing and apiculture. Further, a breakdown of general emerging strengths, weaknesses, opportunities and threats on these resources is provided in Appendix 1.

Socioeconomic development in Grenada is very dependent on the agricultural sector. Agriculture and maintenance of agroecosystems underpins diversity and food systems. Further, healthy agroecosystems are pertinent in climate regulation and enables us to manage and mitigate the impact of health and climate shocks and crises (Abdelmagied and Mpheshea, 2020). Major commercial export crops in Grenada include cocoa (*Theobroma cacao*), nutmeg (*Myristica fragrans*), and soursop (*Annona muricata*). Minor spice tree crops include black pepper (*Piper nigrum*), cinnamon (*Cinnamomum verum*), clove (*Syzygium aromaticum*), pimento (*Capsicum annuum*), sapote (*Pouteria sapota*) and tonkabean (*Dipteryx odorata*). Fruit tree crops include mango (*Mangifera indica*) and avocado (*Persea americana*) (George, 2011). This section will focus on these commercial exports elaborated on in Appendix 8.

The value of this sector can be accounted via instrumental means, however there are a number of other indirect value factors and risk factors to consider in the context of each commercial crop category. In terms of direct valuation, employment in the agricultural sector accounts for around 11% of the country's labour force and the production of the major export crops are a significant source of income, especially for male producers. For example, the Grenada Cooperative Nutmeg Association (GCNA) has 3,500 active registered farmers, of which 90% are male producers. Nevertheless, production and innovation through various value-added incentives were estimated to provide livelihood opportunities to nearly 30% of the population (EU, 2010). Approximately 39% of the registered agroprocessors consist of spice, craft and cosmetic venders, and notably 64% of agroprocessors are women (Ministry of Agriculture, 2009; James, 2015).

Nutmeg and other spices

The main cultivated nutmeg varieties in Grenada are Indonesian (Banda), Papau and Malayan, where Banda is the most dominant, followed by Papau variety. The export value of nutmeg (seed) and mace were estimated at an average of US$8.03 million and US$5.38 million respectively for the period 2017 to 2019 (Selina Wamucii, 2022). Average production for the same period was 521.7 metric tonnes (M/tonnes) and 51.0M/tonnes for nutmeg and mace respectively (Figure 4.18).

Apart from exports of the raw product, value-added commodities from by-products which include a variety of jams and jellies, oils, sauces, soaps, and balms (Table 4.6), were estimated at a value ranging from US$2.47–$4.04 per 30g (Marketing and National Importing Board [MNIB], 2021; Singh *et al.*, 2003). Nutmeg shells also have economic value; for every thousand pounds of nutmeg that is processed by GCNA, 136kg of nutmeg shells are processed and sold as a plant-growth medium or mixed potting soil at US$9.26/6.7kg. Other indirect value includes cultural heritage, as images of nutmeg and other spices are showcased throughout the island on billboard, signs, etc. Value for minor spices was estimated at US$31,669 using the GEF grant (2016 to 2018, # GRD/SGP/OP5/YA/STAR/CC/16/13) as a proxy. One goal of the grant was to maintain biodiversity for education, ecotourism and other non-use/option values.

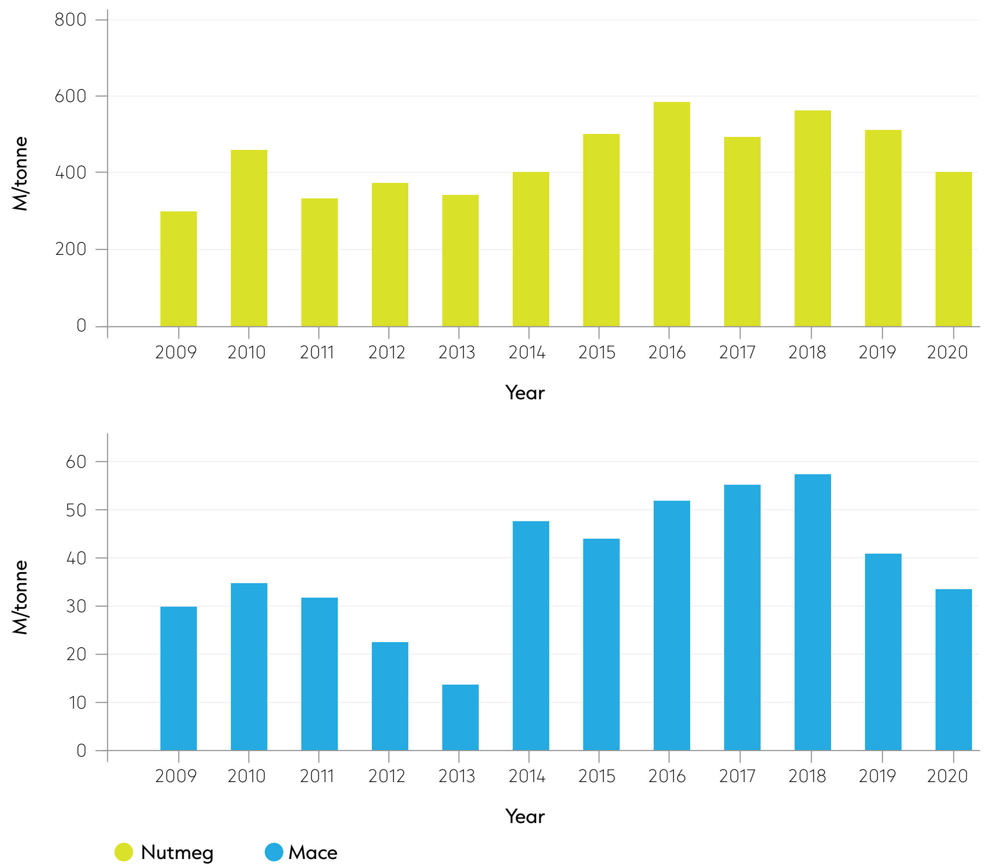

Figure 4.18. *GCNA exports for nutmeg and mace between 2009 and 2020. Measures are in metric tonnes (M/tonnes, where 1 M/tonne = 1,000 kg)*

Table 4.6. *Value-added commodities from by-products (Data provided by Marketing and National Importing Board, 2021)*

Agency/seller	Value-added products from nutmeg and minor spices
GCNA (Nutmeg and by-products)	Grenada nut-moss potting mix; Grenada nutmeg cooler; Grenada ground nutmeg (PET bottle); Grenadian nutmeg oil; Grenada mace oil; Grenada nutmeg spice tea; Grenada nutmeg meat rub; nutmeg hot sauce; whole nutmegs in shell (pack); Grenada nutmeg green seasoning; whole nutmegs out of shell (PET bottle) and Grenada mace (packs).
Local producers/ vendors	Jams; jellies; teas; medicated rubs; syrups; seasoning mix; spice snacks; nutmeg and mace oils and rubs; nutmeg butter; spice gift packs; spice soaps; pain relieving balms; liqueurs; jewellery and spice baskets.

Cocoa

Cocoa represents Grenada's best example for genetic value as linked to genetic diversity. Grenada's cocoa is valued as a high-commodity product and is recognised by the International Cocoa Organization (ICCO) as 100% fine or flavoured. This ranking is based on the fact that germplasm is mostly of Criollo origin (including Criollo-like and Criollo-cross varieties which is known for having distinct flavour qualities) and Forastero origin (Table 4.7). Presently, there are 1943ha under cultivation, and approximately 4,000 active registered farmers at the Grenada Cocoa Association (GCA) producing 727,727kg of cocoa annually. Annually, the GCA purchases cocoa from farmers at an average of US$1.85 million (Ministry

Figure 4.19. Cocoa processing at the Belmont Estate
(Photo credit: Nicole Leotaud)

of Agriculture, 2020). Cocoa is a source of export revenue, as approximately 85% of Grenada's cocoa is exported to Europe. Moreover, between 2017 and 2019, exports grew by 23.37% with an estimated value of US$3.28 million in 2019 (Selina Wamucii, 2022).

Over the years, there have been some notable successes in cocoa value addition initiatives. The production of chocolate on the island in recent times has been observed. Currently, there are over four producers of high-quality chocolate, including the GCA. Local manufactures were estimated at ~91,000kg of chocolate in 2019 and sales were estimated at US$1.11 million (Ministry of Agriculture, 2020). This diversification in product range, including the addition of agroservices, has created employment for locals and is a source of added revenue. For example, the Diamond Chocolate Factory (DCF) has incorporated an agrotourism component, and hires 20 employees for specialised jobs other than chocolate production. Estimated value from agotourism was estimated at US$25/hour per tour (~ 1-15 persons) based on the willingness to pay for services. This was reflective in 2019, where 32,000 visitors toured DCF as part of their agrotourism service (Ministry of Agriculture, 2020).

Table 4.7. Example of cultivars for cocoa in Grenada (Howard and Harvey, 2013; Mirabeau Propagation Station, 2021 personal communication)

Variety	Cultivar	Role/function
Criollo	GS10	Criollo variety is high-quality and of economic importance to Grenada. GS17, GS19, GS29, GS36, GS49, GS48, GS55, GS57, GS65, GS67, GS71, GS65, GS77, ICS95, ICS32, ICS95, ICS1 and ICS6 are the main locally grown and propagated cultivars
Criollo-like	GS29, GS36 and GS11 GS29 cultivar was the most common, representing 97% from a sample size of 1139 trees in 2009 survey	
Criollo-cross	Inter College Selection (ICS): ICS95, ICS32, ICS89, ISC6 and ICS6. UF221, UF667, UF668, UF650 and UF654	
Unknown (but appear to be hybrid or mix cultivars with criollo)	GS17, GS46, GS53, GS67, GS26, GS18, G19, G36, GS57, GS48, GS49, GS43, GS71, GS65, GS67, GS55, GS57, GS77, GS78, GS15, GS40, GS76, GS32, GS30, GS14, GS57, GS04 and ICS98	
Forastero	ICS1 and IMC67	Easier to cultivate, more vigorous and tolerant to disease than Criollo/Criollo-like and clones. However, no high quality and has a lower market value.
Un-known bulk collection	United Food Clone (UFC): UFC221, UFC645 and UFC667. International Marritoris Clones: IMC76.	United Food Clone (UFC): UFC221, UFC645 and UFC667. International Marritoris Clones: IMC76. Locally grown and propagated cultivars at the Mirabeau station.

Soursop

According to FAO (2020) report, the soursop sector is one of the most lucrative agricultural sub-sectors in Grenada, generating significant foreign exchange earnings and attracting investment by farmers, exporters, processors and buyers (FAO, 2020). It is also one of the priority crops targeted for food and nutrient security and for improving small-holder livelihoods in Grenada. Currently, Grenada is the only country which can export fresh soursop to the lucrative USA market because of the absence of key pests that may contribute towards disease. Considering this, Grenada has a competitive advantage and in recent years, the demand for soursop has increased, largely because of its noted cancer-fighting properties. In 2012, Grenada exported 28,500kg of fruit accruing revenue of US$104,148 whereas only five years later, in 2017, 486,500kg of fruit were exported, gaining a total revenue of US$2.67 million. The farm-to-gate price varies between US$2.05 and US$2.45/kg (Ministry of Agriculture, 2020). However, average estimates, assuming peak prices was assumed by the Ministry of Agriculture at US$3.68/kg, making the soursop crop a significant source of income (The Grenadian Voice, 2020).

Fruit trees and ornamental species

Grenada has a rich variety of fruit and ornamental species (Appendix 8) boasting 28 varieties of citrus (US$1.85/sapling), followed by avocado (25 spp., US$1.85/sapling), mangoes (16 spp., US$1.85/sapling), cassava (13 spp., US$0.37/sapling) and yam (12 spp.). In contrast, ornamental species (78 spp.) have by far the greatest variety. Exportation of fruit tree crops, including mangoes, were valued at US$0.03 million for 14 tonnes in 2019. Average exports are 27.25 tonnes from 2016 to 2019 (Selina Wamucii, 2023), which is a major indicator of change. With as many varieties of species, propagation (via budding, grafting, etc.) of various species and therefore genetic variability would improve in the long term.

Carbon sequestration by major agricultural crops

Nutmeg trees sequester carbon at a rate of 0.348 tonnes of carbon dioxide equivalent (tCO2e) over a 20-year period (Table 4.8). With approximately 123 nutmeg trees per hectare (taking into consideration the spacing which can accommodate cocoa and other species), and a conservative market value of US$10/tCO2e (range is US$10 –$30 per tCO2e) (World Bank, 2017), using Helmer's data for 'Nutmeg and Mixed Woody Agriculture' at 8,983.62 ha under mono and mixed stands, Grenada can benefit from a conservative estimate of approximately US$200,000/year (range US$192,267.43–$576,802.30 per year) in revenues from carbon pricing with an increase as nutmeg and mixed woody agriculture stands mature.

Table 4.8. Quantity of carbon sequestration (tCO2/ha/tree over 20 years) potential for various crops

Crop	Trees/ha (spacing)	Carbon Sequestration Rate (tCO2e)
Nutmeg	123 (9m x 9m)	0.3480
Cocoa	730 (3.7m x 3.7m)	0.0696
Banana	730 (3.7m x 3.7m)	0.1590

Macroeconomic importance of agriculture to Grenada

Approximately 75% of Grenada's total land area is used for agriculture, with permanent crops accounting for 63.7% of the land area, temporary crops 7%, and another 4.5% under permanent pasture (UNEP, 2020). Between 1995 and 2012, agricultural acreage declined at a rate of 1.3% per year. Agriculture's declining contribution to GDP from around 20% in 1977 to 5.1% in 2021 (Eastern Caribbean Central Bank [ECCB], 2021) has reduced its economic contribution but not its importance to food and livelihood security. Between 2011 and 2015, the

GDP contribution of agriculture increased by 3% (from 4.4% to 7.4%) before declining by 2% in the ensuing period to 5.1% in 2021 (World Bank, 2022). Despite this declining trend in the last 50 years, major crops such as nutmeg, banana, and cocoa account for 47% of the country's total exports, and the sector employs 13.8% of the labour force (Inter-American Institute for Cooperation on Agriculture [IICA], 2018; Government of Grenada, 2017).

Farming systems are primarily managed by small-scale farmers (~9,200) in rural areas where poverty levels and land insecurity are highest (FAO, 2020). Prior to the passage Hurricane Ivan in 2004, Grenada was the second largest exporter of nutmeg in the world (FAO, 2016). Earnings from exports of nutmegs and mace have increased significantly since 2007, but this growth was mainly driven by price increases (Government of Grenada, 2015). The 2012 Grenada Agriculture Census (GAC, 2012) showed that there were 198,798 bearing nutmeg trees (36% pre-hurricanes level) the equivalent of 913ha (Government of Grenada, 2015; Ministry of Agriculture, 2011).

In 2019, the food import bill of Grenada was US$350 million. In that same year, the top three exports nutmeg, mace and cardamoms (US$6.12 million); non-fillet fresh fish (US$2.08 million); and frozen fruits and nuts (US$1.75 million) amounted to approximately US$10 million, which was less than the total imported poultry meat (US$11.2 million) alone (OECS, 2021). While the main staple food for majority of the rural population include locally-cultivated crops (e.g., sweet potato, cassava, yam, maize, cabbage, banana) imported food accounts for approximately 70% of foods consumed locally (Centre for Resource Management and Environmental Studies [CERMES], 2018). The increased consumption of imported food over time has contributed to the obesity prevalence of 32.4% among adults and the country is 'off course' to meet all of the nutritional targets assessed in the *Global Nutrition Report* published in 2021. One promising trend is that Grenada appears to be moving towards localising its food systems in recent years. This trend is evidenced by socio-metabolic analysis of diachronic biomass flow from 1961 to 2019 (Singh *et al.*, 2023).

The most recent Survey of Living Condition in Grenada revealed that 27% of households are worried they will run out of food (World Bank, 2021). More than half of this total (52%) can be found in poor households. Additionally, 26% of poor households (and 12% of all households) went without eating for a whole day over the 12-month recall period evaluated. In terms of dietary diversity, approximately 30% of households ate only few kinds of food because of a lack of money (World Bank, 2021). The food poverty line in Grenada is set at US$1,074 annually per person and households spend approximately 22% of its income on food (World Bank, 2021).

See Box 4.3 for more information on agrotourism.

Box 4.3. Agrotourism

Farmers are the chief stewards of agrobiodiversity in Grenada and play a key role in developing nutrition-sensitive agriculture and food systems. Despite the economic shift from agriculture to tourism, the two sectors are intertwined (Nelson, 2012) with a wide variety of fruits, vegetables and traditional root crops supplied to resorts (Ministry of Agriculture, 2011).

It is estimated that approximately 80% of vegetables used in the hotel sector is provided by local farmers (Government of Grenada, 2015). Grenada has used its spice identity to create a niche tourism product that promotes distinct, place-based characteristics that clearly associate the island with an experience to be had (Nelson, 2012). The Spice Isle also offers a variety of historical plantations, sugar mills, rum distilleries, spice plantations, and festivals (Allen et al., 2017) further linking agrotourism to heritage tourism.

Belmont Estate and Dougaldston Estate are among the main agrotourism sites in Grenada (Thomas-Francois and Francois, 2014). The latter is adjacent to Belvidere Estate, one of the highest nutmeg producers.

4.3.5. Traditional backyard farming and small-scale to medium size production systems

Backyard farming and small production systems range from 0-2ha, and medium size production systems from 2.4-4.04ha (David, 2004). However, due to the increasing land use reform for housing, evidence suggests that approximately 1.21ha may now be considered as medium size. Traditionally, in Grenada, two forms of rural small-scale food production can be distinguished: small-scale vegetable farm (many of which are considered kitchen gardens) and provision grounds (Brierley, 1985),

Small-scale vegetable farming is epitomised by backyard and kitchen gardens. Kitchen gardens can be scaled towards small backyard farms and eventually towards small business. Such small-scale farms are typically used for the growth of vegetables, herbs and other crops. Vegetables are essential for the nutrition security and human health of the people of Grenada and the Caribbean at large. Most kitchen gardens include various forms of mixed farming systems with a combination of short crop and tree-based intercropping as well as livestock farming. Dominant tree species include breadfruit (*Artocarpus altilis*), mango (*Mangifera indica*), avocado (*Persea americana*), coconut (*Cocos nucifera*), plantain (*Musa × paradisiaca*), banana (*Musa*), sapodilla (*Manilkara zapota*), cashew (*Anacardium occidentale*), papaya (*Carica papaya*), and a wide range of citrus. Common short crops and a wide range of vegetables are found in Appendix 8. These are often inter-cropped with corn (*Zea mays*), cowpeas (*Vigna unguiculata*) and pigeon peas (*Cajanus cajan*).

The kitchen garden also often includes medicinal plants or plants used for 'bush' teas for common ailments (Appendix 7). Moreover, some households also have a provision garden which consists of larger, separate parcels with staple root crops such as sweet potato (*Ipomoea batatas*), dasheen (*Colocasia esculenta*), tannia (*Xanthosoma sagittifolium*), yam (*Dioscorea*) and cassava (*Manihot esculenta*). Roots and tubers have traditionally contributed to Grenada's food and nutrition security. Over the past decades, national demand has partially met with importation of some of these crops from St. Vincent. The most significant substitute or competitor for local roots and tubers is white potato. During the period 2015 and 2019, between 1.35 and 1.6 million kg were imported at a value ranging from US$1.12–$1.97 million dollars (Ministry of Agriculture, 2020). The aforementioned farming systems also support small-to-medium size agroprocessors. A conservative estimate of the agroprocessing sector is US$3.93 million per year (Ministry of Agriculture, 2020).

Land use and agriculture diversity

The general types of farming are also important to discuss e.g. those that use intercropping/mix cropping vs those that are monoculture. Further, it is important to identify what that means for risk of value due to changes in diversity (or lack thereof) in the context of genetic/species diversity. Based on stakeholder perception survey conducted for the Grenada NEA (see Figure 4.11 on page 280) the value of agricultural resources is generally perceived as high to critical which is not surprising as the various agricultural production systems contribute widely in terms of services (Table 4.9).

Poultry and livestock

There are generally two scales of poultry and livestock rearing on island including: 1) subsistence farming (family sustenance), and 2) small-scale commercial (supplying local market). In the context of subsistence farming on the island, many households have a few domesticated animals including rabbits (New Zealand white and red, California, chinchilla, Dutch and English), sheep (Barbados black belly, Virgin island white and kathadin), pigs (large whites, landrace, durocs and large blacks), goats (Nubian, Toggenburg, Alpine, Jamnapari and Sannen), cattle and backyard flocks and unorganised poultry farms also referred to as 'yard fowls'. The value contribution for poultry and livestock is currently not reported but represents a future opportunity towards a shift away from purchasing imported meat.

On a more commercial level, an estimated 90% of Grenada's meat supply is imported, where poultry makes up the bulk of meat imports. Commercial breeds consist of Plymouth Rock broilers bred for meat, and the Leghorn layers for eggs. Estimated value of local broilers (69,754kg) is US$2,841,822.22, and layers (3,767,986kg) at US$1,643,286.74 (Ministry of Agriculture, 2020). In 2009, local poultry meat production supplied 12% of local demand, however consultation with the Poultry Executive Board in August, 2021 suggests local production accounts for 25% of the local supply and demand (Table 4.10). Grenada's 2020 economic recovery plan intends to increase chicken product cost to meet approximately 40% of local demand (James, 2020); a conservative estimate for chicken based on import substitution cost (40%) was US$6.57 million.

Table 4.9. Summary of characteristics of the main ecosystems services or intrinsic and relational value considerations provided by bio-resources in major production systems

Sub-categories	Categories of services			
	Providing	Regulating	Supporting	Cultural
Major commercial production systems	• Food and nutrient security • Medicinal • Raw material for craft and jewellery) • Export and local revenue (especially for rural communities)	• Carbon sequestration • Water filtration and quality • Prevents soil erosion and maintains fertility • Climate mitigation	• Greater biodiversity support (food webs and the productivity of ecosystems) • Nutrient cycling and transport	• Amenity value (agrotourism) • Education for scientific research and teaching
Traditional backyard farming and small-scale-to-medium size production systems	• Wide range of foods with a balance nutrient supply (energy, protein, minerals and vitamins) • Employment and poverty alleviation • Local medicines	• Reduces soil erosion during heavy rains • Protection from the sun's rays • Climate mitigation • Moderation of weather extremes and their impacts	• Maintenance of biodiversity of local land races • Nutrient cycling and transport	• Aesthetic and intellectual stimulation (flowers and other ornamental like croton) • Maintenance of traditional/ cultural cropping practices • Tree crops as land and boundary markers

Table 4.10. Food type met by local production (Allison Haynes, Chief Agronomist, Ministry of Agriculture, 2021, personal communication)

Food type	Demand met by local production (%)
Fruits	93
Vegetables including carrots	50
Eggs	*<100
Poultry	~13-25
Roots and tubers, including white potatoes	30
Herbs	95
Pork (fresh)	75
Lamb (fresh)	10
Beef and beef products	5

** Post pandemic eggs needed to be imported due to lack of local production supply.*

Apiculture

As previously noted, values associated with natural products and bioprospecting are largely unexplored for Caribbean islands, including Grenada. One of the best examples of genetic value is found in bees. Grenada has produced honey that has won international awards. However, the trade in honey has been small-scale, with Barbados as a major market. Within Grenada, there are approximately 1400 beehives that are managed by 40 beekeepers, that on average produce 18kg per hive per annum (Association of Caribbean Beekeepers Organisation [ACBO], 2021, personal communication). At least two species of honeybees are kept in Grenada, the German race of honeybee *Apis mellifera* or 'Black', and the Italian race, *Apis mellifera ligustica*. These are considered to have ideal characteristics for honey production (well adapted and highly productive).

Other important associated products from bees include bee pollen, wax, royal jelly, propolis, and venom. Currently, no cost or value can be assigned easily to such products due to lack of information. However, while the full genetic value of bees and their products and ecological services has yet to be determined in Grenada, given that a 5oz bottle of honey can cost ~US$13, a single hive can bring in ~US$1,664 for each hive per annum in honey alone. A large bottle (750ml) can cost up to US$27.78/bottle. Private beekeepers also sell their honey (Table 4.11), though not necessarily at such high costs.

Cucurbit crops (e.g. pumpkins, squashes and cucumbers) are heavily dependent on bees for pollination. Even in pastureland for livestock, the protein-rich legumes depend on honeybees and other insect pollinators (Figure 4.20). Given the important symbiotic relationships, beehives are often within close proximity to their food sources, which in Grenada includes nutmeg, cinnamon, vanilla and papaya plants for example. Some native fruit trees such as West Indian cherry and its relatives are pollinated by native oil-collecting 'bumblebees' (*Centris* sp). Imported fruit trees such as Carambola and Bilimbi are also pollinated by *Centris* bees.

Figure 4.20. Foraging Bee, Carriacou
(Photo Credit: Antonia Peters)

Table 4.11. Additional information on local honey sold in outlets other than the Marketing and National Importing Board (MNIB)

Product/producer I	Volume and price (US$)
100% honey Glen Findley Apiary Honey Man	750ml bottle-$20.37 300ml bottle- $9.26
Cinnamon G.Links Honey	~ 30ml bottle- $10.24
100% honey Lily Patch Apiary and Gardens	750ml bottle- $17.31
100 % honey Bocage Apiary	750ml bottle- $17.31
100% honey Lily Patch Apiary and Gardens	327ml bottle- $9.26
100 % honey Jade Findley Apiary	347ml bottle- $9.26

4.3.6. Special Note: Ecosystems, tourism and human health

Economics of the sink, source and threat functions of nature

The three-sided functional relationship that exists among the environment (nature) and the society and economy has been summarised using the source, sink and threat functions (Pantin and Attzs, 2010). Nature serves as a source of invaluable inputs for human economic, social and environmental well-being. Nature, among other things, is the source of the genetic, aquatic and terrestrial resources (wildlife and managed) outlined in this chapter. Its sink function also acts as a repository for the absorption of waste generated from human and other ecosystem activity. When this function of nature occurs in a balanced manner, absorption of air and water pollution is sustainably managed and regulated. The devastating impact of nature's threat function on humans, however, is evident with the occurrences of natural disasters such as earthquakes, windstorms and hurricanes, droughts among others. The threat function, unlike the other functions, demonstrates how nature negatively impacts human lifestyles and well-being.

Nature's threat function also has severe economic implications. Natural disasters cause deaths, homelessness, post-traumatic stress disorder (PTSD) and post-traumatic stress symptomatology (PTSS) and injuries. Natural disasters decimate property, retard progress towards national debt reduction and curtail progress made on investments in the education and health sector (Rasmussen, 2004; World Bank, 2003). Of greater concern though, in the economic literature on the impact of natural disasters in developing countries, is the impact of natural disasters on the poor (World Bank, 2000/2001).

For the purpose of the Grenada NEA, quantifiable damage caused by the threat function of nature and related to humans' economic activity is summarised in Table 4.12. This table indicates the following: 1) 40 individuals died from natural disasters between 1978 and 2021 in Grenada, 2) 62,935 individuals were affected (i.e. either injured, became homeless or required immediate assistance) by natural disasters in Grenada over the period, 3) natural disasters caused US$904,500,000 in direct and indirect damage to Grenada's economy, 4) the most occurring natural disaster facing the Grenadian economy over the period was storms, 5) the most total damage caused by a natural disaster occurred in 2004, and 6) an observable change in the disaster profile of Grenada occurred in 2010 with the first-time occurrence of a drought over the period. Even though the database used did not provide specific data regarding this drought, the impact of this phenomenon was enough to be considered a natural disaster versus a hazard (which does not impact humans).

Table 4.12. Natural disaster profile of Grenada between 1978 to 2021 (OECS, 2005; EM-DAT, 2023)*

Disaster year	Disaster types/ names	Total number of deaths	Total number of persons affected	Total damages ('000 US$)
1980	Storm (Allen)	-	-	-
1990	Storm (Arthur)	-	1	-
1999	Storm (Lenny)	-	210	5,5
2002	Storm (Lili)	-	75	-
2004	Storm (Ivan)	39	60	889
2005	Storm (Emily)	1	1,65	53,500*
2010	Drought	-	-	-

According to OECS (2004), the sectors most negatively impacted by Hurricane Ivan were housing, tourism and education, in order of greatest magnitude. Table 4.13 contains estimates of the total, direct and indirect damage caused by Hurricanes Ivan (2004) and Emily (2005). Direct damage included the cost of destroyed assets. Indirect damage referred to the loss in flows of income from these specific sectors (OECS, 2005). In comparison, Hurricane Emily in 2005 impacted the Housing, Agriculture and Education sectors the most (OECS, 2005).

Such costs need to be considered in the valuation of ecosystems as forests, mangroves, seagrasses and coral reefs for example, all contribute towards coastal protection against storms. If such ecosystems are lost, then potentially millions of dollars will effectively also be lost (Table 4.13).

Table 4.13. Total, direct and indirect damages caused by Hurricanes Ivan (2004) and Emily (2005) in Grenada. Damages in millions of US$ (OECS 2004; 2005)

Generic sectors	Specific sectors	Direct damages US$M		Indirect damages US$M		Total damages US$M	
		IVAN (2004)	EMILY (2005)	IVAN (2004)	EMILY (2005)	IVAN (2004)	EMILY (2005)
Social	Housing	508.15	27.41	3.33	0.22	511.48	27.63
	Health	4.07	0.64	0.00	0.39	4.07	1.02
	Education	72.22	4.44	0.37	0.53	72.59	4.97
Productive	Agriculture	20.00	8.70	17.04	4.45	37.04	13.15
	Manufacturing	6.67	-	1.48	-	8.15	-
	Wholesale and retail	-	-	4.07	-	4.07	-
	Tourism	112.96	0.27	37.48	0.41	150.44	0.68
Infrastructural	Electricity	25.93	0.22	7.78	0.10	33.70	0.33
	Water and sewage	2.59	0.19	0.37	0.09	2.96	0.28
	Telecommunication and broadcasting	28.33	0.31	23.11	0.19	51.44	0.50
	Cable	2.96	-	1.85	-	4.81	-
	Transport	3.81	2.67	0.44	0.01	4.26	2.67
Environmental	Environment	-	-	-	0.62	-	0.62
	TOTAL (US$million)	787.69	44.85	97.32	7.01	885.01	51.85

Economic history of the tourism sector in Grenada

Grenada's economic history between 1995 and 2020 generally had a negative impact to the island. Grenada has been affected by the events of September 11, 2001. Two hurricanes (2004 and 2005) impacted the island, then the coronavirus pandemic arose in 2020.

These historical events have been experienced as negative economic shocks in the Grenadian economy and its tourism sector. The sources of these events can be summarised for analytical purposes as internal economic shocks (shocks which originated from events in Grenada) and external economic shocks (shocks emanating from events in another country or countries). Examples of these internal economic shocks, though ecological in origin, in Grenada's economic history occurred in 2004 and 2005 with passage of Hurricanes Ivan and Emily, respectively. Attzs (2005) noted the inseparability that exists between the impacts of ecological shocks and economic shocks when she stated:

"ecological shocks cannot easily be divorced from the impacts of economic shocks since the former can exacerbate the latter, and vice versa."

This island's economic history reveals three negative external economic shocks: 1) the September 11th terrorist attack on the United States of America, 2) the 2008 financial crisis in the United States of America, and 3) the Coronavirus (COVID-19) pandemic. These occurred in 2001, 2008 and 2020, respectively. External economic shocks, therefore, are evidence of one of the negative impacts of globalisation (i.e. when a negative economic shock in one economy or more than one economy contributes to the negative economic shock in one or more other economies).

Figure 4.21 reveals an overall upward trend in the number of international tourist arrivals for the period 1995 to 2020. However, this trend is accompanied with fluctuations. This gently sloped, upward and linear trendline also shows four troughs in the dataset for this period. These troughs illustrate the link between these economic historical events in Grenada and the fluctuations in the number of international

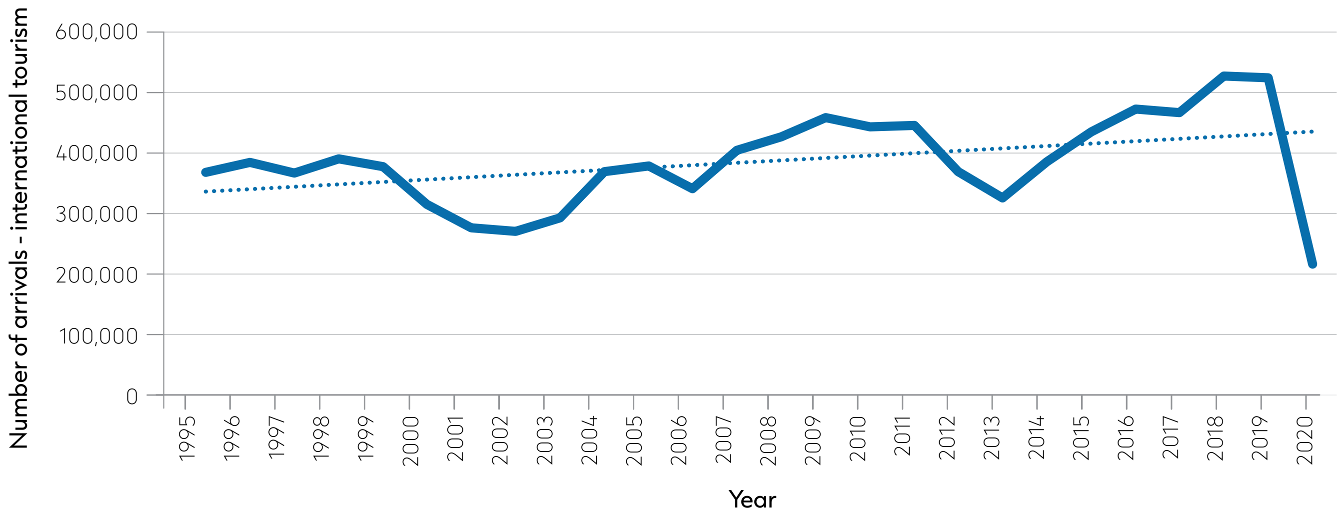

Figure 4.21. Number of international tourism arrivals in Grenada (World Bank, n.d.)

tourist arrivals for the period. In other words, these economic historical events have been experienced as negative economic shocks on the tourism sector (and other sectors) of the Grenadian economy.

These troughs or lowest points in the international tourist arrival dataset occurred in 2002 (271,000 arrivals), 2006 (342,000 arrivals), 2013 (327,000 arrivals) and 2020 (217,000 arrivals). In the case of the latter, this data point represents 309,000 less international tourist arrivals than 2019 or an approximate 59% decline in the number of international tourist arrivals.

Comparing these declines in the number of international tourist arrivals with the events outlined in the economic history of Grenada presented earlier, several preliminary observations can be drawn. First, the decline in the number of international tourist arrivals occurred in 2002 (the year after September 11th terrorist attack on the United States of America in 2001) when there was a resultant fear of travel. Second, the decline in the number of international tourist arrivals occurred in 2006 (the year after Hurricane Emily in 2005 and 2 years after Hurricane Ivan in 2004) when severe destruction occurred to the tourism sector (damage to stock of hotels, loss of jobs etc.) and other sectors of the Grenadian economy. Third, the rapid decline in the number of international tourist arrivals occurred in 2020 (the year the COVID-19 pandemic was experienced in Grenada and the Caribbean) when countries were under lockdown and COVID-19 pandemic restrictions and conditions curtailed global travel.

Such losses are also closely tied to Grenada's ecosystem, as visitors come to the island primarily for its diverse environment. Declines in tourism illustrate the potential loss of revenue to Grenada, and therefore provide another metric towards understanding the overall value of the island's resources.

4.3.7. Value of healthy ecosystems for human and animal health

There is an inextricable link between ecosystem health and human and animal health and well-being. In recognition of this link, the fairly recent field of ecohealth has emerged which dedicates itself to studying how changes in earth's various ecosystems are impacting human and animal health (Charron, 2012). The goal of ecohealth is to re-establish the planet's ecological equilibrium by considering humans as integral and interdependent parts of most ecosystems. Thus, the ultimate objective of ecohealth research and practice is that it helps policy makers engage in environmentally sustainable developments that are supported by the communities that are going to be impacted by such development so that the health of these communities is not adversely affected or compromised.

There are many examples of how anthropogenic driven changes to ecosystems have been the genesis of many virulent new infectious diseases such as SARS, SARS-CoV2, Ebola, Bird flu and Hantavirus to name a few. Many of these diseases have evolved to becoming pandemic events with global adverse impacts on human morbidity and mortality. For example, the current COVID-19 pandemic clearly illustrates the close connection and interaction between humans, animals, and our shared environment. A review of the emergence of this zoonotic virus and its explosive spread provides a sobering reminder of how interconnected humans, animals and their environments are and how things can go very wrong if careful consideration of the impacts of human activities and behaviours is not undertaken.

A powerful conceptual tool that has been developed to help recognise and incorporate this interconnectedness of humans, animals, and ecosystems is the One Health approach (One Health High-Level Expert Panel [OHHLEP], 2022). As visually presented in the Figure 4.22, taking the One Health concept from theory to practice involves 4 Cs: Communication, Coordination, Collaboration, and Capacity building. The One Health concept also recognises the importance of paying attention to issues such as equity, inclusivity, equal access, parity, socioecological equilibrium, stewardship, and transdisciplinarity. The One Health paradigm builds on the ecohealth concept as well as Planetary Health by emphasising a more ecocentric worldview as being necessary in order to secure health and well-being for all lifeforms on this planet.

Figure 4.22. Development of 'One Health' ideology
(OHHLEP, 2022)

4.4. Local knowledge on the value of genetic and ecosystem resources

Local knowledge pertaining to this chapter's focus has been captured through surveys and interviews as described in sections above. Apart from these mechanisms, in September 2022, a stakeholder workshop was held to capture further stakeholder perspectives and indigenous knowledge. This was held in three sessions, with a wide variety of individuals representing civil and private sectors, with youth and elders alike, Government and environmental groups.

Stakeholders found that water (oceans, rivers and lake) should be considered as a valuable resource. Marine resources were perceived as disappearing due to overfishing (e.g. jacks and scads) and agricultural and chemical pollution (e.g sardines and fry). In terms of freshwater resource, besides Titiree and crayfish, one measure of its value can be by its use and reuse.

Another measure is the number of visitors to areas such as Grand Etang. In particular, stakeholders saw the value of Grand Etang given that foreign visitors were much greater than local ones, as could be represented by income to tour operators, transport providers, and such. Rivers in particular were also perceived to have value from a social perspective, including a resource for domestic chores for those who don't have pipeborne water. Stakeholders were aware that possible losses of income will come from pollution, among other things, of these resources.

Second, value of terrestrial resources (including forests) included well known crops such as those associated with spices and cocoa. Lesser known included bay leaf, which is used for bay rum, cooking and natural insecticides. Terrestrial resources were also believed to be key sources of medicines, such as the Sulphur springs (e.g. Clabony and Chambo), while a variety of backyard gardens were important to Grenadians, and supported what was presented within this Chapter. Stakeholders also recognised that diseases can negatively impact crops such as soursop. Plastic pollution was also flagged as harmful to human health as well as to the environment. The ability of Grenada to source food and materials locally was viewed as increasing resource value.

Third, stakeholders were able to indicate emerging issues and opportunities. Ecotourism was of particular interest for Grenada, with a move towards smaller rather than larger hotels in order to support niche tourism opportunities. In addition, natural products needed to be researched more, especially potential medicines (e.g. moringa, turmeric, ginger, soursop).

Most encouragingly, stakeholders were aware and concerned about those resources that may have a possible value though presently unknown or unmeasured. Stakeholders suggested that an inventory be conducted to enhance the findings of the current assessment. Resources to be inventoried included soils, wild seeds, ports and invasive species to name a few. Further, stakeholders were also cognizant that the value of resources were more than economic, and can also have cultural value. Overall, there was a need for Grenada to build capacity, awareness and advocacy for value of resources.

4.5. Key emerging issues

4.5.1. Conservation, wise use and benefit-sharing

Much of the instrumental value of genetic resources is tied to current and potential use of the organism. This potential use, or possible bioprospecting of genetic resources is generally viewed as holding significant promise for example through: 1) future direct revenue, 2) development of new drugs and other products that can be used to address key developmental challenges including combating disease, and 3) contributing to food security through sustainable agriculture practices. Given the largely untapped potential exploration, coupled with the paucity of knowledge on Grenada's genetic resources, it is important to ensure that these are conserved and protected now, to ensure the continued access to future use and potential.

The contribution and impact to both intrinsic and relational values are also important. The impact of natural disasters, for example, is of increasing concern. Islands especially struggle to keep up with the velocity of impacts due to environmental changes such as climate change. It is important that genetic resource ecological services and functions are well understood in order to cope with the increasing impacts of climate change. In addition to this, the introduction of non-native species, and the loss of plant and animal genetic resources are among some of the key emerging issues threatening endemic genetic resources in the tri-island state.

The introduction of IAS with emphasis on the impacts to endemic genetic resources is an emerging threat that has received increasing attention. IAS have taken on increased significance more recently with interest in blue economy and marine genetic resources. Additionally, the identification and maintenance of genetic variability for animal and plant breeding programs where local genetic stock are the cornerstone of unique niche markets are well suited to local conditions. Appendix 1 assesses the genetic and ecosystem resource potential via a SWOT analysis that should be considered in conservation and protection actions.

Another area for future consideration is the issue of microbial genetic diversity. While biodiversity is often limited to charismatic megafauna and flora it is important to ensure meiofauna and microbial communities maintain their integrity and ecological balance. Soil microbiome genetic diversity is linked to macro flora and fauna and there before better understanding of threats (e.g. sick soil syndrome) and potential opportunities for utilisation of new genetic resources should be part of national policy.

Another consideration is the impact of climate change impacts on terrestrial and marine genetic resources. Global warming has resulted in more extreme levels of natural hazardous events such as hurricanes. For example, in the marine context, hurricanes and coral bleaching have both direct and synergistic impacts on coral reefs. Hurricanes can cause massive damage to the structure of coral reefs and cause widespread reef death (Pendleton *et al.*, 2016). The combined effects of hurricanes and bleaching have been blamed for much of the decline in coral cover in the places that are otherwise well managed. Sustained bleaching events also can cause reef death (Hoegh-Guldberg, 1999). Climate change impacts affect reproduction and growth of plants and animals in addition to the abiotic substrates (soils, marine benthos) that living organisms depend on.

4.5.2. Recommendations for policy makers and key policy tools to consider

Policy recommendations at the ecosystem resource level

In Grenada, there are a number of policies, institutional mandates and laws (see Chapter 1) that form a patchwork to regulate ecosystem conservation and wise use including through the establishment and operationalisation of PAs. In this section, we explain five different types of policies and measures that can be considered for the conservation and sustainable management of Grenada's genetic and ecosystem level goods and services. These are: 1) Natural Capital Accounting, 2) Payment for Ecosystem Services (PES), and 3) NCP and stakeholder engagement.

Natural Capital Accounting

Natural Capital Accounting approaches are necessary because the benefits provided by ecosystems to human welfare and economic systems are not fully captured in national accounting frameworks because most of these benefits are non-market goods and services [1]. Without considering these values and benefits in our national accounting systems that develop GDP and growth estimates, public and private decisions made often lead to the loss of some or all of these net benefits. Natural Capital Accounting frameworks such as the United Nations System of Environmental-Economic Accounts offer a framework that integrates not only environmental but also economic data to provide a more comprehensive view of the complex relationships between humans, their economies and the environment. These accounts can be used just like national accounts to understand the effects environmental trends have on national well-being and national environmental assets.

Natural Capital Accounting approaches can also be used and promoted in private sector contexts. The natural capital protocol is a decision making framework for private sector organisations that helps them identify and value their impacts on the environment but also their dependencies on natural capital.

In the Grenadian context these tools are particularly important, as many economic activities are built on a foundation of natural capital, yet current macroeconomic decision making primarily articulates investments in human-built capital. Large foreign investors in industries such as construction, tourism and education (but not limited to these) should consider applying the natural capital protocol to their operations to ensure that they are not degrading the natural capital upon which they depend and thus jeopardising their long-term operations.

Payments for Ecosystem Services Approaches

PES are payments to farmers or landowners who have agreed to take certain actions to manage their land or watersheds to provide an ecological service. PES is recognised as a market-based mechanism, similar to subsidies and taxes, to encourage the conservation of natural resources (International Institute for Environment and Development [IIED], 2022). For example, a forest regulates water flow

[1] Non market good and services are things that are not bought and sold directly,

and purifies rainwater; due to the existence of this forest, the urban population enjoys a good quality of water (which is the well-defined ES). Here those who maintain this forest (often the landowners) are considered the ES providers and the urban populations are the ES buyers. PES is a scheme to provide payment or subsidies to the ES provider if they properly manage nature to deliver certain types of ES. PES often takes the form of taxes, which is not voluntary as the cost of negotiating payment (transaction cost) for individual ES buyers and ES providers is very high (Vatn, 2010). Often the state or local government has to play the role of intermediary between ES buyers and ES providers in setting up the conditionality and level of payment (Muradian *et al.*, 2010).

NCP and stakeholder engagement

NCP "are all the contributions, both positive and negative, of living nature (i.e. diversity of organisms, ecosystems, and their associated ecological and evolutionary processes) to the quality of life for people" (IPBES 2023). This term was coined to broaden the framework of ES based on four categories, provisioning, regulating, supporting and cultural. It was argued that the valuation based on ES prioritised the narrow set of values, especially monetary or instrumental values, and ignored the indigenous people and local communities' (IPLC) worldviews and knowledge systems (Pascual, 2022). This new notion of NCP allows the incorporation of diverse values of nature into policy making as well as the engagement of diverse stakeholders.

Policy recommendations at the genetic resource level

The genetic resources found in Grenada may have many potential uses and can provide opportunities to derive economic and social benefits from harvesting, thereby forming a niche economic sector. However, to fully realise this potential, measures must be considered which can safeguard the country from biopiracy and illegal bioprospecting. Being a party to the *Nagoya Protocol* offers a framework to allow Grenada to better manage its genetic stock and forge partnerships for use and harvesting in a transparent manner, by creating enabling conditions. Moving towards ratification of the *Nagoya Protocol* gives Grenada, and by extension its genetic resources, protection under international law, thereby having a recourse under said laws should it be required. In addition, acceding also gives more access to resource and training.

Grenada's environmental laws impacting genetic resources have been noted as having a particular focus e.g. dealing with issues such as conservation of flora and fauna and protecting species, or by covering specific activities or possible effects e.g. *Fisheries Act*, 15/1986, *Grenada Territorial Sea and Maritime Boundaries Act*, 25/1989, *Plant Protection Act*, 19/1986, *Wild Animals & Bird Sanctuary Ordinance*, Cap.314 (1928, revised Cap.234 (1934) & 29/1956) and *National Parks and Protected Areas Act*, Cap. 206 (1991).

Positively, the *Environmental Management Bill, 2007* (EMB) with update in 2018 can create a basic framework for holistic management with an objective of ABS in Grenada. Regulations would however need to be drafted under an overarching approved Environment Management Act that may provide further specificity to the implementation of fair and equitable benefits from sustainable utilisation of genetic resources.

Along with the legislation, Grenada's Systems Plan for Parks and Protected Areas provides a basis for the establishment and management of a national parks and PAs programme. The steps involved include: site identification, site assessment, boundary demarcation, Cabinet approval, Parliament approval, Governor General signature on key documents and three postings in the Grenada Government Gazette.

Green and blue bonds

Bonds are debt and lending instruments issued by public or private organisations to raise capital to finance projects generating environmental impacts alongside financial returns. They are an investment-based mechanism that can be used to address social and political priorities of terrestrial and ocean conservation. Bonds are used to provide countries with immediate upfront cash flow and long-term benefit via strengthening natural resource conservation (for example forests and fisheries) that can be re-monetised (additional rounds of bonds) with higher value in the long term. Terrestrial conservation can be funded through green bonds while financial support for ocean and coastal conservation have been through blue bond instruments.

Environmental bonds have been used as a debt-repayment/debt-swap instrument to reduce sovereign debt while simultaneously providing cash flow for conservation. The design and purpose of these bonds will be context specific and tailored to national needs. Well designed and enforced blue or green bond instruments should, over time, generate both principal and interest that can be returned to investors, while nations such as Grenada would keep the initial bond cash flow. These funds can be used however the Government of Grenada sees fit, including direct conservation of natural resources, to build roads, improve schools or hospitals, or provide social benefit funds to the general public.

It should be noted that natural resource bonds are not a panacea and may come with challenges to investment such as lack of clarity about structure of the bonds, absence of viable local projects and strong governance structures.

4.6. Conclusions

Although Grenada is viewed as having an abundance of genetic resources, an accurate inventory is still lacking. However, it is evident that both the terrestrial and marine environments are rich in biodiversity including endemic species. Genetic resources stem from biodiversity, and are important to humans, their well-being and development. These resources serve to support food security, dietary health and livelihood sustainability. They also provide important resources for medical research as studies of wildlife anatomy, physiology and biochemistry can lead to important developments in human medicine. These genetic resources also provide important resources for traditional and modern medicine, where many modern drugs are derived from wild species.

Emerging opportunities on the horizon include sustainable development of the bioprospecting sector, the documentation of traditional knowledge associated with genetic resources and the opportunity to set up integrated legal and institutional management of genetic resources through instruments such as the *Nagoya Protocol* on ABS.

As such, opportunities for conserving, managing and using genetic resources within a coherent framework that considers prior informed consent and mutually agreed terms in concert with traditional knowledge about those resources, as available through the *Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits* needs to be explored.

In this light, two clear policy recommendations are for Grenada to accede to the *Nagoya Protocol* and for Grenada to review, update and pass strong, overarching, environmental management legislation. Should this occur, alongside of enforcement, the instrumental, intrinsic and relational values of Grenada's rich genetic and ecosystem resources will be enjoyed for generations to come.

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Appendices

Appendix 1. Emerging issues, threats and opportunities for management of resources (SWOT Analysis) based on (A) Aquatic, (B) Unmanaged, (C) Managed and (D) Agrosystems

A. Aquatic resources

STRENGTHS	OPPORTUNITIES
• Existing marine-based eco-tourism sector – educational and recreational diving, turtle-watching • Network of Marine Protected Areas • Strong network of Fisherfolk Associations and Cooperatives	• Further development of existing marine educational and research institutions e.g. St. Georges University and The University of the West Indies • Develop suitable policies and legal framework to protect marine biodiversity • Use of technology to monitor coastal activity
WEAKNESSES	**THREATS**
• Lack of awareness of wealth of genetic resources, and finite nature of marine resources • Challenges in effectively implementing and managing Marine Protected Areas • IAS such as lionfish • Vulnerability to climate change and associated events such as hurricanes • Lack of data on freshwater species • Unregulated clearance of mangroves, unregulated removal methods for sargassum, continued illegal sand mining • Nature of multiple islands' coast and coastline provides challenges for enforcement of regulations and controls	• Poorly managed marine tourism and ecotourism • Unsustainable and indiscriminate fishing practices • Challenges of protecting extensive marine borders from invasive species and disease • Further impacts of climate change • Illegal, unreported and unregulated fishing • Evidence of coastal populations of conch and lobster in decline for many years • With the most valuable real estate being coastal, inadequately managed tourism and property development impacts the marine and coastal aquatic ecosystems disproportionally • Bad land management practices impacting fresh water and coastal ecosystems • Pressure from outside interests to maximise catch, impacting development of sustainable national fishing management practices

B. Unmanaged resources

STRENGTHS	OPPORTUNITIES
• Strong indigenous culture and knowledge of medicinal plants • Many plants of medicinal value • Local production of natural wellness and cosmetic products from local plants • Existing- if limited- development of pharmaceutical products	• Support for further development, production and export of natural wellness and cosmetic products • Document and record indigenous knowledge- both medicinal applications and how and where plants grow • Strategy to facilitate development of pharmaceutical and nutraceutical products • Encourage local use of local medicinal and wellness products
WEAKNESSES	**THREATS**
• Lack of access to research and development (R&D) facilities and expertise • Undocumented indigenous knowledge • Lack of awareness of genetic wealth and how ecosystem degradation will impact this wealth • No association or formal representation of medicinal plant interests • Vulnerability to climate change and associated events such as hurricanes • Lack of data due to non-formal nature of sector	• Social changes reducing opportunity for knowledge transfer from older generations to youth • Uncontrolled bioprospecting • Loss of habitat such as mangrove and offshore islands as a result of unregulated physical development including tourism development • Further impacts of climate change • Alien and invasive species

C. Managed

STRENGTHS	OPPORTUNITIES
• National importation and border controls for plant material and animals • National farmers cooperatives and support organisations • Membership and support from international agencies e.g. FAO and the Inter-American Institute for Cooperation on Agriculture and regional agencies e.g. Caribbean Agricultural Research and Development Institute (CARDI) • National e.g. Ministry of Agriculture and cooperatives, associations and farmers support systems, with specific organisations for women (e.g. Grenada Network of Rural Women Producers) • Unique ecosystem niches supporting the cultivation of specific high value commodity crop species • Network of National Parks and Protected Areas • Strong cultural agricultural history, with widespread indigenous knowledge of cultivation, farming, both plants and animals • Existing linkages between agriculture, horticulture, culinary and tourism sector • Growing entrepreneurial agroprocessing industry • Rich range of native species across all food groups suited to small-scale and home garden cultivation • Resilience (disease, drought, security) • Strong and established brand recognition for existing agricultural and horticultural products	• Cultivation and crops suited for internationally growing niche markets, for example organic and ethically-farmed markets • Existing 'Pure Grenada' tourism branding well placed for promoting nationally branded agricultural products for export • Digital and smart agriculture • Further development of existing centres of agricultural and ecological education, expertise and research e.g. CARDI, the National Science and Technology Council, and SGU • Review and develop suitable policies and legal framework to protect terrestrial biodiversity • Increasing level of interest in agriculture amongst young people • Demonstrated benefits from pest-free status for soursop exports • Public education of value of national genetic resources • Renewed focus on food security and production as a result of COVID-19 pandemic • Increased regional export opportunities as climate change and other events impact other nations
WEAKNESSES	**THREATS**
• Loss of yield due to previously imported diseases and pests • Damaging and unsustainable land and agricultural practices • Ongoing soil erosion and degradation • Limited R&D expertise and facilities • No existing capacity to protect or preserve plant species and varieties • Lack of data • Vulnerability to climate change and associated events such as hurricanes • Isolated stakeholder associations for different agricultural sectors • Extensive private ownership of land and inability to control its management • Land protection policies and controls inadequately enforced • Lack of awareness of wealth of genetic resources • Continued use of damaging and unsustainable agricultural and land management practices	• Housing trends in the low income sector – towards homes without garden • Inadequately controlled commercial and private development of areas of unique habitat such as agricultural land, mangroves and offshore islands • Loss of genetic strains as households purchase rather than grow food for home consumption • Further impacts of climate change • Alien and invasive species • Diseases and pests • Poorly managed ecotourism • Unmanaged synthetic biology impacts

D. Agrosystems

<table>
<tr><th>STRENGTHS</th><th>OPPORTUNITIES</th></tr>
<tr><td>
• Rich, fertile volcanic soils and humid, tropical marine climate with little seasonal variations.
• Unique ecosystem niches that support the cultivation of high value commodity crops:
◦ Forastero cocoa varieties require cooler conditions present within Grenada's mountainous interior.
◦ Unique nutmeg flavour profile which appears to be a combination of genetics and environmental factors.
• International, regional and national agencies (e.g. FAO, CARDI and Ministry of Agriculture) that support farmers, with specific organisations for women and youth.
• Established cooperatives with strong farmer ties
• Lots of business and investment opportunities as it pertains to producing local products.
• Wide diversity of established seasonal flowering trees within the forest and agroforest ecosystems (supports the apiculture industries)
• A relatively young population interested in applying new innovation and science-based techniques to agriculture.
• International brand recognition e.g. 15 time gold medallist at the Royal Horticultural Society Chelsea Flower Show in London and gold medal at the 84th National Honey Show in London.
• The Grenada Chocolate Family won best in the world at the Gourmand World Cookbook Awards in China.
• Internationally known for 100% fine flavour cocoa by the ICCO
• Available markets
◦ Local markets: Grenada imports about 70% of its food and has a high local demand for sweet potatoes, bananas, dasheen leaves, cabbage, tomatoes, pineapples and yams that can be produced locally.
◦ Agrotourism: High demands for locally produced tomato, watermelon, honeydew melon, avocado, citrus, cantaloupe, mangoes (Julie, Graham and Ceylon varieties).
◦ Regional markets: Mangoes, golden apples, sapodilla, plums, and avocados, dry coconut and breadfruit.
◦ International markets: Soursop, local flowers, cocoa, nutmeg (raw and value-added products)
</td><td>
• Diversification of agronomic practices to support and provide multiple ecosystem services.
• Bioprospecting from species adapted to unique micro-climates.
• Niche markets such as:
◦ carbon markets for farmers
◦ horticulture
◦ organic farming
</td></tr>
<tr><th>WEAKNESSES</th><th>THREATS</th></tr>
<tr><td>
• Competition for land (especially for housing)
• Lack of integration between conservation and utilisation programmes.
• Lack of human and financial resources.
• Lack of coordinated programmes that adequately reflect agricultural needs/ demands.
</td><td>
• Climate change and seasonal variability (shifts in species distributions, loss of plant, animal and soil microbial biodiversity)
• Deforestation (affecting ecosystem services, which includes pest control, soil conservation and water provision, quality and quantity)
• Loss of wildlife habitat.
• Poor farm management practices
• Overuse of chemical inputs (loss of diversity/ increases in resistant pest and disease)
• Monocropping farming practices (genetic erosion)
• Limited landrace conservation over imported high yield varieties.
</td></tr>
</table>

Appendix 2. *Overall top marine species based on fisheries landings for the period 1978-2017, separated by large and small pelagic species, reef species, and other catch. Data from Fisheries Division (2021)*

Rank	**Large Pelagic**	**Small Pelagic**	**Reef Species**	**Other**
1	Yellow fin tuna* *Thunnus albacares*	Bigeye scad* *Selar crumenophthalmus*	Red hind* *Epinephelus guttatus*	Lobster *Panulirus argus*
2	Blackfin tuna* *Thunnus atlanticus*	Round scad* *Decapterus tabl*	Snapper Lutjanidae	Conch *Aliger gigas*
3	Atlantic sailfish* *Istiophorus albicans*	Jack Carangidae	Parrot fish Scaridae	Turtle Cheloniidae
4	Common dolphin fish* *Coryphaena hippurus*	Brazilian sardine *Sardinella brasiliensis*	Coney *Cephalopholis fulva*	Sea urchin *Tripneustes ventricosus*
5	Great barracuda *Sphyraena barracuda*	Ballyhoo halfbeak *Hemiramphus brasiliensis*	Grouper Serranidae	Squid Loliginidae
6	Wahoo *Acanthocybium solandri*	Atlantic thread herring *Opisthonema oglinum*	Grunt Haemulidae	
7	Flying fish Exocotidae	Keeltail needle fish *Platybelone argalus*	Sandtile fish *Malacanthus plumieri*	
8	Blue marlin *Makaira nigricans*	False herring *Harengula clupeola*	Squirrel fish Holocentridae	
9	Rainbow runner *Elagatis bipinnulata*	Anchovie *Anchoa hepsetus*	Doctor fish Acanthuridae	
10	Swordfish *Xiphias gladius*	Common snook Centropomidae	Queen trigger fish *Balistes vetula*	
Total spp.	28	11	16	5

**Commonly overall top catch species per year*

Appendix 3. Common fisheries between domestic (production) and export for Grenada between 2013 and 2017, showing the summary value (Raw data obtained from Fisheries Division (2021))

Production	Species	Production income (US$)	Export income (US$)	Total income (US$)
Atlantic sailfish	*Istiophorus albicans*	$ 3,658,675.11	$ 53,465.48	$ 3,712,140.59
Bigeye scad	*Selar crumenophthalmus*	$ 693,884.59	$ 117,561.09	$ 811,445.68
Bigeye tuna	*Thunnus obesus*	$ 585,452.25	$ 317,973.00	$ 903,425.25
Blue marlin	*Makaira nigricans*	$ 1,327,198.06	$ 4,770.47	$ 1,331,968.54
Cavalli / Jack	Carangidae	$ 899,619.77	$ 7,031.11	$ 906,650.88
Conch	*Aliger gigas*	$ 818,917.73	$ 570,696.66	$ 1,389,614.39
Coney	*Cephalopholis fulva*	$ 1,191,166.36	$ 127,609.63	$ 1,318,775.99
Grunt	Haemulidae	$ 158,305.14	$ 21,570.37	$ 179,875.51
King mackerel	*Scomberomorus cavalla*	$ 252,415.80	$ 480.00	$ 252,895.80
Lobster	*Panulirus argus*	$ 1,986,848.08	$ 1,865,239.53	$ 3,852,087.61
Parrot fish	Scaridae	$ 2,886,425.64	$ 1,167,504.43	$ 4,053,930.07
Red hind	*Epinephelus guttatus*	$ 3,245,742.64	$ 620,136.30	$ 3,865,878.94
Round scad	*Decapterus tabl*	$ 557,790.06	$ 36,422.96	$ 594,213.02
Snapper	Lutjanidae	$ 1,738,043.63	$ 136,977.46	$ 1,875,021.09
Squirrel fish	Holocentridae	$ 113,899.86	$ 34,880.74	$ 148,780.60
Sword fish	*Xiphias gladius*	$ 876,269.97	$ 352.25	$ 876,622.21
Wahoo	*Acanthocybium solandri*	$ 871,372.10	$ 4,775.19	$ 876,147.29
White marlin	*Tetrapturus albidus*	$ 441,148.28	$ 2,243.52	$ 443,391.80
Yellow fin tuna	*Thunnus albacares*	$ 37,558,996.70	$ 32,714,236.98	$ 70,273,233.69
TOTAL		$ 59,862,171.77	$ 37,803,927.17	$ 97,666,098.95

Appendix 4. Common river species and their associated value in Grenada (Data compiled from Fisheries Division (2021) and Ministry of Agriculture (2021))

Common Name	Latin Name	Economic Value (US$)	Intrinsic Value	Cultural Value
Invertebrates				
Cray fish	*Macrobrachium* spp.	$3.26/kg	Important part of freshwater food web	Consumption is common among friends (especially young males) as part of a specialised event e.g., "river cook"
Caca dos (giant freshwater shrimp)	*Atya* spp.	$0.81/kg [1]	Part of food web and possible new subspecies	Used as bait by little boys
Land crabs	Gecarcinidae	~$48,148/yr (sold locally and exported to neighbouring islands)	Key part of wetland ecosystems and food web; scavenger	Appetiser/delicacy for local dishes
Manicou crab	Potamonidae	Not investigated	Part of inland and riparian zone food chain; scavenger	Appetiser/delicacy for local dishes
Fresh water snails	*Ampullaria*	~$1.01/kg (used as bait instead of worms by young boys fishing in rivers.	Potential intermediate host for a parasite	Not investigated
Oysters *brackish water and marine environment	*Crassostrea* spp.	~$2.42 –$5.70/kg (used by local Carriacou communities) [2]	Part of food web Trapping food and nutrient particles, chemical pollutants, and residue	Not investigated
Caddisfly larvae	*Trichoptera* spp.	Not investigated	Important part of food web	Not investigated
Fish				
Mullet	*Mugilidae*	Used to be economically important but declined. Current status unknown.	Part of freshwater food chain - herbivore	Recognised in poetry
Mud fish	*Neochanna burrowsius*	Status unknown	Part of food chain	Not investigated
Shad	*Clupeiformes*	Used to be economically important but declined. Current status unknown.	Part of food chain	Not investigated
River Snapper	*Lutjanus argentimaculatus*	Used to be economically important but declined. Current status unknown.	Food for larger fish	Not investigated
Brochet	*Centropomidae*	Not investigated	Part of food chain	Not investigated
Silver Eel	*Ariosoma mellissii*	Not investigated	Part of food chain	Not investigated

Common Name	Latin Name	Economic Value (US$)	Intrinsic Value	Cultural Value
Suck fish	*Hypostomus plecostomus*	Not investigated	Food for other fish	Not investigated
Titiree	*Sicydium* spp.	~$22,222/season per site (sold fresh for local market only – no export).	Food for other fish	Equipment and skill handed down from one generation to the next; family may use same site (site fidelity)
Sards	*Taxonomy unclear*	Status and economic importance unknown	Food for other fish	N/A
'Millions'	*Girardinus poecilodes*	Status and economic importance unknown	Food for other fish	Not investigated
Amphibians				
Lesser Antillean Whistling frog	*Eleuthrodactylus johnstoni*	Part of ecotourism product; part of academic tourism	Important part of food chain, eats insects	Not investigated
Whistling frog	*Pristimantis urichi*	Part of ecotourism product	Important part of food chain; bioindicator eats	Not investigated
Grenada piping frog	*Pristimantis euphronides* (genetic work being undertaken to inform nomenclature)	Part of ecotourism product; part of academic tourism	Endangered, endemic * (genetic work now being carried out to support morphometric work) with limited range.	Not investigated
Mountain Chicken	*Leptodactylus fallax*	$3.26-$8.95/kg [3]	Important part of food chain, eats insects	Not investigated

1. Sold only as bait
2. Carriacou oysters
3. Edible/Delicacy (not eaten in Grenada but considered a delicacy in other islands e.g. Saint Lucia, Dominica, Martinique)

Appendix 5. List of endemic species of Grenada (Hawthorne et al., 2004; Daniel Lewis, Ministry of Agriculture, 2021, personal communication)

	Name	Latin name
Vertebrates	The Grenada dove	*Leptotila wellsi*
	The Grenada flycatcher	*Myiarchus nugator*
	The Grenada hook-billed kite	*Chondrohierax uncinatus mirus*
	Lesser Chapman's murine opossum	*Mormosa robinsoni chapmoni*
	The Grenada tanager	*Stilpnia cucullata*
	Grenada rice rat	*Megalomys camerhogne*
Reptiles and Amphibians	Grenada tree anole	*Anolis richardii , A. aeneus*
	Grenada tree boa	*Corallus grenadensis*
	The Grenada piping frog	*Pristimantis euphronides*
	The Grenada worm snake or Grenada bank blind snake	*Amerotyphlops tasymicris, (Typhlops tasymicris)*
	Barbour's tropical racer	Mastigodryas bruesi
	Garman's thin-toed frog	*Leptodactylus validus*
Insects	velvet worm	*Epiperipatus barbouri*
	ant	*Nylanderia coveri*
	Bess beetle	*Passalus antillarum*
	caddisflies	*Neotrichia nesiotes , Smicridea grenadensis*
	chalcidoid wasp	*Miotropis histrionica*
	darkling beetle	*Cyrtosoma grenadense*
	flat bug	*Peggicoris grenadensis*
	ground beetle	*Pseudaptinus thaxteri*
	long-horned beetles	*Eutrypanus grenadensis* **,** *Decarthria albofasciata*
	mayfly	*Farrodes grenadae*
	ox beetle	*Lutrochus grenadaensis*
	stenomid moth	*Antaeotricha suffumigata*
	sweat bee	*Habralictus insularis*
	flea beetles	*Monotalla obrienorum*, *Lactica grenadensis*
	travertine beetle	*Strategus tarquinius*
	tumblebug	*Canthon perseverans*
	weevil	*Sicoderus woodruffi*
Other invertebrates	marine snail	*Triphora grenadensis*
	millipede	*Epinannolene grenadae*
	centipede	*Gonethina grenadensis*
	goblin spider	*Simonoonops etang*
	land snails	*Bulimulus wiebesi, Neocyclotus grenadensis* *Helicina keatei*
Plants	flowering plant	*Charianthus grenadensis*
	shrub	*Rhytidophyllum caribaeum*
	cinnamon	*Monteverdia (or Maytenus) grenadensis*
	tree fern	*Cyathea elliottii*
	orchid	*Epidendrum grenadense*

Appendix 6. Example of timber species of economic importance in Grenada (Daniel Lewis, Ministry of Agriculture, 2021, personal communication)

Tree	***Latin name***	Status
Bois agoutie	*Maytenus grenadensis*	Endemic
Laurier	*Ocotea eggersiana; O. martinicensis*	
Mauricif/Bois Tan	*Pouteria multiflora; Byrsonima martinicensis*	*B. martinicensis* only in windswept mountain thickets and elfin forest
Caca poule	*Ilex sideroxyloides*	
Bois gris	*Licania ternatensis*	
Chataignier	*Sloanea massoni, S. caribaea*	endemic to lesser and greater Antilles
	Hymenaea coubaril L.	
	Guapira fragrans	
	Pouteria multiflora	
	Dacryodes excelsa	
	Manilkara bidental	

Appendix 7. List of traditional/cultural and back-yard herbal and medical genetic resources (Pavy A, 1987; Maureen M. Charles, Rastafarian Heritage Society, 2021, personal communication, 30 July)

Common Name	Scientific Name	Local uses
Chadon beni	*Eryngium foetidum*	- Use as seasoning and food flavoring - Help with blood circulation and headaches
Bird pepper	*Capsicum annuum 'Pequin'*	- Use as seasoning and food flavoring (e.g., homemade hot sauces) - Help to alleviate headaches cause by stroke
Heliconia	*Heliconia rostrata*	- Flower bracts used as cups - Sometimes used as food additive in food rich in iron for better taste.
Clove	*Syzygium aromaticum*	- Help elevate pain and has anti-inflammatory properties - Use to keep arteries clean
Sharpo glow		- Use for headache and sweating out impurities when placed on the forehead - Lowers high blood pressure
Santa maria	*Parthenium hysterophorus*	- Leaves use in teas - Used for colds and respiratory issues
Sugar dish		- Cold and respiratory issues
Guava	*Psidium guajava*	- Sometime used as toothpaste for its antibiotic properties
Glory cedar	*Gliricidia sepium*	- Used for dermatological issues - Used as a stake for vanilla vines to grow on
Corailli or Corilla bush	*Momordica charantia*	- Used for eczema and other dermatological issues - Leaves use in teas
Tamarind	*Tamarindus indica*	- Leaves are used for lowering and regulating blood pressure - Leaves used in teas
Moringa	*Moringa oleifera*	- Used for cancer treatment - Used as an additive in foods
Blue ven ven	*Verbena hastata*	- Used for bathing, COVID-19 and in teas
Cojo root	*Petiveria alliaceae*	- The root is used for sinus issues, cold and fever
Jumbie cucumber		- When ripe can be used as a laxative
Nettle (zoti)		- Help with circulation - Help cleans the liver
Turmeric	*Curcuma longa*	- Combined with black pepper, it helps activate anticoagulated properties in it and makes it easier to digest - Reduces inflammation - Use for chest inflammation and diabetics - Used on skin and teeth as a lightening agent
Skinip	*Melicoccus bijugatus*	- Filled with vitamin C and B and good for the immune system
Soursop	*Annona muricata*	- Young fruits help with sleeping
Coleous	*Coleus scutellarioides* (Sub sp.)	- Antifungal properties use to help with athletes' foot
Sweet basil	*Ocimum basilicum*	- Use as food seasoning and for high fever
Goldenseal	*Hydrastis canadensis*	- Use as blood cleanser, and to help treat enzyme
Lemon grass	*Cymbopogon citratus*	- Leaves used in teas, and to treat high fever
Dandelion	*Taraxacum* sp.	- Help with prostrate issues
Zebapique	*Neurolaena lobata*	- Use as a blood cleaner
Stone breaker or seed-under-leaf	*Phyllanthus niruri*	- Use to remove kidney stones and lower blood sugar

Appendix 8. Variety and sale cost of common propagated plants in Grenada (Data provided by Ministry of Agriculture (2021))

Propagated plants	Specific trait/ variety (e.g., good root stock, drought resistance)	Sale price (per plant) US$
Citrus		
Grapefruit, Marsh seedless	Good scion material	$1.85
Grapefruit, Thompson pink	Good scion material	$1.85
Lemon, Rough	Good rootstock,	$1.85
Lemon, Villa Franca	Dense foliage, good vitamin C source,	$1.85
Lime, West Indian	High in vitamin C, Good source of antioxidants	$1.85
Lime, Tahiti	Large fruits, disease resistant but susceptible to root rot.	$1.85
Orange, Ruby king	Good scion material	$1.85
Orange, Surprise	Good scion material	$1.85
Orange, Parson Brown	Good scion material	$1.85
Orange, Campbell	Good scion material	$1.85
King Orange	Good scion material	$1.85
Orange, Pineapple	Good scion material	$1.85
Orange, Jaffa	Good scion material	$1.85
Washington Navel	Good as scion, highly palatable	$1.85
Valencia Orange, Olinda	Good as scion, highly palatable	$1.85
Mandarin Duncan	Good scion material	$1.85
Mandarin, Ponkan	Good scion material	$1.85
Mandarin, Encore	Good scion material	$1.85
Ortanique		$1.85
Tangerine	Good scion material	$1.85
Pomello		$1.85
Bergamot		$1.85
Sweet gospo/ Seville sweet	Good rootstock, Hardiness	$1.85
Sour Gospo	Good rootstock, Hardiness	$1.85
Kumquat		$1.85
Grapefruit, Chironja		$1.85
Ugli fruit		$1.85
Rough Lemon		$1.85
Varieties of yams		$0.93
Belep	Highly nutritious, rich in antioxidants,	$0.93
Kinabayo		$0.93
Purple moonshine	Highly nutritious, rich in antioxidants,	$0.93
Atuta	Highly nutritious, rich in antioxidants,	$0.93
Chinese	Highly nutritious, contains bioactive metabolites	$0.93
Ackam	Highly nutritious, rich in antioxidants,	$0.93
Pimblite	Highly nutritious, rich in antioxidants,	$0.93
Ashmore	Highly nutritious, rich in antioxidants,	$0.93
Lisbon	Environmental hardiness	$0.93
Campbell		$0.93
Local bush Yam	Environmental hardiness,	$0.93
Kush- Kush		$0.93
Varieties of Pineapple		
Sugar Loaf	Drought resistant, intolerant to heat stress	

Propagated plants	Specific trait/ variety (e.g., good root stock, drought resistance)	Sale price (per plant) US$
Tainung # 4	Drought resistant, intolerant to heat stress	
Tainung # 11	Drought resistant, intolerant to heat stress	
Smooth Cayenne	Drought resistant, intolerant to heat stress	
Varieties of Cassava		
Senorita	Tolerant of low pH and high aluminum saturation	$0.37
MCOL 1468	Tolerant of low pH and high aluminum saturation	$0.37
MCOL 26	Tolerant of low pH and high aluminum saturation	$0.37
Chinese	Tolerant of low pH and high aluminum saturation	$0.37
MCUB 75	Tolerant of low pH and high aluminum saturation	$0.37
MCUB74	Tolerant of low pH and high aluminum saturation	$0.37
CM 2600-2	Tolerant of low pH and high aluminum saturation	$0.37
CM 2766-5	Tolerant of low pH and high aluminum saturation	$0.37
CM 2772-3	Tolerant of low pH and high aluminum saturation	$0.37
CM 6119	Tolerant of low pH and high aluminum saturation	$0.37
COL 1823	Tolerant of low pH and high aluminum saturation	$0.37
PAN 139	Tolerant of low pH and high aluminum saturation	$0.37
PER 183	Tolerant of low pH and high aluminum saturation	$0.37
Ornamentals propagated at Ashenden		
Acallypha		$1.85
Aralia		$4.44
Allamanda/Buttercup, dw		$1.85
Allamanda/Buttercup, lg		$1.85
Ashoka (Saraca indica)		
Begonia		$4.44
Bell/Trumpet flower		
Black Pearl		
Bougainvillea		$1.85
Bromeliad		$7.41
Byonar (Boenia??)		
Cock's Comb		
Cordyline (eg. Song of India)		$1.85
Cranium		
Croton		$1.85
Crown of Thorns		$4.44
Cup of Gold		$1.85
Desert Rose		$4.44
Dracaena/Dragon blood		$1.85
Draconia		$1.85
Elang Elang		
Elephant foot		
Fence Types		
Ficus		$1.85
Firecracker/Horsetail fern		$1.85
Flamboyant		$1.85
Frangipani		
Gardenia		$1.85
Garlic vine		

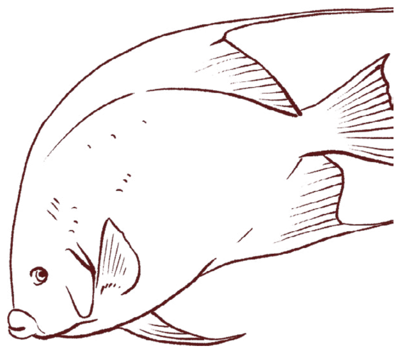
Propagated plants	Specific trait/ variety (e.g., good root stock, drought resistance)	Sale price (per plant) US$
Ginger lily		$1.85
Grass, ornamental		
Hibiscus		$1.85
Hydrangea		
Ixora, dwarf		$1.85
Ixora, large		$1.85
Japanese heart		$1.85
Jasmine		$1.85
Joseph's coat		
Juranta		$1.85
Ladies of the night		$1.85
Lantana/Sugardish		
Macrophyllus		$1.85
Musseanda		$4.44
Neem		
Oleander		
Orange Flower"		$1.85
Orchid, Ground		
Palm, Fan		$1.85
Palm, Fishtail		$1.85
Palm, Foxtail		$1.85
Palm, Golden		$1.85
Palm, Phoenix		$1.85
Palm, Redstem		$1.85
Palm, Sago		$1.85
Periwinkle		$1.85
Petria		
Philodendron		$3.70
Plumbago		$1.85
Poinsettia		
'Pot" lily		
Queen of flowers/Popcorn		
Roucou/Annatto		
Rose		$1.85
Rubber tree		$1.85
Shade tree		$1.85
Shef		$1.85
Silver tree		$1.85
Snake plant (eg Mother in law tongue)		$1.85
Snow on the Mt./Euphorbia		$1.85
Spider plant		$1.85
Thumbergia (like Black eye susan)		$1.85
Tree of Life (Lignum vitae)		$1.85
Tulip tree (purple flower)		
Vanilla box		$1.85
Xmas tree, spreading		$1.85
Xmas tree, tall and straight		$1.85

Propagated plants	Specific trait/ variety (e.g., good root stock, drought resistance)	Sale price (per plant) US$
Yellow vine		
Yesterday,Today,Tomorrow		
Avocado		
Booth	Highly nutritious, highly palatable	$1.85
Bottleneck		$1.85
Choquette		$1.85
Collinson		$1.85
Evans		$1.85
Everton		$1.85
Forshaw		$1.85
Grepina # 5		$1.85
Grepina # 7		$1.85
Hall		$1.85
Harford		$1.85
Lander		$1.85
Ludbur		$1.85
Lula		$1.85
O. Special		$1.85
Ottley no. 1		$1.85
Pollock		$1.85
Semil # 31		$1.85
Semil # 34		$1.85
Simmonds		$1.85
Special		$1.85
St.Vincent		$1.85
Watchman		$1.85
Wayne		$1.85
Williamson		$1.85
Mango		
Aromanis		$1.85
Bombay		$1.85
Ceylon		$1.85
Double stalk		$1.85
Goleck		$1.85
Graham		$1.85
Grenada special		$1.85
Imperial		$1.85
Julie		$1.85
Kinghuang		$1.85
Long grafted		$1.85
Palouis		$1.85
Peach		$1.85
‘Pearls‘		$1.85
Starch Trinidad		$1.85
Mango, unspecified		$1.85
Herbs		
Albe’		
Anise		

Propagated plants	Specific trait/ variety (e.g., good root stock, drought resistance)	Sale price (per plant) US$
Basil		
Dill		
Lemon grass		
Mint		
Moringa		
Oregano		
Peppermint		$1.85
Rosemary		$1.85
Spinach		$1.85
Thyme, fine leaf		$1.85
Other Major Crops		
Clove		$1.85
Cocoa		$0.37
Nutmeg		$0.37
Soursop		$0.74
Bread fruit		$1.85
Cinnamon		$0.37
Sapodilla		$1.85
Sugar Apple		$1.30
Golden Apple		$1.85
Mauby		$1.85
Corn		$1.85/lb
Peas		$1.85/lb
Okra		$0.74/pkt
Sorrel		$1.85, $0.74/pkt
Minor Crops		
Pomegrante		$1.85
Cashew nut		$1.30
Plum		$1.85
West Indian Cherry		$1.85
Guava		$1.30
Custard Apple		$1.85
Atemoya		$1.85
Ackee		$1.85
Bread nut		$1.30
Carambola		$1.85
Coffee		$1.85
Fig		$3.70
Granadilla		$1.30
Kola nut		$1.85
Tamarind		$1.85
Wax Apple		$1.85
Minor Spices		
Bois d'Inde		$0.37

Fishermen off the coast of Carriacou, Grenada
Photo credit: Natalie Boodram

5. Supporting, enhancing and amplifying ecosystem services for the economic and social well-being of Grenadians



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Summary

This chapter uses the ecosystem framework of preceding chapters (i.e. agricultural, terrestrial, freshwater, coastal and marine) to identify response options for the maximisation of ecosystem services (ES) returns to the people of Grenada. It does this by applying problem- and objective-trees to identify underlying drivers and potential policy and programmatic approaches for multi-sectoral ES management. The underlying consensus of the chapter is that many of the ES management and delivery challenges are complex problems that require multisectoral, stakeholder-led solutions and high-level political engagement.

A key recommendation of this chapter is to explore different modes of high-level leadership in governance, as an action to promote transformational cross-sectoral thinking and mainstreaming of ES. Such leadership is key to resolving thorny issues, including designation and management of protected areas and elimination of perverse incentives that undermine maximisation of ecosystem services to local people. Herein too, leadership is essential, not only to ensure stakeholder buy-in, effectiveness of communication and management of limited financial and human resources, but also to facilitate innovation and systems-level change. During the National Ecosystem Assessment (NEA) stakeholder consultations, a key concern was the dichotomy between high-level decision making vs. grassroots stakeholder engagement. It is critical here to indicate that these are parallel and complementary modalities for effecting ecosystem services management. Ultimately, the lack of implementation, identified throughout the NEA, reflects the weaknesses inherent in silo-based decision making. Given the country's Westminster-based governance system, ultimate decision making power lies in the State, its application of national policy, enactment of legislation, budgeting and personnel allocation, which are actions only the State can take.

The chapter highlights the importance of developments at the global level such as the United Nations Convention on Biological Diversity's (CBD's) recently agreed Global Framework for Biodiversity as timely opportunities to realign existing national policies, programmes and plans important for all ecosystems of Grenada and as an opportunity to build on the global leadership in environmental governance, for which Grenada is known and recognised.

The ES management approaches are framed as foundational, enabling environment and instrumental tools. Here, foundational issues refer to current knowledge about ES, the gaps identified in the NEA, and potential responses to fill these gaps. Instrumental issues include the technological, educational, social, and economic approaches and practices that can be used to mainstream ecosystem services. The enabling environment refers to the political and policy context and the cultural environment, including societal values, attitudes, and behaviours central to the acceptance (or rejection) of ecosystem service opportunities identified in the NEA. The chapter provides some exploration of the issue of finance and on potential options such as Payment for Ecosystem Services (PES), green levies and debt instruments, where these may provide a means to support management of specific ES.

The chapter's ecosystem-specific reviews point to complex linkages and feedback loops as a central feature of Grenada's ES that undermines existing sectorally-focused decision making, planning and resource allocation. Given such realities, the chapter notes that where ecosystem services are to be restored and maximised, the current compartmentalisation of governance and management of ecosystem services needs to be transformed. An example of an issue with complex implications is the management of the tri-state island nation's limited land area, which underpins an intense demand for space across all economic sectors. Maintaining healthy ecosystems and their services, while reducing conflict over space, requires cross-sectoral planning, budgeting and management that reflects the interconnectedness of Grenada's ecosystems.

The chapter's ecosystem-specific analyses of key threats, policy, resource allocation and opportunities are as follows:

Terrestrial ecosystems

The following are key recommendations arising from the analyses of challenges to managing terrestrial ecosystem services:

- Enabling: revise and implement draft policies and legislation (e.g. Revised Forest Policy, Protected Area, Forestry and Wildlife Legislation, land use policy, *Environmental Management Act*) and mainstream ecosystem services in existing policies and legislation (e.g. national adaptation plan, energy policy, agriculture plan). Limited land area and high proportion of private land ownership constrain new terrestrial protected areas designation, as a result, land use governance is an ES management priority. Revision of existing legislation to include Other Effective Area-Based Conservation Measures (OECMs) is a potential mechanism for engaging private landowners within the Terrestrial Protected Areas network, to mitigate the challenges of further protected areas development;
- Instrumental: strengthen existing financial tools (e.g. environment levy, national parks development fund), and capacity building within existing institutions (e.g. Forestry and National Parks department). Incentivisation of private landowners through the adoption of new tools (e.g. payments for ecosystem services [PES]) to improve terrestrial ecosystem services is a key tool for achieving restoration of such services; and
- Foundational: baseline Knowledge, Attitudes and Practices (KAP) surveys, citizen science and knowledge transfer at the local, national and regional level as well as open knowledge sharing are central to addressing the substantial gaps in our knowledge of the status of ES, stakeholder interactions with these services and the effectiveness of current and proposed management approaches.

Agricultural ecosystems

Analysis of the agricultural policy framework of Grenada reveals a need for mainstreaming of ecosystems and ecosystem services across these policies. Specifically, an integrative approach that builds bridges across the respective policies would ensure development is based on the sustainable management of ecosystems. Such approaches include:

- Enabling Responses: the adoption of a multi-sectoral/institutional approach to sustainable land management, addressing land tenure security, adaptive governance and the inclusion of non-state actors. Updating and revising legislation to support and implement the national land use policy are also key approaches;
- Foundational Responses: emphasising nature-positive farming in policy for rural and urban areas, integrating and promoting restoration good-practice and mainstreaming of indigenous and local knowledge (ILK) in agricultural policy. Use mitigation hierarchy approach to assess targets for ecosystem restoration as a proportion of degraded systems; and
- Instrumental Responses: allocating support within the agricultural national budget for nature-positive farming, including support for citizen science, adoption of Information and Communication Technology (ICT) to address data constraints, and broader support for public awareness and education.

Freshwater ecosystems

- Enabling: a recurring theme is the need for an organisational framework for change through the creation of enabling environments. Creating and updating the national policy framework is fundamental. Key recommendations here include to: 1) update and enforce policies for construction and road development projects to prevent indiscriminate land clearing and better manage stormwater runoff, landslides and flooding, 2) update the *Waste Management Act* to include climate change responsiveness,

3) ratify and implement at a national level the Basel, Rotterdam, Stockholm and Minamata Conventions on hazardous waste, 4) enact stricter regulations to prevent destruction of wetlands, 5) prohibit importation and use of chemicals that are banned in other countries, 6) create an enabling environment for the proper disposal of waste chemicals (e.g. implement seasonal household waste collection events, collaborate with private sector companies such as auto parts or auto mechanic shops for the placement of hazardous waste drop-off bins), and 7) create an enabling economic environment for climate-smart practices and the use of greener or organic products (e.g. lower duties on the importation of organic natural products);

- Instrumental: the institutional and technical capacity is vital for tackling the challenges discussed. In addition to the provision of tools and technical expertise to government agencies, the private sector must be incentivised to improve ES management. Financial incentives can be used to encourage farmers and gardeners to use more environmentally-friendly farming practices; and
- Foundational: significant knowledge gaps related to freshwater ecosystem services exist. Thus, the data needed for deeper understanding of the status of Grenada's waterways should be prioritised. One approach to improve water quality monitoring is through a collaborative approach with local universities. Knowledge transfer to local communities can further contribute to improved practices and investing in training technical staff is necessary.

Coastal and marine ecosystems

A suite of response options is recommended to address the multiple stressors that threaten coastal and marine ecosystems. These include

- Enabling: an integrated, multi-sectoral and participatory approach is needed to address issues of national concern. For example, the establishment of a National Sargassum Task Force to effectively manage Sargassum influxes to Grenada. Several protocols and management strategies have been drafted related to Sargassum influx in Grenada and these need to be finalised and implemented. For example, the *Protocol for the management of extreme accumulations of Sargassum and the Grenada Sargassum Adaptive Management Strategy*. Presently, there are several proposed Marine Protected Areas (MPAs), for which draft Management Plans have been prepared. In order to ensure that these sensitive ecosystems are not adversely impacted by future anthropogenic activities (including new coastal developments) these MPAs should be formally designated, the Management Plans implemented, and the MPAs actively managed;
- Instrumental: in order to address specific challenges, there is also a need to encourage new technologies and practices. For example, promotion of private-sector driven initiatives to commercialise use of Sargassum, and identification of sector-specific adaptive responses and investigate approaches to mitigate influxes of Sargassum in designated coastal areas. Blue carbon, nature-based solutions and blue bonds are all potential options for improving opportunities for funding livelihoods and management in the marine space; and
- Foundational: knowledge and information are critical in ensuring there is evidence-based management. For example, formalised monitoring efforts are needed to provide spatial and temporal data as it relates to Sargassum influx, marine debris, fisheries, invasive alien species (IAS), coral diseases, etc. Here, citizen-science, community-based initiatives can boost data collection efforts, monitor and evaluate effectiveness of policy and law enforcement in the coastal and marine zone and simultaneously raise awareness and public support for ES in the marine environment.

Synthesis

Traditional sectoral planning, budgeting and management of the economy is an accepted norm in national-level governance. However, the recurrent message of this chapter's analysis of the policies, plans and programmes relevant to the ecosystem services, suggest that the maximisation of ES can only be achieved by explicitly mainstreaming such services into all national plans, policies and programmes.

Current weaknesses in management of ES suggest a lack of meaningful cross-sectoral engagement at the national level. Here key steps are required. The chapter recommends high-level governance engagement in implementation and monitoring and evaluation of the activities identified in the NEA. This may involve an explicit Cabinet-level responsibility and/or cross-party parliamentary committee for such coordination. Building a cross-party consensus on insulation of institutional frameworks for management of ES from frequent political disturbance, while at the same time ensuring accountability and transparency, has been highlighted by stakeholders as an important criterion for ensuring long-term approaches to ES management.

Grenada currently has many existing draft national policies and plans, which require revisions to include ecosystem services and biodiversity. Such revisions can lead to big improvements in ecosystem service management and increased economic and social well-being of Grenadians. A directly-related issue is the need to undertake a review of national legislation for fisheries, forests, wildlife and waste management to ensure that international obligations (e.g. Convention on International Trade in Endangered Species of Wild Fauna and Flora [CITES), co-management tools (e.g. stakeholder led resource management), responsiveness to climate change and the relevant policy-specific decisions, are supported in national law.

Recurrent across all sectors is the need to (re-) invest in human capacity, knowledge generation and monitoring of the state and management of ecosystem services, and monitoring and enforcement of national regulations. Priorities identified include fundamental issues associated with land tenure, poor waste management, misuse of agrochemicals, transparency of decision making at all levels, and stakeholder participation in knowledge-generation, governance and management of ecosystem services.

A central task is the development and adoption of funding mechanisms to pay for such investments in maximisation of these ecosystem services. The chapter suggests PES, implementation of a Green Fund, exploration of green bonds and blue carbon as means to finance the investments for ecosystem services identified in the chapter. Current approaches that emphasise project-focused financial models rather than longer term financial support, are identified as undermining stakeholder capacity to plan and act on system-level challenges such as capacity development, institution building, shifting of relational and values frameworks and ecological restoration. Finally, the re-examination of existing taxing and subsidy structures that support business, manufacturing, tourism, agriculture, fishing and private forestry are key recommendations of the chapter. It is critical to ensure that such subsidies do not lead to perverse incentives that encourage waste or externalisation of degradation of ecosystem services, but instead support a transition to climate-smart practices and a more circular economy, and to nature-positive benefits for all Grenadians.

5.1. Introduction

5.1.1. Contextualising our response

The previous chapters of Grenada National Ecosystem Assessment (NEA) have provided a snapshot of the diversity of services provided by the natural environment of Grenada, the status of these services, the opportunities, particularly with respect to genetic resources, and the challenges posed by climate change. In this chapter, we identify potential response options for Grenada, which can improve the delivery of ecosystem services to the country. These responses are framed by the policy, economic and cultural context within which these living resources are embedded.

Global understanding of nature's services to people has evolved since the Millennium Ecosystem Assessment (MA) (2005) (Chapter 1, Figure 1.3) and the Nature's Contribution to People (NCP) framework (Diaz *et al.*, 2018) (Figure 5.1) has emerged as an alternative framework for understanding how people benefit from and interact with nature. We do not rationalise these alternative frameworks here but note that the Grenada NEA is being written at a time of growing confluence between the primarily natural sciences and socio-ecological lenses of the values frameworks. We recognise that measures of quality of life are represented in the forgoing chapters and craft the chapter's responses on these. The cultural context for solution-making is an important issue that is given due consideration in this chapter.

In our review of potential response options to support, enhance and amplify the delivery of ecosystem services in Grenada while boosting resilience to the climate and opportunities for restoration, we lean heavily on the framework of

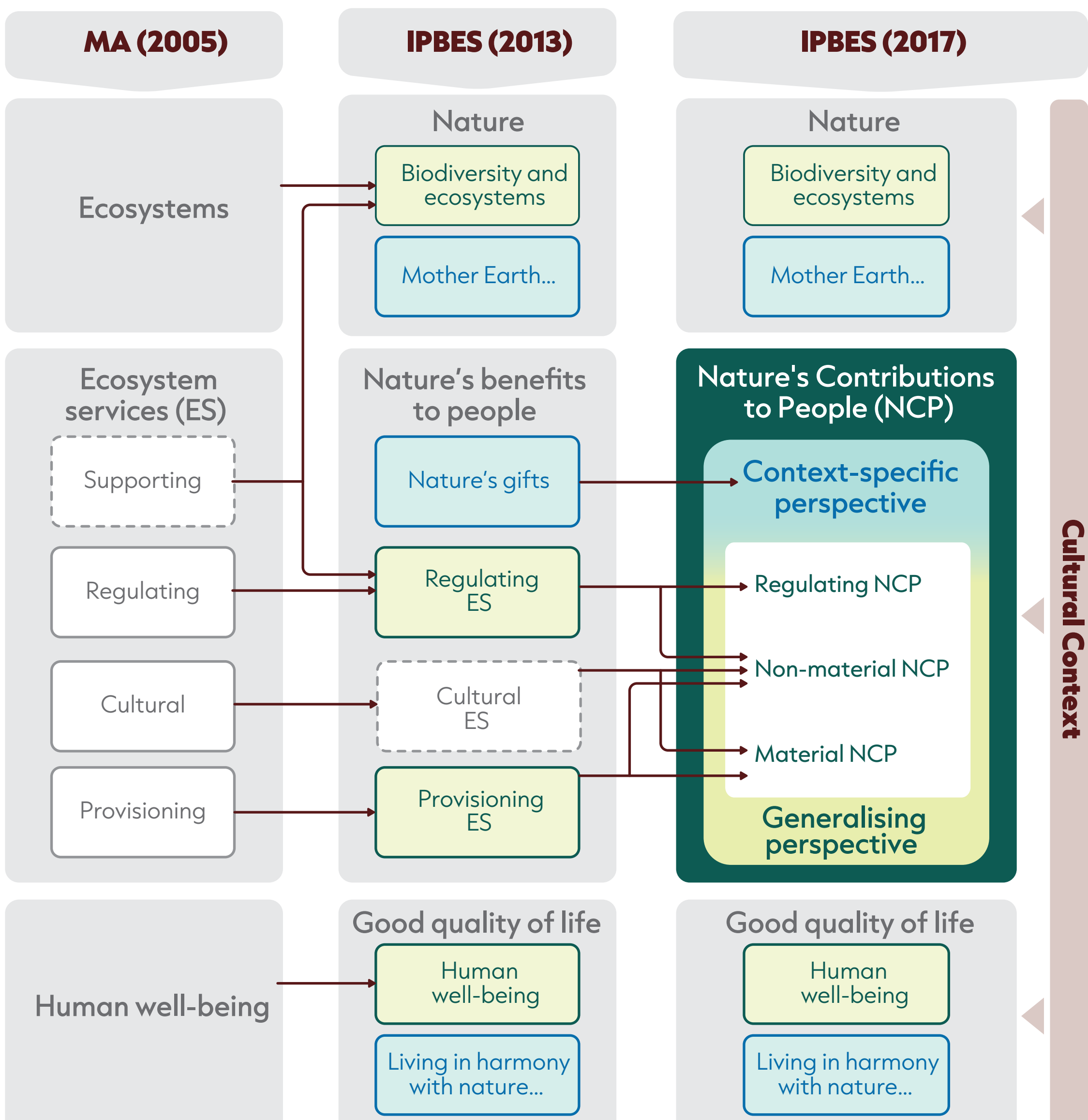


Figure 5.1. Evolution of global frameworks for understanding ecosystem services (Diaz et al., 2018)

response options proposed by Vira *et al.* (2011), and specifically the three tiers of response options proposed by those authors for the United Kingdom's NEA. In that work, Vira *et al.* (2011) propose classifying responses as: Foundational (responses related to the generation and distribution of knowledge- we include local and indigenous knowledge in this category); Enabling (including policy, laws, institutions, governance and social attitudes); and Instrumental (including markets, incentives, technology, practices and voluntary actions) (Vira *et al.*, 2011). Readers are directed to Chapter 27 of the *UK National Ecosystem Assessment: Technical Report* for a more complete description of these tiers of responses (UK NEA, 2011).

In the previous chapters, current knowledge of biodiversity, ecosystem services and the existing drivers, pressures, state, impact and responses have been identified and contextualised across the tri-island archipelago, in the face of climate change and existing normative values and local perceptions of biodiversity and its services. In this chapter, response options to specific ecosystem service challenges and opportunities are presented in a similar ecosystem-focused approach for consistency. However, our intention is not to translate these ecosystem patterns into a sectoral template of responses, nor is it to prioritise sites for restoration. Rather, we emphasise the value of trans-sectoral response, which explicitly acknowledge the interconnected nature of the ecosystems and the idea that the stakeholders do not experience these values as siloed processes or systems but as a bundle of interrelated, interdependent and intercalated outcomes.

While this chapter's scoping mandate had proposed the development of recommendations for identifying priority sites for ecological restoration as a key target, our review of the previous chapters, and of the state of knowledge, capacity and enabling environment, suggests that a meaningful output without the collection of new data, data-analysis and modelling is well beyond the scope of the NEA. As such, this chapter focuses on providing general guidance using a cross-sectoral collaborative, mitigation hierarchy approach when considering the role of restoration in management of ecosystem services.

Similarly, our chapter explicitly recognises that the negative or positive impacts that people's deliberate or unintended actions have on these ecosystems and their services are not siloed in their outcomes on nature, but have multiple consequences across ecosystems and across multiple temporal and spatial scales. As a result, the chapter focuses on developing and promoting locally-relevant and locally-driven policy frameworks and economic responses that cross sectoral boundaries, with an aim to build support for interventions that may be acceptable to the people of Grenada.

5.1.2. International, regional and national frameworks and obligations

Grenada has a comprehensive existing national policy framework (agriculture, marine, coastal, forests, biodiversity, fisheries) and associated legal framework (including existing draft legislation) (Chapter 1; Chapter 5, Appendix 2, 3, 5). The country is also signatory to a wide range of multilateral environmental agreements (MEAs) which have direct implications for the management of natural and anthropogenic ecosystems and the ecosystem services arising from these systems (Chapter 1). These international obligations have also committed the country to work programmes arising from these multilateral instruments, and which have important policy and economic impacts on Grenada relevant to ecosystem services management and delivery, for instance, across land use, protected areas, forests, wildlife, and marine resources. It should be noted that the country is recognised for its leadership in the international environmental agreements space (e.g. at the United Nations Convention to Combat Desertification [UNCCD], in its engagement at negotiation processes at the Conference of the Parties (COP) (UNCCD, 2022)).

Despite this comprehensive web of international obligations, there remain important gaps in the country's treaty framework, with the country yet to ratify agreements such as MARPOL (Convention for the Prevention of Pollution from Ships), the Convention on Migratory Species, and the Convention on Persistent Organic Pollutants, to name a few (Chapter 1, Table 1.2,). In some cases, implementation of its international obligations has fallen short of treaty requirements and/or is not reflective of the urgency of the issues from a national perspective. For example, Grenada has for several years been unable to provide annual reports to CITES, regarding trade in CITES species, which among other issues, has resulted in a ban on trade in CITES specimens originating from the country (CITES, 2016). In this instance, the failure to provide such annual reports is directly attributable to a lack of clarity of responsibility, lack of human capacity within the country's national management authority and ultimately weakness in responsiveness of State institutions. Inability to fully implement these treaty obligations and/or participate in these multilateral processes represents a missed opportunity to leverage potential sources of administrative and technical capacity, secure funding for national projects and programmes, and participate in information generation and sharing processes central to the management of the country's ecosystem services (Chapter 1).

Engagement in the diversity of multilateral processes relevant to the management of ecosystem services requires a country to balance the direct and indirect costs associated with such engagement. Here the alignment of national policy with the undertaking of international treaty obligations inherent in the country becoming signatory to any of the environment-related treaties, should reflect the national desire to participate in the shared governance of the global patrimony inherent in nature. The multiple benefits of Grenada's engagement with the global system of MEAs can only be fully realised when there are adequate human resources assigned to these international processes, transparent communication and engagement of local stakeholders, and timely integration of treaty obligations into national laws, policy, programme and plans. These issues are not new and have been previously highlighted in the country's *National Capacity Self-Assessment* project as a challenge to MEAs implementation (Thomas, 2005). Almost two decades later, while some progress has been made in developing the national policy framework, that many of these policies remain draft, speaks to the need to address the policy authorisation and implementation issues that continue to prevent the realisation of the benefits from engagement in global environmental governance framework.

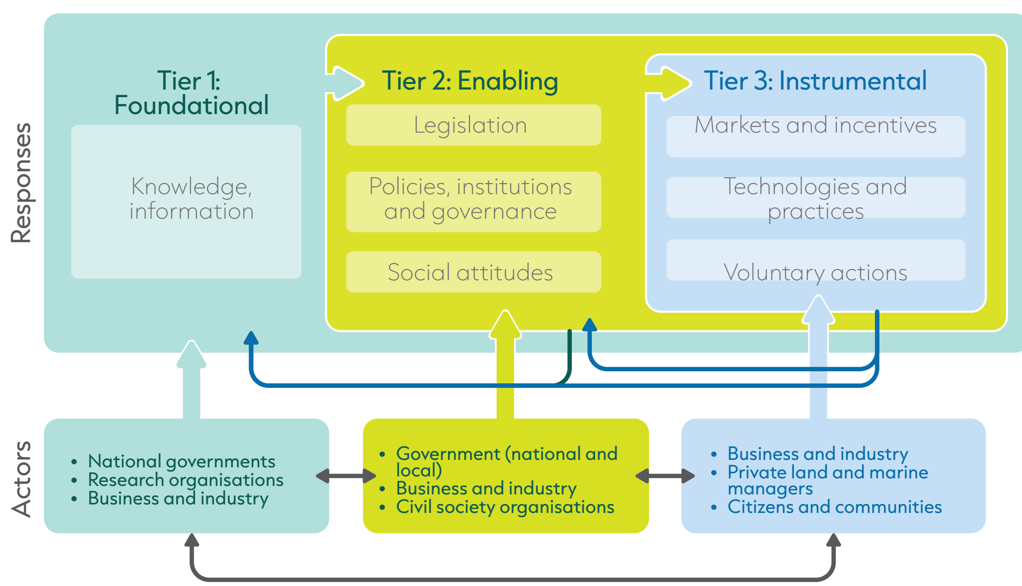


Figure 5.2. Conceptual framework showing relationship between foundational, instrumental and enabling response options (Vira et al., 2011)

5.1.3. Conceptual response framework

To understand, assess and structure our response options for addressing decline of ecosystem services in Grenada, we adopt a typology for our response (Figure 5.2) which uses the categories of foundational, instrumental and enabling (*sensu* Vira *et al.*, 2011) to define our policy, economic and legislative responses.

Foundational – refers to our current understanding of the drivers, pressures, state, impact and responses, including uncertainties in current knowledge and the gaps in this knowledge. It also includes existing systems for leveraging the available knowledge i.e. who generates, controls and provides access to the knowledge needed to improve management of ecosystems and their services. This element also includes the conversion of this knowledge into new ways to manage, exploit and enhance ecosystem services. Finally, it represents the means used to fill the gaps in this knowledge. Here, indigenous/local knowledge are recognised as important sources of evidence.

Instrumental tools – include the technological, educational, social and economic approaches and practices that are relevant to crafting ecosystem services management in the Grenadian context. These include financial mechanisms (budgets, taxes, public incentives, private finance) and informal local-level arrangements.

Enabling environment – refers to the political and policy frameworks (formal and informal from the national to the local) such as institutions, policies, laws, to informal arrangements at the local level, as well as an explicit acknowledgement of the role of cultural context in the form of societal values, attitudes and behaviours in shaping existing norms

Box 5.1. Confidence Assessment

Uncertainty is inherent when making predictions or recommendations, based on current best understanding. The chapter follows the Intergovernmental Panel on Climate Change (IPCC) guidance for assessing and communicating the degree of certainty in responses to support, enhance and amplify ecosystem services for the economic and social well-being of Grenadians (Mastrandrea *et al.*, 2010). Confidence in the validity of current understanding of potential responses was assessed based on the degree of agreement between the amount, type, quality and consistency of evidence (e.g. expert opinion, data, theory, models) available during the NEA's development (Figure 5.3) (Mastrandrea *et al.*, 2010). Where this evidence was unavailable for Grenada, we referred to relevant evidence from the wider Caribbean region, where available/possible.

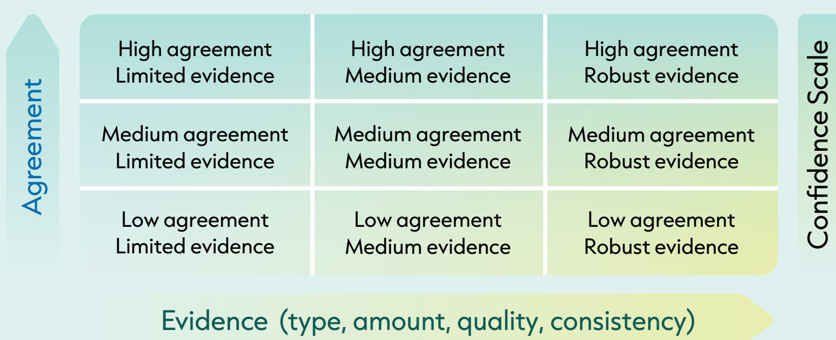


Figure 5.3. The influence of evidence and the degree of agreement on the assessment of confidence (Mastrandrea et al., 2010)

in the acceptance (or rejection) of management approaches to ecosystem services in Grenada.

This conceptual response framework was used to develop problem tree-based analysis across the major ecosystems that have been the focus of this national ecosystem assessment i.e. terrestrial, agricultural, freshwater and marine and coastal ecosystems. These problem trees are used to examine the gaps in current national responses to changes in biodiversity and ecosystem services and to propose responses to these challenges.

To meet the requirements of the NEA, ecosystem author-teams provide expert judgements of the existing scientific and social understanding of selected key response options. Confidence assessments (Box 5.1) are a mechanism for qualitatively evaluating and communicating the degree of uncertainty that is inherent in all forms of knowledge (e.g. natural variation in existing data, imperfect measurements or predictions, data gaps or lack of information on efficacy of different policy alternatives). Examples of sources of uncertainty include natural variability in management outcomes due to heterogeneities in community structure and individual values, long-term impacts of management that are not captured by short-term monitoring, failing to include a measure of a fundamental environmental parameter, or inherent weaknesses in measurement tools or systems.

5.2. Ecosystem-level challenges and response options

The development of response options appropriate to the ecosystems and their services, including the use of relevant policy interventions, economic and cultural levers, need to be considered in the context of the existing challenges to these services and the current management frameworks and options being considered by the stakeholders. Policy responses need to be viewed in light of barriers that inhibit the support and amplification of the delivery of ecosystem services for Grenadians. While many of these barriers are shared with other Small Island Developing States (SIDS), it is worth reviewing those relevant to Grenadian ecosystems.

To illustrate how our proposed framework might be applicable to the key threats to Grenadian ecosystems, we have developed a series of interventions that are based on problem tree analysis of issues relevant to ecosystem services. Problem trees used here are exemplars and are not intended to address all potential threats. Where threats are not addressed in problem trees, this does not imply that they do not pose a threat to ecosystems but may reflect the case that their impacts are less substantial due to current management activities, or the information base is poorly developed and we are not currently able to clearly quantify the threat posed by the specific activity under consideration. Threats were identified and prioritised in this analysis based on the assessments presented in the previous chapters.

The potential mechanisms for enabling the delivery of ecosystem services are then explored through the development of objective trees arising from the problem trees presented for ecosystems reviewed in this chapter. We build on responses suggested in previous chapters (Chapters 2, 3, 4) and discuss recent and ongoing projects (Grenada and regional) that highlight current tools for developing or scaling-up responses to deliver, sustain and improve terrestrial ecosystem services. Potential responses will be discussed through the lenses of knowledge, enabling and instrumental environment. Key considerations here are also trade-offs and feedback loops between options, feasibility and any disproportionately affected groups from potential responses and economic transitions. Synergies and common themes relating to response options and their adoption will be highlighted, including with links to responses identified for other ecosystems (win-win activities).

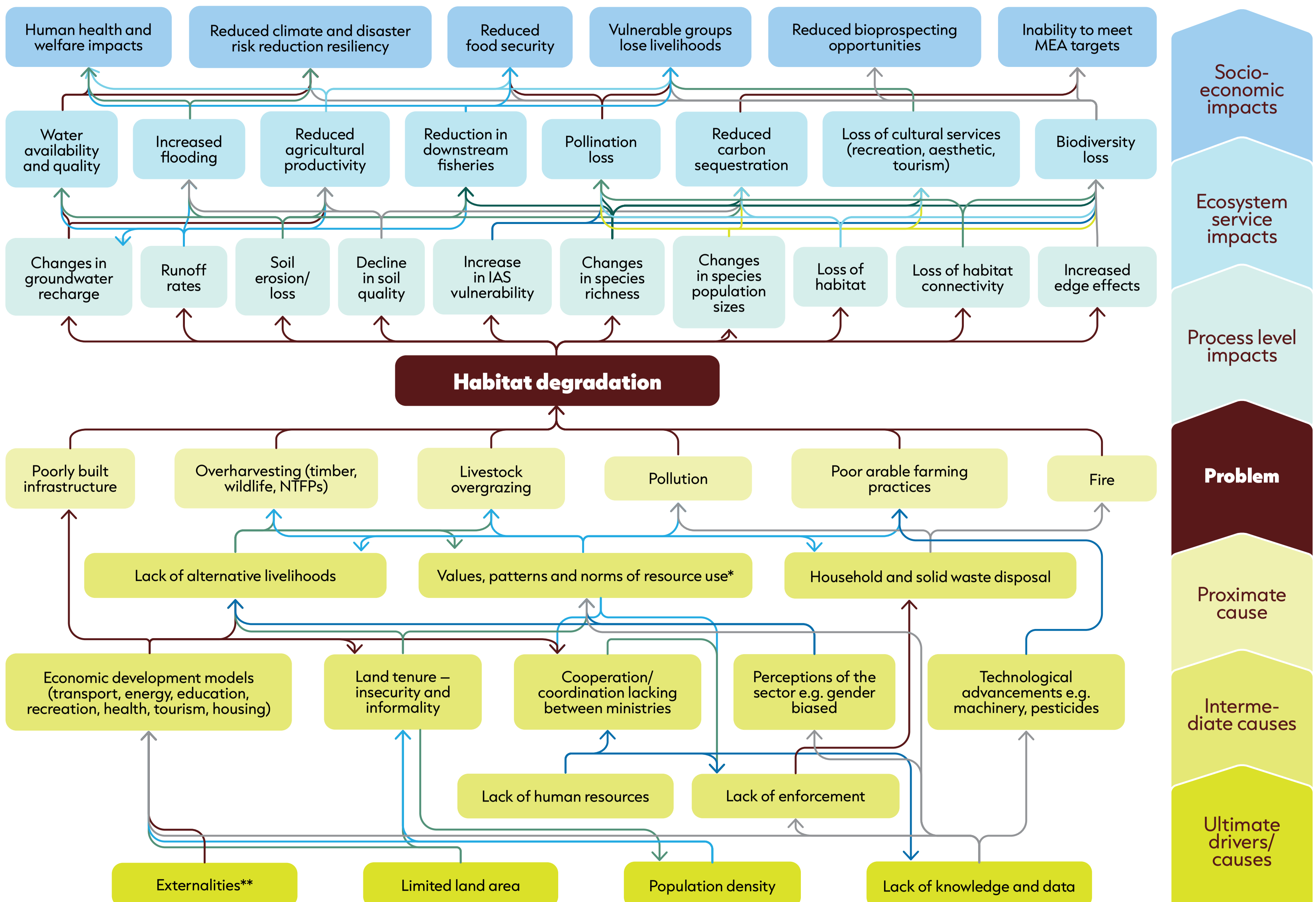


Figure 5.4. *Problem tree showing causal factors leading to terrestrial habitat degradation and the effects for terrestrial ecosystems and services. **Externalities include global markets, national debt, trade balances, global financing, global information trends, global tourism trends, conservation finance mechanisms. *Patterns and norms of resource use refer to public perceptions at the individual level, including of the value of natural spaces, waste elimination function of nature, externalisation of cost to public commons*

Box 5.2. Habitat Degradation

As previous chapters have described, degradation of natural habitats through anthropogenic activities is the most significant terrestrial threat to the tri-nation state and has wide-reaching impacts on ecosystem services and human wellbeing (Chapters 2, 3; Figures. 5.1, 5.4). In this chapter, we define habitat degradation to include changes in species richness, abundance, composition, vegetative physiognomy, anthropogenic waste presence, changes in abiotic chemical composition, aural and radiation environment beyond normal baselines, changes beyond natural rates of energy cycling, and nutrient-source,-sink and -decomposition processes. Such degradation is in part ultimately shaped by external economic and social drivers, including global financial instability (Chapters 1, 3, 4). At the national level, socio-economic drivers fuel the pressures that lead to habitat degradation (Chapters 1-4). These drivers are the outcome of development and land-use decisions such as transportation networks, communication, housing, tourism and agriculture. Examples of habitat degradation on Grenada include acidification of soil estimated to affect over 860ha and on Carriacou, where water erosion affects over 1800ha of land (GoG, 2015).

Figure 5.5. *Habitat degradation in Mt. Hartman National Park*
(Photo credit: Howard P. Nelson)

Box 5.3. Overexploitation

As described in previous chapters, unsustainable use or overexploitation of natural resources places significant pressure on terrestrial systems and has direct links to habitat degradation and other threats (Figure 5.4 and Figure 5.5). In Grenada, examples of such resource use include the over-use of Non-Timber Forest Products (NTPFs) used in the craft industry or hunting of wild game species. Overexploitation refers to the use, or extraction of renewable resources from nature, at a rate faster than they can be naturally replenished. In the case of wild animals and plants, it implies deliberate or incidental harvesting/by-catch at a rate faster than these animals and plants can recover in a given breeding cycle. Such overharvesting can have knock-on effects that impact a species' ability to recover, for instance, in the form of processes known as demographic Allee effects. At an ecosystem level, overharvesting of a species can lead to the decline of ecosystem services it may perform (e.g. pollination, dispersal, predation, nutrient recycling, physical restructuring of its habitat etc.). In the case of ecosystem services such as pollination or ground water recharge rates, as examples, overharvesting implies changes that reduce the supply of that service, as well as over-utilisation of a product of that service. It is important to note that many of nature's services arise from complex processes that are often poorly studied, and subject to multiple regulating factors.

Figure 5.6. *Hunted common opossum (Didelphis marsupialis) or manicou in Grenada*
(Photo credit: Howard P. Nelson)

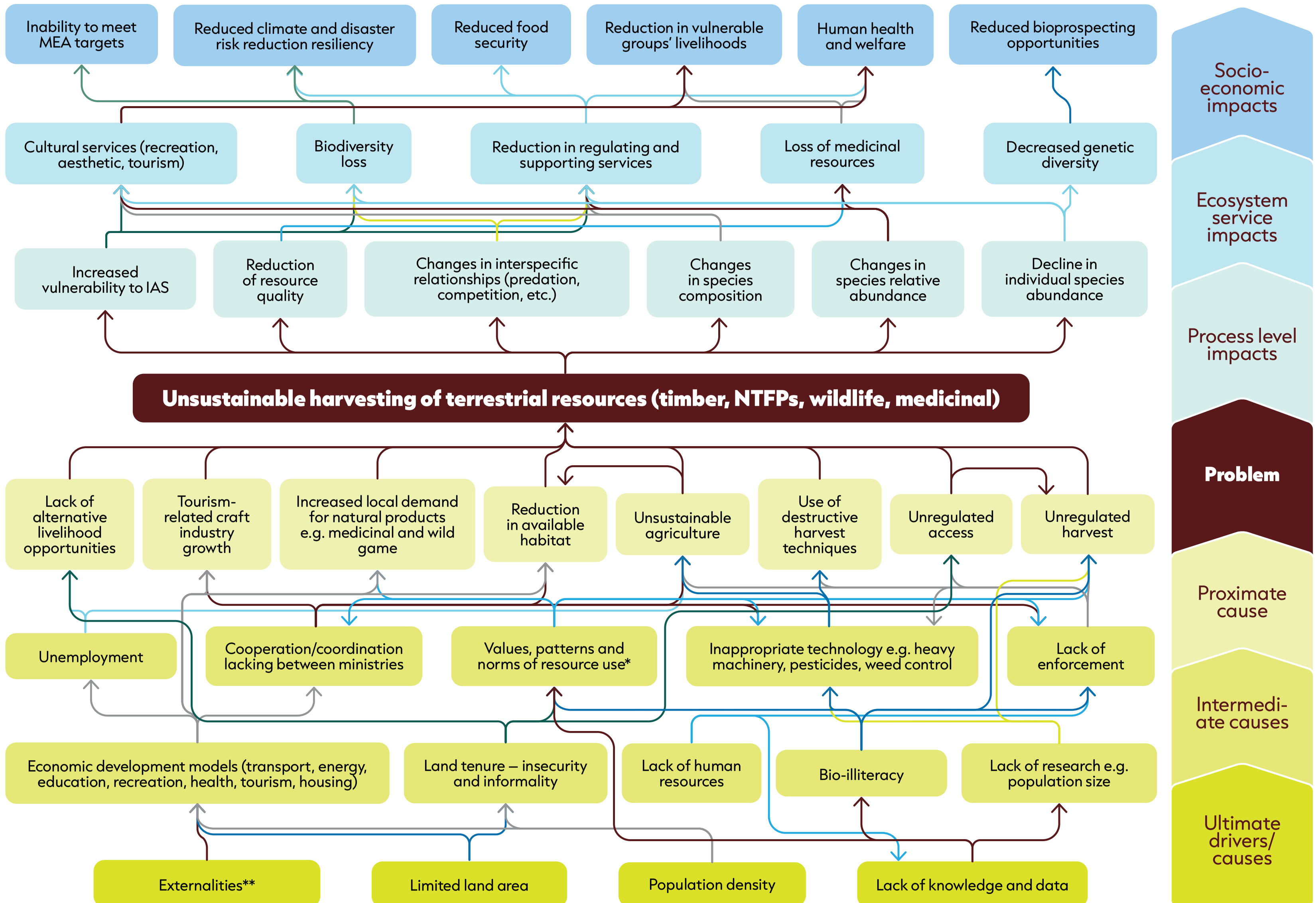


*Figure 5.7. Problem tree showing causal factors leading to overexploitation of natural resources and the effects for terrestrial ecosystems and their services. **Externalities include global markets, national debt, trade balances, global financing, global information trends, global tourism trends, conservation finance mechanisms. *Patterns and norms of resource use refers to public perceptions at the individual level, including of the value of natural spaces, waste elimination function of nature, externalisation of cost to public commons*

5.2.1. Terrestrial ecosystems

This section covers the main terrestrial systems in Grenada as defined in earlier chapters and includes the terrestrial elements of offshore islands. Two key threats, habitat degradation (Figure 5.4, Box 5.2, Figure 5.5) and overexploitation (Box 5.3, Figure 5.6, Figure 5.7) were identified in Chapters 2 to 4 as having significant negative impacts on terrestrial ecosystems. Pollution and IAS were also identified in those chapters as being responsible for substantial pressure on native wildlife and habitats. To investigate the options to address these issues, we developed problem trees for habitat degradation, over-exploitation and IAS. For brevity we have placed the problem tree for IAS at Appendix 1 and discuss interlinkages with pollution (see habitat degradation problem tree and the freshwater section of this chapter) and the other threats where relevant. Climate change exacerbates all these threats (Chapter 3) and thus solutions for these threats also need to be viewed through a climate adaptation lens. However, climate change was not examined in a specific problem tree since it is addressed in detail in Chapter 3. Interdependencies between terrestrial and agroecosystems, freshwater, coastal and marine ecosystems have also been highlighted, as in previous chapters. Here, we used the problem trees to explore challenges facing terrestrial ecosystem services, particularly in the context of existing knowledge gaps, the enabling-environment, and society. In the responses section, these problem trees were transformed into objective trees to identify opportunities for responses and to highlight synergies between the terrestrial ecosystem service challenges.

Challenges

Foundational

At the national level, a diverse range of formal and informal knowledge frameworks and initiatives provide the primary means of understanding the current state of terrestrial systems, and for the evaluation of the efficacy of interventions for enhancing ecosystem services. These include:

- Government reports that address MEA obligations (e.g. *CBD 5th Assessment Report* (2014) and *National Biodiversity Strategy and Action Plan* (GoG, 2016)
- Peer-reviewed literature on the status of specific ecosystem services
- Components or broader regional studies on anthropogenic pressures
- Unpublished agency reports and student dissertations
- Undocumented cultural practices and local knowledge about native plants, animals and ecosystems and their traditional uses, practices for their management and cultural symbolism. These indigenous and local knowledge systems are not well documented in the unpublished or scientific literature for terrestrial systems of Grenada.

The processes that support the generation of knowledge from these frameworks are not only determined by national government agencies or the locally-based academic, non-governmental organisations (NGOs) and civil society sectors (e.g. see Chapters 2-4) but are also, to a large extent, externally driven. For example, decisions on what types of research projects may be funded for terrestrial ecosystems in Grenada are determined by large-funding organisations or research councils or programmers that are not Grenada-based. This situation can lead to persistence of knowledge gaps that are of importance for the management of local ecosystem services.

Another key challenge to decision making and management of the terrestrial ecosystems is ease of access and availability to data archived by the diverse stakeholders controlling access to these knowledge resources. Barriers include:

- Journal publications that are not open-access
- Unavailability of unpublished data
- A lack of funding to maintain online databases
- Limited access to government agency resources
- Inadequate and unsystematic repositories for data storage mean there is incomplete knowledge of existing data, such as missing documentation for

the Permanent Sample Plots (PSPs) established by the Food and Agriculture Organization (FAO) in the 1980s, as well as foreign-based student projects.

Weaknesses in data access and availability compound genuine knowledge gaps. For example, long-term precipitation and temperature data is available for only a limited number of terrestrial locations on Grenada due in part to financial and logistical challenges, with access to these datasets only available through government agencies (see Chapter 3). For terrestrial systems, one of biggest knowledge barriers is the lack of an accurate land cover change assessment (see Chapter 2). Inconsistencies in the methodologies used to generate existing land cover maps, as well as temporal gaps in coverage and exclusion of the smaller island dependencies and offshore islands, means current comparisons of land use change over time are unreliable (high agreement, high evidence). There is also a lack of a clear mechanism to enable data collected from monitoring, evaluation and learning, to be used in the iterative development of adaptive policies, strategies and interventions at the science-policy interface in Grenada.

Knowledge deficits have multiple implications for terrestrial management (Figures 5.4 and 5.7 problem trees) such as barriers to mapping provision of ecosystem services and planning new physical developments, but also limit the development of effective legislation and policy to address the impacts of habitat degradation. Central to good decision making about nature and its services is the need to accurately measure the current and potential contribution of ecosystems and biodiversity to national development and prosperity. State agencies, NGOs and community-based organisations (CBOs) are the institutions through which this knowledge is converted into management options for utilisation and enhancement of ecosystems and their services. The existing framework of knowledge on terrestrial systems and their ecosystem services has substantial gaps, including estimation of habitat extent, population trends of harvested and invasive alien species (Chapter 2), species responses to climate change (Chapter 3), economic valuation of nature and its services, and the genetic variation of NTFPs (Chapter 4). Cumulatively, these gaps in knowledge limit our ability to predict thresholds for the resiliency of ecosystem services such as groundwater recharge, soil regeneration, provision of NTFPs and persistence of threatened species (high agreement, high evidence). Despite these gaps, there is a growing literature on local biodiversity and ecosystem services (see Chapters 2-4).

Environmental decisions are made within a societal context, including the social values, patterns and norms related to the traditional relationships which local people have developed with terrestrial ecosystems and their services. Such local values and norms are central to the successful acceptance and adoption of proposed responses that might address the decline in ecosystem services. Civil society bio-literacy plays a critical role in the success of management implementation, which further shapes values, patterns and norms. KAP surveys for Grenada indicate that while there is a high awareness of the importance of the terrestrial environment and natural resources, particularly 'soil and land', there is much scope for improvement, with low understanding of the importance of sustainable land management to Grenada's development and potential impacts of climate change (Fontenard, 2016). Substantial knowledge gaps exist in current understanding of the relationship of communities with terrestrial systems and their ecosystem services, including NTFPs contributions to livelihoods, fire awareness, attitudes towards sustainable development, perceptions of enforcement for biodiversity and ES (Figures 5.4, 5.7; Chapters 2- 4).

Enabling

On small islands, the multiple, often-conflicting demands (that shift with national priorities and economic conditions over time) for limited terrestrial space, makes some land use change inevitable. However, existing policy gaps have facilitated landscape transformation and unsustainable natural resource use at the often-unintended expense of the ecosystem services provided to local people:

- failure to implement a land use planning policy has led to missed opportunities to balance the needs of socio-economic development with that of natural resource management, leading to unsustainable built infrastructure (high agreement, high evidence). This has meant degradation of ecosystems and the provision of their services (e.g. recent hotel developments in Levera, La Sagesse and Mt. Hartman and housing developments in lowland areas vulnerable to climate change impacts (high agreement, medium evidence) (Figure 5.4 on page 341);

- that the revised 2018 *Forest Policy* is still in draft form means that updated knowledge and current best practices have not been incorporated into forest management. Specifically, gaps in the existing forest policy include insufficient recognition of the importance of climate change, cross-cutting issues, livelihoods, MEA obligations and stakeholder participation for effective forest management;
- the as-yet unimplemented *Protected Area, Forestry and Wildlife Legislation and Protected Area Systems Plan* means there is a lack of an overarching policy for protected areas, which prevents sufficient clarity and support for protected area management (see below) as well as hinders fully realising MEA obligations;
- policy gaps in waste management enable the continuation of practices such as household burning and unlawful solid waste disposal that result in pollution and uncontrolled fires. These not only degrade habitat but also have direct public health impacts such as respiratory diseases and consequently loss of productivity or education days (high agreement, medium evidence) (Figure 5.4), running counter to the holistic principles of One Health. Lack of regulations to control quantities or types of pollutants and the failure to implement the *Environmental Management Act* leaves a large gap in development of an integrated management approach to pollution on terrestrial ecosystem services; and
- while hunting seasons for legal game species are in place, the absence of enabling legislation for a permitting system, user fees and bag limits means some terrestrial species are vulnerable to overexploitation (medium agreement, low evidence).

Ultimately, however, successful amplification of terrestrial ecosystem service delivery requires a step beyond sectoral environmental policies. Specifically, the thinking embodied in 'whole-ecosystem' Ecosystem-based Approaches (EbA) such as Ridge-to-Reef (GCN, 2017; Forteau, 2017; Serra, 2018) that transcends compartmentalised sectoral policies, is needed to achieve meaningful cross-sectoral mainstreaming.

Existing policy overlaps also weaken the enabling environment for natural resource management (high agreement, high evidence). For example, protected areas can be designated under eight legal Acts, while responsibility for protected area management falls under five institutions, which has resulted in uncertainty in institutional arrangements and a lack of clear leadership and enforcement. This is particularly apparent in overlaps and uncertainties in terrestrial protected areas management arrangements as four institutions have direct responsibilities for their management: Forest and National Parks Department (FNPD), National Water and Sewerage Authority (NAWASA), Tourism, and Carriacou Environmental Committee. An important example of the impact of a lack of policy clarity on globally important resources in Grenada can be seen in the repeated cycles of de-gazetting/re-gazetting of the Mt. Hartman Protected Area. Here, lack of clarity of policy objectives and transparency in prioritisation has underpinned the poor management outcomes at this site (Rusk, 2010).

To date, only 9.54% of the tri-nation's terrestrial area is protected (United Nations Environment Programme World Conservation Monitoring Centre [UNEP-WCMC], 2023). This means that Grenada missed CBD Aichi Target 11, protecting 17% of land area by 2020 and further, missed the target of protecting at least 20% of land area by 2020 set by the Caribbean Challenge Initiative (established by The Nature Conservancy [TNC] to align with the Aichi targets and to which the Government of Grenada has made financial and substantive commitments). Now, the post-2020 Global Biodiversity Framework (GBF) calls for 30% of terrestrial habitats to be protected by 2030. It is unclear how the tri-nation state can achieve this with Crown land alone, given that approximately 90% of all lands are currently under private ownership. One strategy may include developing programmes to obtain engagement from private landowners and mechanisms to promote the enhancement of ecosystem services on private land. Such an approach is essential for achieving MEA targets and enabling the amplification of ecosystem services across the landscape (high agreement, low-medium evidence) given the land-ownership realities in the country.

Insecure land tenure (Figure 5.4 on page 341) can promote habitat degradation and encroachment into protected areas (Griffith-Charles, 2011), since occupants have no incentive to apply protection measures for land they do not own, (e.g. arable farmers unmotivated to use soil conservation methods or integrated pest management) (medium agreement, medium evidence). This is a particular concern as steep slopes are among the land areas

Box 5.4. The Forest and National Parks Department –organisational case study of capacity erosion and implications for ecosystem services

The maximisation of ecosystem services (ES) from the terrestrial natural capital of Grenada, presupposes the existence of efficient and capable national organisational frameworks for planning, managing, and monitoring the state of these ES and stakeholders' interactions with these ES. In Grenada, many state agencies play a role in this function (e.g. NAWASA, Tourism, and Carriacou Environmental Committee etc.), but central to these is the FNPD (Figure 5.8). As the primary state agency charged under national legislation for management of the state forests and the wildlife resources, its role in addressing the bottlenecks to maximising ES makes it central to the facilitation of many of the actions envisaged in this NEA. For example, whether by IAS control in protected areas, habitat restoration in critical habitats, patrols to monitor endangered species, illegal harvesting, encroachment of agriculture or grazing into protected areas, as well as permitting and reporting actions for international treaty obligations.

Paradoxically, state agencies such as the FNPD have undergone steady human capacity erosion since the 1980s (Lugo, 1990), which was recently further exacerbated by personnel attrition arising from International Monetary Fund (IMF) loan conditionalities (IMF, 2019) and a lack of technical training for junior staff to replace this loss of knowledge within the agency (Nelson and Devenish-Nelson, 2022). Such a skills-loss compounds the '1-person deep phenomenon', common in small countries, where agency personnel are required to perform multiple often disparate functions at the same time (Nelson and Devenish-Nelson, 2022). This lack of human capacity within the agency has multiple impacts beyond technical resource management activities, which include impacts on effectiveness of interagency coordination, inability to collect and assess ES data, as well as a lack of capacity to fully engage with the agency's diverse stakeholders in civil society. These weaknesses ultimately manifest in a lack of implementation of MEA agreements such as CITES. At the same time, frequent reorganisation has resulted in uncertainty of the agency's place in the government's ministerial structure, further contributing to despondency within the organisation (Chapter 1).

Reversing these losses will require deliberate investments in training, organisational team-building and strategic recruitment. The development of the *2018 Grenada Forest Policy* and the diverse suite of programmes envisaged under the NEA will require an explicit focus on the development of the FNPD, in a way that allows it to fulfil the diverse needs identified as essential for management of the ES in terrestrial systems. Here, tying key funding mechanisms (Green Fund, PES, the National Parks Fund, Debt for Nature and Green Bonds) to explicitly support the costs of the agency should be explored as a matter of urgency. This action should take place in parallel with the adoption of the Forest Policy, and the revision of the national legislation to reflect this decision.

most likely to suffer from squatting and here poor land management practices, have a high likelihood of increasing the risk of degradation and vulnerability to disasters (high agreement, medium evidence). Land tenure is also a causal factor for overgrazing, as are a lack of alternative livelihoods, unemployment and education and awareness (Peters, 2002). Insecure land tenure means livestock owners graze their animals on State or unfenced private lands (e.g. 'Leggo' season in Carriacou) and current grazing patterns at Mt. Hartman National Park). A lack of enforcement perpetuates this practice, leading to overgrazing that increases erosion, soil degradation and alters species compositions (medium agreement, low evidence).

Financial, technical and personnel capacity issues, stemming from multiple complex factors that include the historical relics of colonialism, the brain drain, and low wages, are a substantial barrier to effective terrestrial governance in SIDS (Nelson and Devenish-Nelson, 2022). A lack of capacity within national governing institutions, particularly within the FNPD, as well as insufficient interagency coordination are part of a negative feedback loop limiting knowledge generation and the capacity for converting knowledge into management actions (Box 5.4). Not only has this led to habitat degradation, unsustainable resource use and increased pollution (e.g. through lack of patrols to monitor illegal harvesting, encroachment of agriculture or grazing into protected areas, [high agreement, medium evidence]), but it also reduces the ability of staff to collect and assess data critical for monitoring and evaluation, and further perpetuating knowledge gaps. Such capacity barriers also hinder the meeting of MEA implementation, monitoring and reporting, for instance leading to suspension of trade in Appendix II CITES species originating from Grenada due to the non-submission of annual reports since 2016, and the non-submission of 6th National Report to the CBD.

Assessments of the state of Grenada's terrestrial systems recognise that ineffectiveness of policy implementation stems in part from a weak or a lack of enforcement (high agreement, high evidence; Figure 5.4 on page 341 and Figure 5.7 on page 343). The reasons for this are complex, including financial and human resource limitations, but also the lack of social-distance of small islands that means enforcement officers are often working within their own communities (Everest-Philips and Henry, 2018). Additionally, fines for contravening rules are often outdated e.g. the *Forest Land Act* was last amended in 1984 and thus the maximum US$74 fine in 1984 was approximately 5% of average per capita GDP while in 2021, this same fine was <1%. Without follow through of enforcement and application of deterrent penalties, those conducting unlawful actions will continue to offend if there are no repercussions or the benefits gained from the offence outweigh the likelihood and scale of potential sanctions. Unlawful activities lead to overexploitation, habitat degradation, illegal grazing, littering (Box 5.5), pollution and lack of management of terrestrial invasive species, which have significant impacts on native species e.g. the Grenada dove, nesting seabirds and native herpetofauna (high agreement, medium evidence).

Figure 5.8. Forestry Staff sampling dry forest monitoring plots (Photo credit: E. S. Devenish-Nelson)

Lack of enforcement is also impeded by the policy gaps and overlaps, leading to uncertainties in institutional jurisdiction and responsibility for management, regulation of access and use. Interagency coordination for the management of terrestrial resources is limited by financial and human resource capacity and tends to be informal and ad-hoc, often relying on individual personnel to sustain data sharing, communication, management-activity coordination and other operational synergies. A common theme emerging from the enabling environment landscape is a sectoral approach that hinders joined-up thinking and mainstreaming, with this siloed approach perpetuating the knowledge-gap loop and hindering effective policy development and enforcement (high agreement, high evidence).

There is a growing understanding of systemic inequalities in the delivery of ecosystem services across all members of society e.g. gender, rural vs. urban communities, class, income and age and intersections between these groups. For example, there was a disproportionate impact on livelihoods for rural women relying on certain NTFPs after Hurricane Ivan (CARIBSAVE, 2012). Given that the reasons for these inequalities are multifaceted, addressing these issues requires explicit cross-sectoral recognition and participation in the enabling environment. Grenada has a strong history of public participation in policy processes (e.g. in the 2018 Forest Policy) and a large number of active environmental and sustainability focused CBOs and NGOs. However, the degree to which these organisations can effect change for an equitable delivery of terrestrial ecosystem services is limited by, among other factors, a lack of legal provision for public participation in environmental legislation, NGO management of protected areas and public private partnerships (PPP).

Instrumental

Sectoral economic activities and perverse incentives/disincentives lead to undesirable impacts on terrestrial systems (Figure 5.4 on page 341), such as subsidised fertilisers for farmers, or land taxes which punish landowners for maintaining natural cover in sensitive watersheds, forcing them to transform these into less-resilient and less-diverse monoculture

Box 5.5. Littering and the impacts of the legislative-enforcement gap

The need for clear follow-through where environmental legislation has been adopted, is critical to the legitimacy of state action on the environment. Such failures undermine policy actions to improve the environmental conditions for Grenadians, by normalising rule-breaking and externalising environmental costs. In this condition, even comprehensive legislation has little value without enforcement. A pervasive example is the lack of enforcement of the *Abatement of Litter Act 2015*. This important environmental management legislation addresses littering and dumping of waste across Grenada and is a key issue repeatedly raised by stakeholders when asked about environmental conditions.

It is estimated that on Grenada 1.14kg of waste is generated per capita per day, with an estimated 2% littered or dumped (Elgie *et al.*, 2021). The environmental impact of terrestrial littering is less studied globally than marine litter, but potential impacts include altered nutrient cycling of the soil, ingestion of microplastics by wildlife, incorporation into bird nests, incidental morbidity and mortality of wildlife, and adsorption and amplification of pollutants (Orona-Návar *et al.*, 2022; Khalid *et al.*, 2020; Madden and Danielson-Owczynsky, 2023). Not only does terrestrial litter lead to environmental degradation on land, but it is also a significant source of marine pollution across the Caribbean, making it a transboundary issue (Courtene-Jones *et al.*, 2021). Littering can have direct economic impacts, as exemplified by the potential for a loss of US$8.5 million in tourism revenue in coastal Brazil, due to littering (Krelling *et al.*, 2017).

Despite this extensive evidence for the negative consequences of littering, and an existing national legislative framework for its control, this problem persists in Grenada. Its persistence reflects a combination of a lack of public understanding of the detrimental environmental consequences of littering, and a lack of awareness of existing legislation and a lack of enforcement of fines set by the Act (Elgie, 2022).

landscapes. These activities are driven by traditional economic models, through which the government plans and implements compartmentalised sectoral development, including agriculture, transport, energy, health, housing and tourism. This siloed approach lacks an inter-sectorality that recognises and incorporates ecosystem services in national accounting.

The current system is framed by the influence and pressure from externalities on all sectors of the economy, including those that sustain ecosystem services. These externalities include national debt, trade balances, global financing, global information trends, global tourism trends and conservation finance mechanisms (see Chapter 1). One example is instructive; the government's civil service attrition policy is an example of the cascading outcomes on terrestrial natural resource management by such external forces (Box 5.4 on page 347). Ironically, this comes at a time of increasing demand for expertise in ecological restoration (Box 5.6), management of forests for improved carbon sequestration and endangered species recovery (medium agreement, medium evidence).

Conservation and management of natural resources relies primarily on government funding and Official Development Assistance (ODA) through instruments such as national budgets, grants, taxes, incentives and user fees. The limited allocation for managing terrestrial systems and ecosystem services (especially high elevation habitats, Figure 5.9) in several national policies and plans (e.g. *National Adaptation Plan and Medium-Term Action Plan for Economic Recovery, Transformation and Resilience 2022–2024*) and a general lack of funding for monitoring and evaluation, compounds existing financial constraints. In Grenada, national financial mechanisms intended to provide sustainable funding for terrestrial environmental management and biodiversity conservation have not been implemented, updated or suffer from a lack of transparency, e.g. the Environmental Levy and the National Parks Development Fund (high agreement, medium evidence).

Conservation and climate change adaptation actions have a high reliance on project-based funding. Such external funding streams have characteristics that force recipient governments and NGOs to plan and allocate work and resources on project-to-project scales. Donors are typically unwilling to fund long-term management and overheads, including permanent staff, resulting in a lack of continuity and institutional memory. This means there are few mechanisms for scaling up projects and developing sustainable project financing. Further, monitoring and evaluation tends to stop at the end of a project leading to a lack of long-term data and measures of success (e.g. PSPs). Ultimately, the short-term thinking inherent in project-to-project funding can become embedded institutionally. This affects the ability of

Figure 5.9. View over Grand Etang Lake (Photo credit: E. S. Devenish-Nelson)

stakeholders to plan and act to address system-level challenges that require long-term investments in capacity development, institution building, shifting of relational and value frameworks and ecological restoration.

At the local level, producers (e.g. those with livelihoods from agriculture, agroforestry, NTFPs) often lack sufficient access to financial mechanisms that could encourage individual and private investment in sustainable agricultural and land management planning and practices (Figure 5.4 on page 341 and Figure 5.7 on page 343). Such financial mechanisms include micro-financing, PPP or PES. Here, policy weaknesses in the legal provisioning that would enable such financial mechanisms are an important gap in the conservation finance landscape in Grenada (low-medium agreement, low evidence).

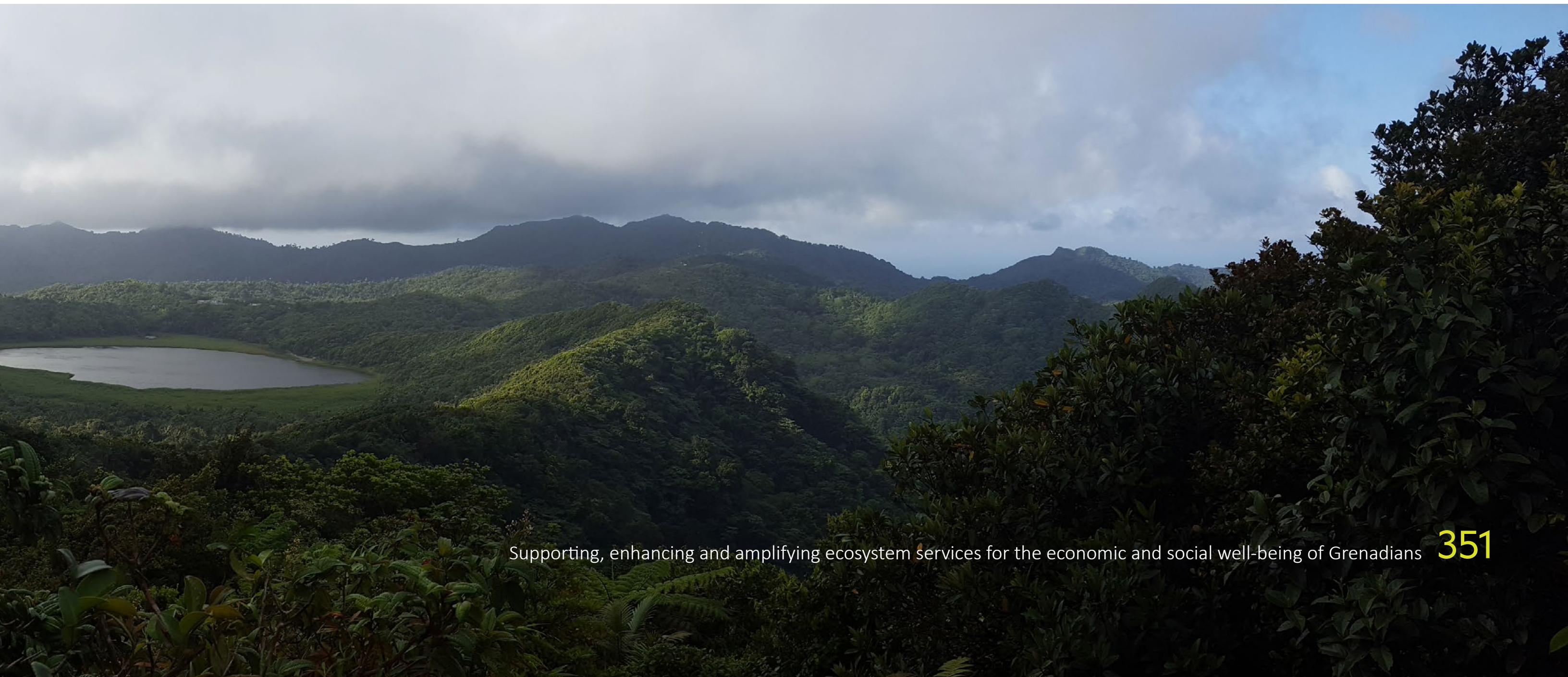
Response options

Foundational

At a national level, existing knowledge frameworks can be further developed to align with Grenada's MEA commitments. Of particular relevance here are indicators for the post-2020 GBF, which among other things, focus on building capacity to generate new data (i.e. beyond existing or remote sensing data). While the specific GBF monitoring and indicator structure is currently still being formulated, the headline (and component and complementary) indicators agreed at COP15 will be central to revising the country's NBSAP (the reporting instrument for the GBF) due to be completed by 2024. This presents an important opportunity to address key ecosystem services management gaps while also meeting MEA commitments (high agreement, medium evidence). Response options in Grenada's NBSAP (Thomas, 2016) that focus on improving knowledge of terrestrial

Box 5.6. Habitat restoration

Habitat restoration (Figure 5.10) is an area of global interest as a means to increase the resiliency of overexploited species, improve the flow of ecosystem services, repair damaged ecological systems or processes, and to reintroduce biodiversity on the landscape, to reduce or reverse habitat degradation and so improve livelihoods and benefits to communities reliant on these ecosystem services. The United Nations General Assembly has designated 2021–2030 as the "Decade of ecosystem restoration", and habitat restoration is an explicit target (Target 2) of the Global Biodiversity Framework recently agreed by the CBD, to which Grenada is a signatory. Restoration can have multiple objectives and methods, and often aims to establish or recover specific suites of species, and or restore, improve or create specific ecosystem functions. Examples of terrestrial restoration not only include re-planting of native species, but also the reduction of other stressors such as invasive species or pollution.



ecosystem services, include key government agency partners and local knowledge generation institutions such as St. George's University (SGU), who can increase understanding of how to amplify in Grenada while aligning with the GBF goals. However, the last national report highlights a lack of progress in this area (GoG, 2014).

Improving frameworks for data generation is critical for addressing capacity issues and maintaining the long-term monitoring that is lacking in many SIDS, including Grenada. It is necessary to not only review administrative arrangements and budgeting for efficiencies, but also streamline on-the-ground sampling design to maximise human capacity. For example, multi-taxa and socio-ecological monitoring of PSPs would contribute to knowledge across multiple areas of terrestrial systems (e.g. spread of invasive species, climate responses, habitat assessment and restoration, sustainable use of NTFPs) (Figures 5.10 and 5.11). Here, efforts to digitise historical data on the forest PSPs established in the 1980s would be invaluable for understanding climate change impacts, and provide baselines for other terrestrial ecosystem service indicators (high agreement, high evidence). A thorough review of the repository of data held by the FNPD and other government agencies could identify unpublished data on which to build, for example, the 2013 FAO baseline population survey of game species critical for their sustainable use (Figure 5.11, Box 5.7).

Encouraging coherence and collaboration between educational institutions, local NGOs, FNPD and other government agencies in project design and implementation, will maximise training and capacity building and ensure foreign-based researchers engage with these organisations. Options to engage not only locally but also regionally with organisations such as the Caribbean Foresters Association or BirdsCaribbean to instigate shared region-wide monitoring, where groups of experts would conduct inter-island monitoring, may mitigate some island-level data-collection capacity issues (medium agreement, high evidence). Finally, to increase data access and availability, a systematic re-structuring of state agency data repositories, and adoption of policies that encourage both national and international partners to share their data digitally, through widely-used open source data management portals such as Zenodo or Dryad (Figures 5.10 and 5.11) (high agreement, high evidence), is required.

Box 5.7. Sustainable harvesting of terrestrial resources

Sustainable harvesting (Figure 5.11) implies extraction of species, or their parts or products from nature at a rate that does not deplete the plants and animals from the landscape. Implementation of a sustainable harvesting system often implies that managers and stakeholders have a system in place for monitoring how populations or ecosystem services related to these populations are changing over time, as well as an agreed means to control the use of such resources. Sustainable harvesting can make important contributions to resiliency of ecosystems facing other external pressures. For example, prevention of overharvesting can improve a species' resilience to climate-induced stress such as through the maintenance of viable populations and genetic variation.

Local and regional knowledge transfer activities are known to be an effective response for addressing knowledge gaps and generation, particularly for harnessing local and traditional knowledge (high agreement, medium evidence). For example, the Caribbean Natural Resources Institute's (CANARI's) Forestry and Livelihoods Action Learning Group (ALG) programme was a valuable mechanism to facilitate collaborative problem solving, bringing together regional stakeholders to generate new knowledge (CANARI, 2012). In Grenada, this ALG provided the Morne Longue Progressive with support to build their organisational capacity and recommendations for trail development (CANARI, 2009). Response activities that would benefit from this type of regional knowledge sharing include management of fire (e.g. law enforcement, awareness, prevention and control), grazing (e.g. behaviour change incentives/

disincentives), NTFP (e.g. supporting cooperatives) and restoration (e.g. stakeholder involvement) (Figures 5.10 and 5.11).

The conversion of knowledge into policy and practice required to manage terrestrial ecosystems and their services is partly dependent on a high level of public knowledge and awareness of environmental issues. Assessment of environmental literacy through tools such as KAP surveys (Figures 5.10 and 5.11), is a first step to identifying levels of awareness and needs for targeted education. Here, there is an opportunity for government agencies to engage with SGU, who have conducted previous KAP surveys (Glasgow *et al.*, 2018). Designing, establishing and maintaining cross-sectoral education and awareness activities (e.g. Box 5.8) to increase understanding of the interconnectedness of environmental degradation, ecosystem services and human health and livelihoods, will shape the values, patterns and norms associated with sustainable land use. Such efforts will translate into important positive outcomes for ecosystem services such as increased fire awareness, pollution literacy, grazing impacts, valuation of NTFPs and benefits of restoration (Figures 5.10 and 5.11).

Box 5.8. Leading the way with citizen science

Efforts to designate the Grenada dove as the National Bird in 1991 exemplifies the national pride of the peoples of Grenada in their natural environment, and lessons from this initiative could be applied to harness this pride to encompass the wider environment. Voluntary response options that draw on this pride, such as citizen science projects (e.g. the region-wide BirdsCaribbean Caribbean Waterbird Census organised in Grenada by the Grenada Fund for Conservation) would serve not only to increase engagement and awareness in civil society, but also to contribute to knowledge generation and increased stakeholder buy-in for management of ecosystem services (high agreement, medium evidence).

Enabling

Institutional and governance frameworks responsible for management implementation act at state, parish, and community levels, as well as informally and can lead to power asymmetries and 'turfism', which limits the effectiveness to develop streamlined approaches. Yet, terrestrial ecosystem-based management approaches offer valuable opportunities for finding synergies in interagency coordination, such as between disaster risk reduction, climate change adaptation, sustainable development goals (SDGs), food security, health and tourism (high agreement, high evidence). Here, there is an opportunity to establish a Cabinet level role for cross-sectoral integration (Figure 5.10 and 5.11) with oversight to address efficacy and mainstreaming of ecosystem services. Further, as identified in Chapter 1, frequent changes in the ministerial portfolios and movement of departments have substantial and long-lasting impacts on the prioritisation and management of Grenada's terrestrial ecosystems (Box 5.4 on page 347), as well as creating inter-ministerial tension, emphasising the need for stability and transparency in ministerial portfolios. Consideration of this issue, particularly through a holistic and cross-sectorial lens, is central to successful implementation of responses arising from the NEA (high agreement, medium evidence).

Assessments of human resource needs is a first step towards identifying specific training, readiness and capacity gaps and requirements for terrestrial protected areas and NTFP management and enforcement of harmful anthropogenic activities (Figure 5.10 and 5.11). Personnel options for conducting more efficient management, data collection and enforcement with limited staff, include exploring how to devolve responsibilities for management and/or data collection to NGOs, CBOs, citizen science, educational or private institutions and establishing an honorary game warden system for enforcement (high agreement, high evidence). Technological options to address human resource limitations include the use of remote sensing, artificial intelligence (AI) and automation (medium agreement, medium evidence).

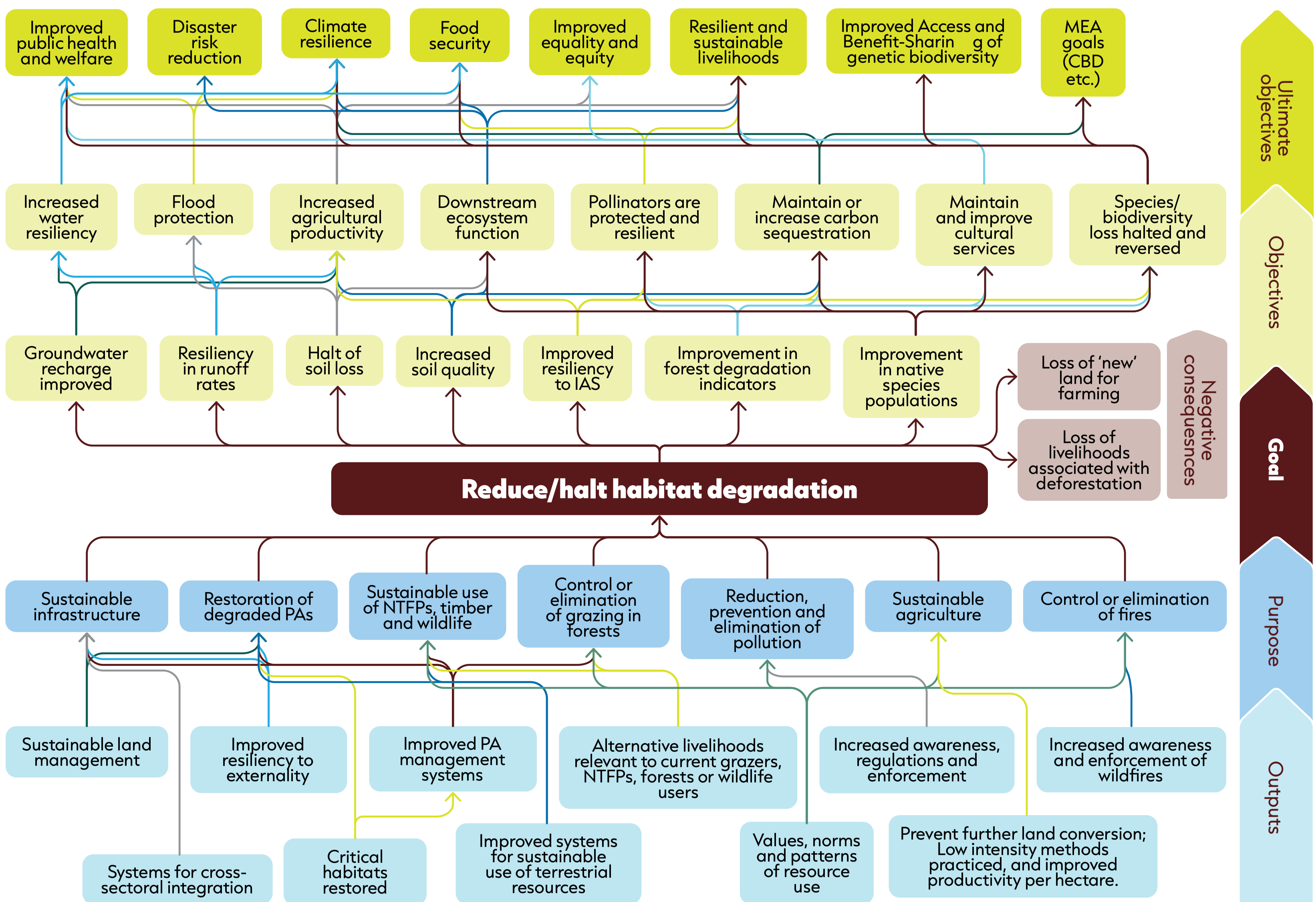


Figure 5.10. Objectives tree showing outputs, purposes, goals and objectives for responding to terrestrial habitat degradation and improving the delivery of ecosystem services (see Box 5.6). Activities (foundational, enabling and instrumental) that map to the outputs are presented in Appendices 4 and 6

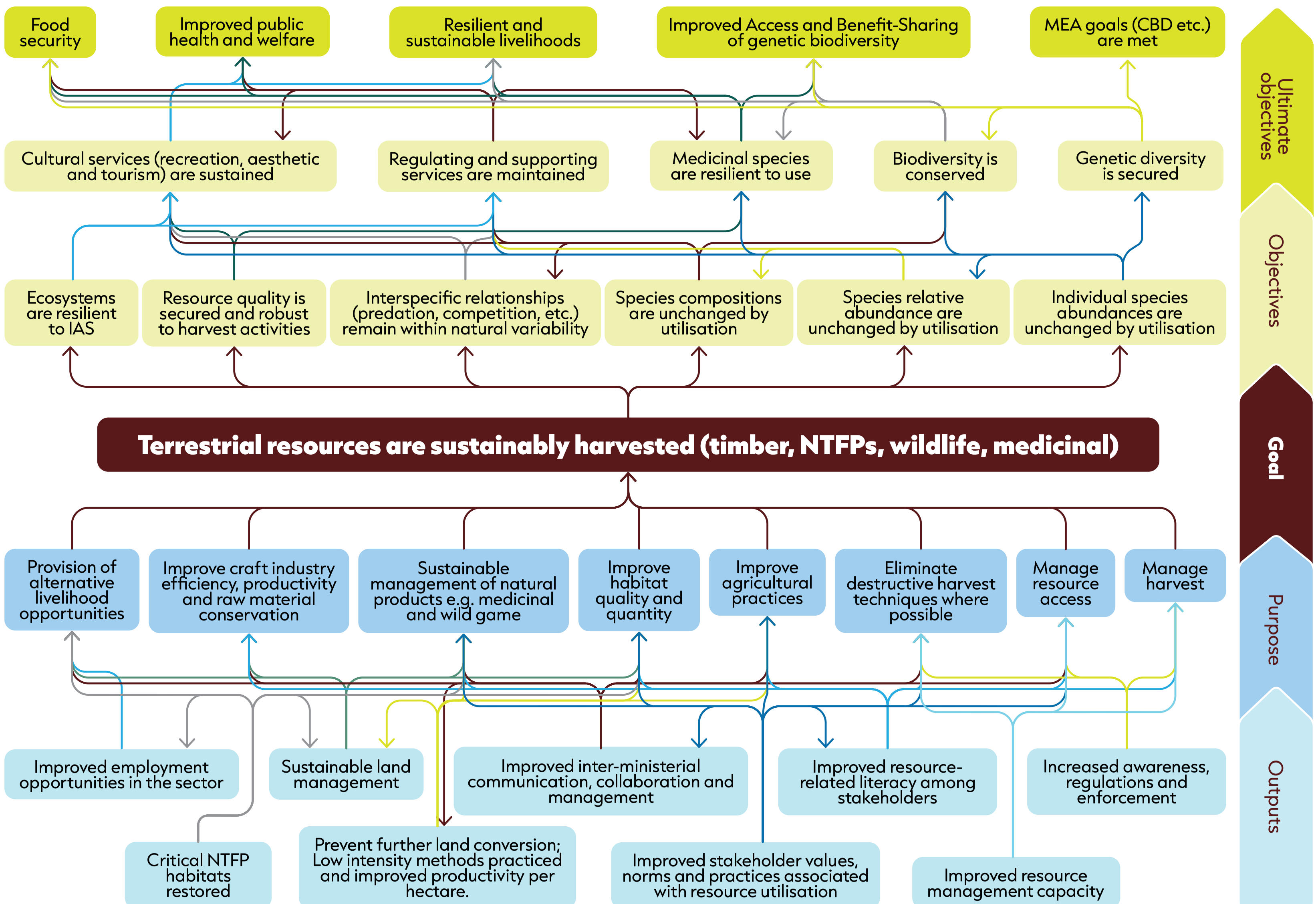


Figure 5.11. Objectives tree showing outputs, purposes, goals and objectives for responding to overexploitation of terrestrial nature resources and improving the delivery of ecosystem services (see Box 5.7). Activities (knowledge, enabling and instrumental) that map to the outputs are presented in Appendices 4 and 6

Grenada has an engaged, active and environmentally aware civil society and NGO movement (e.g. Grenada Land Actors advocacy for sustainable land management). That the Grenada government has this year ratified the *Escazú Agreement* is a positive step towards strengthening public participation in, and disseminating information about environmental decision making. Participatory tools are an effective response for developing bottom-up and inclusive legislation and policy to meet the needs of civil society and contribute to achieving long-term protection (high agreement, medium evidence). For example, the participatory process in 2018 to revise the *Grenada National Forest Policy* (under the *iLAND Resilience Programme*) was highly regarded, due to its ability to successfully engage a diverse range of stakeholders (CANARI, 2012).

Increasing engagement in decision making will give greater voice to those groups disproportionately affected not only by inequalities in provision of ecosystem services but also from potential responses and economic transitions. Examples of successful community response actions that educate and empower youth, rural communities, small farmers and women, include those by the Grenada Community Development Agency (GRENCODA) to reduce poverty and the Grenada Education and Development Programme (GRENED) to educate youth. Increasing the support for capacity building to increase the cross-sectoral focus of existing programmes could be an effective mechanism to achieve landscape scale delivery of terrestrial ecosystem services while increasing equality (medium agreement, low-medium evidence). Small local actions embedded in a wider network of activities have the potential to promote ownership of ecosystem service delivery and have island-wide cumulative benefits (medium agreement, low-medium evidence). Strengthening the enabling and instrumental environment (see policy/finance sections; Figure 5.10 on page 354 and Figure 5.11 on page 355) can empower local communities to take actions and in so doing, promote sustainable, alternative livelihoods and increase environmental and human resiliency, such as to developing NTFP cooperatives, restoring local green spaces.

Increasing mechanisms to engage private landowners is central to achieving widespread amplification of ecosystem services due to the limited area of Crown lands across the tri-nation state (high agreement, high evidence). One such mechanism is strengthening support for PPP (Figure 5.10). There is a PPP unit within the Finance Ministry (Queyranne *et al.*, 2019) but to date the 2014 PPP policy has not been implemented. In general, PPP have been underutilised throughout the Caribbean for terrestrial environmental management (Guasch, 2013). Devolving power would address 'turfism', as well as capacity issues and inadequate participation of civil society in environmental management such as protected areas (Gardner, 2006). There is precedent for shared protected area management in Grenada, with St. Patrick Environmental and Community Tourism Organisation (SPECTO) engaged in management of Levera National Park. While the State can through existing legislation already acquire private lands for activities deemed nationally critical, the existing lack of management capacity within the State institutions undermines this option as a means to widen the protected areas system for Grenada.

Enabling legislation for OECMs is critical for management of private lands for ecosystem services (medium agreement, medium evidence). OECMs are areas that are not designated with conservation as a primary objective but nevertheless deliver effective conservation, have been recognised as contributing to protected area goals by the GBF and can include private land, community lands, agricultural set-asides and water catchments among other areas (Dudley *et al.*, 2018). OECMs offer a potential option for engaging private land owners for restoring habitats and amplifying ecosystem service delivery beyond the limited space of terrestrial protected areas. Resolving and harmonising protected areas policy and legislation would be a critical step to enable formal recognition of OECMs.

Instrumental

The inappropriate use of technology and poor land management practices have inadvertently led to the destruction of biodiversity (e.g. excess agricultural fertilisers and pesticides making it possible to temporarily expand into previously unsuitable areas). One response option here is to review the certifiable activities for Environmental Impact Assessments (EIAs) as required under the *Environmental Management Act* to ensure they promote best practices for sustainable land management, and minimise, offset or restore negative effects of activities on ES, where they are unavoidable.

Technology also has a role in reversing negative impacts by exploiting technological advances for protecting ecosystems and ecosystem services. For example, the potential development of the biochemical industry to build the value chain for essential oils from NTFPs (Rodriguez, 2003), the use of eDNA to monitor habitat degradation drivers or the use of remote sensing and networked sensors for monitoring fire, poaching or other disturbance risks in real-time (Lahoz-Monfort and Magrath, 2021). Regional collaboration options also provide a real opportunity to share knowledge and lower the cost of innovation, for example, applying learnings from an innovative fire detection programme using old cell phones in Jamaica (Neotropical Migratory Bird Conservation Act project). Technology can also be used to address capacity limitations through increasing reporting efficiency, such as using digital MEA reporting tools (e.g. DaRT)

While the majority of Grenada's restoration efforts have been focused on coastal areas, lessons from these and reforestation efforts in terrestrial areas can be used to develop best practices in restoration and sustainable land management. Grenada has signed up to the UNCCD's voluntary Land Degradation Neutrality (LDN) targets with ambitious targets for restoring degraded terrestrial land by 2030 and has recently implemented a national soil survey. It is unclear how much progress has been made towards reforestation targets since the last national LDN report in 2015 (GoG, 2015). Globally, reforestation efforts often fail due to multiple factors including short time frames, not planting the right trees or in the right places, as well as a lack of post-planting ownership and management (Duguma *et al.*, 2020).

Climate-smart agriculture and other agri-environment schemes (Figure 5.10) offer an opportunity for landscape restoration beyond reforestation, with some successful pilot projects in Grenada such as the *Integrated Climate Change Adaptation Strategies (ICCAS) Programme* (GoG, 2017b). However, such schemes are also known from global evidence to frequently suffer from failure and can lead to increased land degradation when poorly implemented, due in part to an emphasis on productivity (Ollinaho and Kroger, 2021) at the expense of other ecosystem values and services. Improving the chances of successful restoration thus demands filling the knowledge gaps of local ecosystem functioning and long-term monitoring of previously implemented projects, without which we lack the evidence to evaluate success and scale-up implementation (high agreement, high evidence). Maintaining post-project funding is essential for sustaining long-term monitoring, for initiatives such as the Grenada Ecological Resilience Research Institute (GERRI). Importantly, the development of integrated national targets for terrestrial restoration, provides a key opportunity to harmonise and build strategic synergies for not only addressing national level ecosystem-service needs, but to also move in lock step with the achievement of GBF and LDN targets for restoration of degraded habitats and the goals inherent in the UNs Decade of Restoration.

Key to successful terrestrial habitat restoration are response options that increase and maintain connectivity between intact habitat fragments, particularly those that include private lands (high agreement, high evidence). Given the paucity of knowledge of the impacts of anthropogenic threats on Grenadian ecosystems (Chapters 2-4), it is prudent to maintain connectivity in order to maintain natural processes to allow natural species dispersal and energy flows, ecosystem functioning such as genetic variation (e.g. climate resilient species), ground and surface water recharge, climate resiliency (e.g. allowing species range shifts) and preventing pollinator loss. Maintaining connectivity reduces the intensity of management actions (e.g. assisted migration in isolated populations) required to be undertaken by the government and stakeholders to maintain ecological processes, and so reducing management costs in the long-run. Updating land cover maps through remote sensing would be an important first step to prioritise restoration areas and develop a mitigation hierarchy. Identifying key connectivity between different habitat types (e.g. transitions between dry and moist forest) and those areas vulnerable to extreme weather events (e.g. highly eroded steep slopes) and drought (e.g. particularly on Carriacou and Petite Martinique) will help establish areas suitable for mitigation. Transitions between forest ecotones are particularly important on islands with steep topography such as Grenada being vulnerable to climate-induced elevational shifting of vegetation types (Harter *et al.*, 2015). By restoring habitats and promoting connectivity, functioning terrestrial ecosystems can deliver co-benefits to people through sustainable livelihoods, health benefits, food security, disaster risk reduction, increasing equality and ultimately increasing people's ability to adapt to environmental change (Figure 5.10 on page 354 and Figure 5.11 on page 355).

5.2.2. Agricultural ecosystems

Grenada's agroecosystems provide essential benefits to the people of Grenada. These systems are primarily commercial and small-scale (Figure 5.12), operating on plot sizes averaging 1.03ha (James, 2015). At the national level, agroecosystems are valued for their contribution to food security, trade and tourism.

The major agroecosystem types in Grenada are crop systems such as nutmeg (*Myristica fragrans*), cinnamon (*Cinnamon umzeylanicum*), banana, plantain (*Musa paradisiaca*), cocoa (*Theobroma cacao*) and non-traditional crops, citrus and livestock (Chapter 2, Chapter 4). In previous chapters of this report, it has been established that climate change, natural disasters, and biodiversity loss significantly threaten agroecosystems and their services (Chapters 2-4). Chapter 3, in particular, has discussed the drivers of change across ecosystems. In this section, we will focus on the governance challenges that impact the enhancement and protection of agroecosystems and their services. These governance challenges are barriers towards agroecosystem transformation.

Challenges

In this section, we discuss the key governance challenges along three dimensions: foundational, enabling and instrumental (Figure 5.13).

Foundational

Foundational challenges are systemic barriers to governance that impact the sustainability of the entire ecosystem. In the Grenada context, existing foundational challenges are not specific to agroecosystems but cross-cut terrestrial, freshwater, coastal and marine ecosystems management. The key foundational challenges identified are: 1) competing land uses and 2) land tenure governance.

Competing land uses

In Grenada, land is a limited resource. Recent estimates by the GoG suggest that between 31,566ha and 32,375ha of land are available for agriculture and other land uses (Grenada Broadcasting Network [GBN], 2022). In terms of agricultural land use, there has been a marked decline in agricultural activities over the past two decades, which is reflected in shifting land use patterns away from agriculture to urban, manufacturing and other uses (GoG, 2016b). The latest agricultural census undertaken in 2012 recorded 9,345 farms covering an area of 9,542ha

Figure 5.12. Crop farming in Grenada (Photo credit: Ministry of Agriculture and Lands, Fisheries and Cooperatives)

across Grenada (FAO, 2012; GoG, 2016b). This figure represents approximately a 21% and 24% decrease in the number of farms and farm coverage, respectively, since 1995 (GoG, 2016b). The decline in agriculture and related livelihoods in rural areas has created the knock-on effect of increased rural-to-urban migration as people seek better livelihood opportunities in the major urban centres (GoG, 2016b). This, in turn, has led to increasing demand for housing in urban areas (GoG, 2016b). Due to the scarcity of land in urban areas coupled with high land/housing prices, informal settlements and squatting emerge on available lands at the edge of urban areas to meet demand (GoG, 2016b).

It is well acknowledged that land use changes are a major driver of biodiversity loss and the degradation of ecosystem services (high agreement, high evidence) (Poertner *et al.*, 2021). In Grenada, underutilised or abandoned agricultural lands are at risk of conversion to other uses, such as housing. Land use conversion from agriculture to urban and manufacturing uses can exacerbate agrobiodiversity loss through habitat fragmentation and destruction, disrupt soil nutrient cycles, increase the risk of surface runoff and flooding, and contribute to food insecurity, as soil and crop cover are replaced with impermeable surfaces and concrete structures. Furthermore, increasing urbanisation coupled with climate change can contribute to urban heat island effects in urban centres (high agreement, high evidence) (Dodman *et al.*, 2022). Urban heat island effects can disproportionately impact Grenadians depending on age, socio-economic status and state of health.

The competing land uses underscore the embedded value conflict attached to the land. The scarcity of land places pressure from a governance standpoint on how best to allocate available land to ensure maximum productivity at present while keeping sustainability and biodiversity targets in focus to address perennial issues of food security, public health, ecosystem degradation, biodiversity loss, natural disasters and climate change.

Lack of legislation to enable land-related policies coupled with lack of policy enforcement

On the global stage, the Government of Grenada is a signatory to a number of international agreements to address climate change, disaster risks and biodiversity loss (see Chapter 1). Ratified agreements and international commitments shape national policies concerning agroecosystems management, sustainable livelihoods and societal well-being. Key national policies that steer the sustainable development of the agriculture sector include the *National Climate Change Adaptation Plan for Grenada, Carriacou and Petite Martinique (2017-2021)*, *National Agriculture Plan (2015-2030)*, *Technology Needs Assessment for Adaptation to Climate Change, National Agriculture Policy (Draft)*, *Grenada National Water Policy, Grenada National Land Policy*, *Grenada National Biodiversity Strategy and Action Plan (2016-2020)*, the *Grenada Nutmeg Sector Development Strategy 2010-2015* and the *Gender Equality Policy and Action Plan (2014-2024)*.

While a suite of policies is available to engender sustainable agroecosystem management, two critical issues facing governance are effective legislation and the need for policy implementation. In terms of legislation, outdated legislation, lack of supporting regulation, and enforcement of existing legislation are barriers to effective ecosystem governance. This can be attributed to a lack of political will. For example, the *Grenada National Land Policy*, which is the cornerstone of the sustainable land management of ecosystems, has only been ratified in November 2022; however, it still requires legislative teeth to enable its full enactment. Furthermore, there is still the need to legally recognise family land tenure in Grenada. A lack of policy enforcement can contribute to the proliferation of unsustainable land use practices. Existing policies related to land, water, livelihoods and agriculture need to be reviewed and updated to reflect a common objective of nature-positive agriculture that targets biodiversity management, climate change, sustainable land management, disaster risk reduction, food security and poverty reduction. There is also a need for optimal implementation of policies in order to achieve sustainable development and biodiversity targets

(GoG, 2016a). For example, in the *Grenada National Biodiversity Strategy and Action Plan 2016-2020*, it is reported that projects implemented based on the previous strategy were under the satisfactory benchmark (GoG, 2016a).

Enabling

Institutions play an important role in the sustainable management of ecosystems, their services and enable how benefits are distributed and accessed by people. Institutions are the rules, norms, values, beliefs, and practices that reproduce in daily life, for example, in the family, community and organisations as social structures (Cortner *et al.*, 1998; Hodgson, 2006). Decision making is tightly connected to institutions, and therefore, when it comes to ecosystem governance, institutions influence the functioning, outcomes, and impacts of ecosystems (Olsson and Folke, 2001). Existing institutional challenges can directly or indirectly enable barriers to ecosystem sustainability (Cortner *et al.*, 1998) and impede progress towards meeting national commitments and targets as outlined in the United Nations Sustainable Development Goals and Aichi Biodiversity Targets. Two key institutional challenges that hinder the enabling environment towards sustainable agroecosystems are discussed below.

Land tenure governance

In Grenada, approximately 90% of available lands are privately owned, with 10% being state-owned (GoG, 2016b). Informality and land tenure insecurity are perennial issues that impede the sustainable land management of agricultural lands. Most farmers in Grenada operate under some degree of tenure insecurity ranging from land rental without documented rental agreements, the use of family land to squatting. There is a correlation between tenure security and investments into sustainable land management (SLM) (Baribier and Hochard, 2018) (high evidence, high confidence). A farmer that is tenure insecure is less motivated to invest in SLM practices (Barbier and Hochard, 2018). Furthermore, tenure insecurity reduces the livelihood resilience of farmers, as farmers without proper documentation can be excluded from state incentives and lines of credit to improve agriculture production (Daniel *et al.*, 2019) (Figure 5.13). Evidence from the Caribbean has also shown that in post-disaster events, lack of tenure documentation has impeded aid delivery and the reconstruction of livelihoods (Griffith-Charles *et al.*, 2014).

In the case of the eastern Caribbean countries, two major challenges farmers face are land access and access to credit for livelihood development from lending agencies due to the lack of capital (collateral) in the form of land titles (Barry and Gahman, 2021). According to Barry and Gahman's study, women farmers are more affected since they are less likely to own land (Barry and Gahman, 2021). In Grenada, it is estimated that 77% of men are landowners (GoG, 2014b). As a result, men have a greater access to financing from banks than women (GoG, 2014). Tenure insecurity in the eastern Caribbean, therefore, affects women in agriculture more and can negatively impact their agricultural productivity (Barry and Gahman, 2021).

Out-of-date land tenure registries and databases can stymie efforts to foster the enhancement of agroecosystems and their services (medium confidence). An incomplete picture of the stock of land available for agriculture hinders livelihood development and food security targets. It provides the opportunity to misappropriate land use and land access. From a governance perspective, efforts to promote conservation and the enhancement of agroecosystems and their services should address the issue of tenure insecurity and work towards a quasi-recognition of family land tenure legally via fit-for-purpose land administration. Furthermore, updating land registries is important for effective and productive land allocation for the purposes of agriculture, supporting livelihoods and addressing food security. The GoG has recognised the issue of land tenure and gaps in land tenure data as disabling conditions towards sustainable development and has embarked on the establishment of a national land bank with the assistance of the FAO. This existing response option is further discussed in Section 5.3.

Siloed governance

The interconnected nature of ecosystems requires an integrative approach to governance and management to mitigate negative cascading effects across ecosystems and support long-term sustainability (high

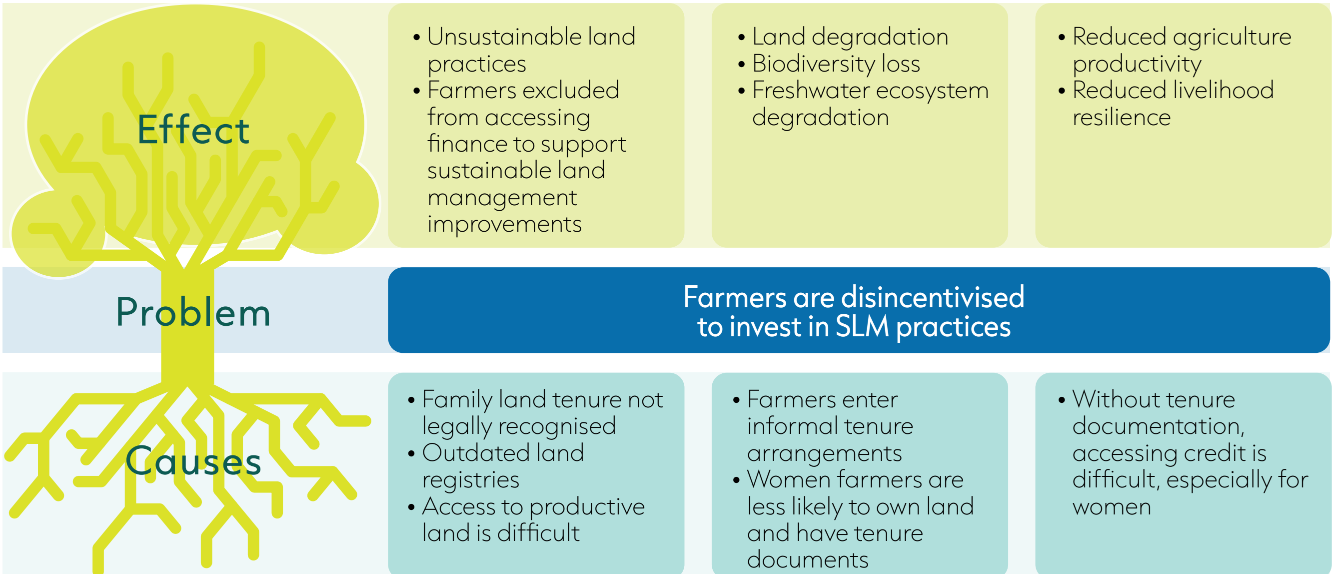


Figure 5.13. Problem tree illustrating the linkages across land tenure insecurity, ecosystem degradation and livelihood resilience

agreement, high confidence) (Primmer and Furman, 2012; Poertner *et al.*, 2021). While there is evidence of integrative approaches being used to address socio-ecological challenges within agroecosystems and across other ecosystems in Grenada (e.g. *Ridge to Reef Project*), there is still a strong focus on siloed or sectoral-based governance of these ecosystems. This can lead to a mismatch in policies that can create short-term benefits in one part of the system but then disable the long-term sustainability of the entire agroecosystem. For example, the FAO has stated that agriculture policies that allow for the importation of hybrid seeds and plant material in Grenada have, over time, created a dependence by farmers on foreign genetic material (FAO, 2016). This, in turn, has contributed to negative cascading effects such as the loss of local genetic resources in the long term (e.g. local legumes), the introduction of IAS and diseases (e.g. red palm mites, fruit flies, and black sigatoka disease), farmers bearing high costs to manage pests and disease as well as the loss of export markets for fruits due to fruit flies (FAO, 2016).

Mismatching policies is one direct consequence of sector-based governance of agroecosystems. Indirectly, a lack of data sharing, knowledge sharing, and communication between key departments with responsibilities for agriculture are other side-effects of sector-based governance. These issues are symptomatic of the broader issue of 'fit' between institutions and ecosystems as interconnected ecological systems (Cash *et al.*, 2006; Primmer and Furman, 2012). The administrative arrangement is one in which various departments with their own rules, practices and policies have oversight on some aspect of an ecosystem, its access, use and distribution of their services (Primmer and Furman, 2012). For example, the Department of Lands and Surveys under the Ministry of Agriculture has jurisdiction over the allocation of land guided by the *Grenada National Land Policy*, whereas the Ministry of Climate Change, the Environment and Renewable Energy manages protected areas. However, Grenada's agroecosystems are not separate from but rather connected with its freshwater, terrestrial and coastal ecosystems. Therefore, governance actions undertaken within the agriculture sector will affect terrestrial, freshwater and coastal ecosystems. Hence, what is required is a greater inter-sectoral approach to ecosystem governance that is flexible and also makes room at the table for farming groups, NGOs and civil society to participate in the process (Primmer and Furman, 2012).

Instrumental

Sustainability outcomes are determined by the strategies (instruments) implemented at the national, regional, and local levels to bring about change. However, in Grenada, resource constraints can hinder the implementation of policy-related strategies and programmes that help mitigate agroecosystem disservices (e.g. pollution, soil degradation, biodiversity loss) and support sustainable livelihood development across agroecosystems. The following resource constraints have been identified as critical issues that impact progress towards achieving desired outcomes.

Mobilising long-term sustainability financing

Access to finance is a key enabler for the sustainable management of ecosystems and their services. The level of financing available can influence the success or failure of measures to enable equitable benefit sharing and address issues of biodiversity loss and climate change (high evidence, high confidence) (Poertner *et al.*, 2021). In Grenada, funding for agriculture is obtained from three primary sources: The GoG, the private sector and international donors via bilateral and multilateral agreements. Although there is a concerted effort by stakeholders in Grenada to address climate change, biodiversity loss and ecosystem degradation, which threaten the functioning of agroecosystems, the challenge for Grenada and the wider OECS lie in mobilising funding for long-term sustainability initiatives (Figure 5.14) (United Nations Framework Convention on Climate Change [UNFCCC] 2022). Financing sustainability as a small island developing state is costly, and it is estimated that Grenada requires approximately US$200 million to address climate adaptation and mitigation needs for the period 2015 to 2030 (Table 5.1) (Mohan, 2022). This figure represents 19% of the total GDP for 2021 that is required to fund adaptation and mitigation to 2030 (Mohan, 2022). One of the critical areas identified for climate mitigation and adaptation in Grenada is agriculture, forestry and other land uses. However, the UNFCC (2022) acknowledges that within the OECS, there are a few barriers to mobilising sustainability financing, which critically undermines progress towards a climate-resilient economy. These barriers include but are not limited to (UNFCCC, 2022):

- lack of knowledge on available sustainability-related funding sources and ways of tapping into these sources;
- data paucity relating to adaptation and mitigation needs;
- lack of human and institutional capacity to spearhead and carry out mitigation and adaptation projects; and
- sector-based approach to addressing climate change that leads to a lack of coordinated interventions.

*Table 5.1. Climate finance needs of OECS states 2015-2030 (*GDP based on World Bank's 2021 data; "-" represents no information)* (Mohan, 2022)

Cost in $US million

Country	Mitigation cost	Adaptation cost	Total cost	Total cost per GDP (%)	Total average cost per capita
Antigua and Barbuda	200	200	400	29	4,085
Dominica	100	25	125	24	1,736
Grenada	-	-	200	19	1,778
St. Kitts and Nevis	-	-	-	-	-
Saint Lucia	400	-	400	25	2,178
St. Vincent and the Grenadines	-	-	-	-	-

Other resource constraints

In addition to long-term sustainability financing, agriculture governance in Grenada towards nature-positive agriculture is stymied by the lack of up-to-date spatial and temporal data on land use and land cover changes, land availability, land ownership, farm system production, biodiversity and greenhouse gas emissions produced across the agriculture sector (GoG, 2015; GoG, 2016b). This, in turn, can lead to gaps in monitoring, evaluating and reporting on agroecosystems. Gaps in reporting on agroecosystems can foster inadequate adaptation and sustainability action plans across ecosystems (GoG, 2017a). The issue of data and reporting is connected to the broader issue of a lack of human resources across government departments connected to agriculture (GoG, 2016b; GoG, 2017a).

In the previous sections, we shed light on key governance challenges that impact the sustainability of agroecosystems and the enhancement of their services. In this section, we present responses to these challenges, which can support transformative change across agroecosystems that bring about their improved sustainable land management and support livelihood development. Similar to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) Biodiversity and Climate Change Report (Poertner *et al.*, 2021) we used the concept of levers (system interventions) presented by Chan *et al.* (2020) as an analytical tool to discuss context-specific governance-based response options. Chan *et al.* (2020) identified the following five levers to support sustainable transformation: 1) incentives and capacity building, 2) coordination across sectors and jurisdictions, 3) pre-emptive action, 4) adaptive-decision making and 5) environmental law and implementation. We have adapted these levers to address foundational, enabling and instrumental response options for agroecosystems in the Grenada context.

Response options

Foundational response options

Pre-emptive action to address underlying drivers of land use changes

As stated in Section 5.2, land use change is a major driver of biodiversity loss, habitat degradation, soil erosion, and flooding. Pre-emptive action will require intervening to mitigate underlying drivers (both known and unknown) of land use change (see Chapter 3 for a comprehensive discussion on drivers)

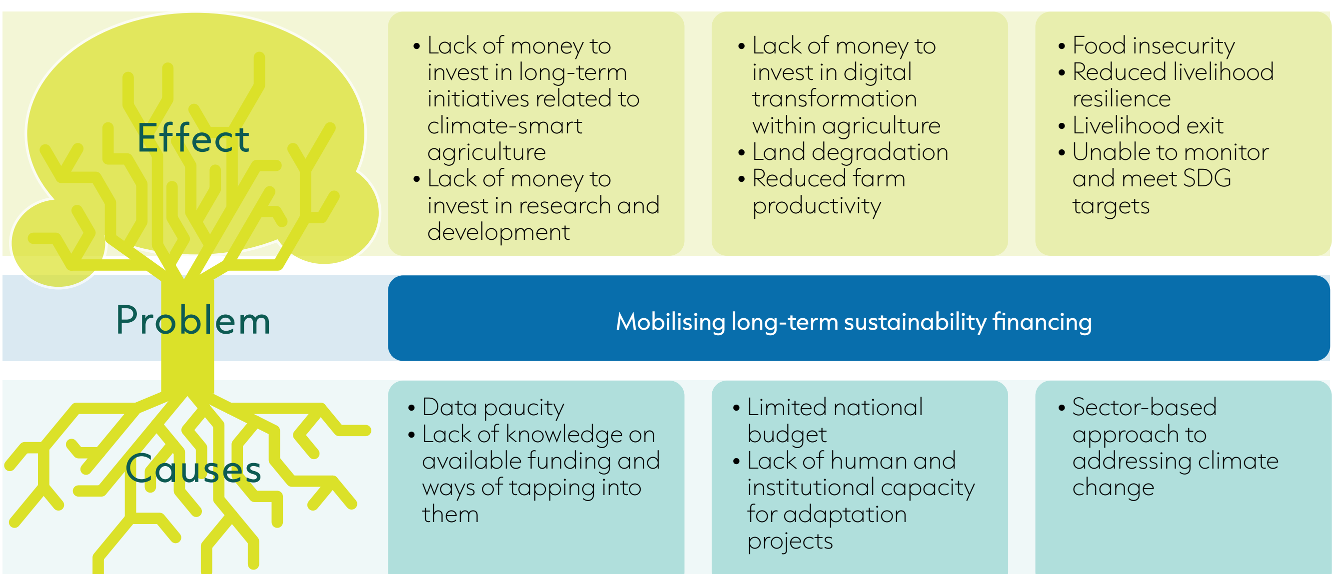


Figure 5.14. Problem tree illustrating the linkages across institutional deficiencies, long-term sustainability financing and impacts to agriculture and livelihoods

before they become unsustainable changes. From a governance perspective, this will entail coordinated pro-active planning by stakeholders that balance political, socio-economic and environmental agendas, considers sustainable development trade-offs and leverage scenario-based modelling (see Chapter 6). One key initiative that can support pre-emptive action is the ongoing Agricultural Land Bank pilot project, which intends to catalogue available agricultural lands in order to reduce idle lands and enable legitimate land access to farmers especially for women and landless farmers. If used effectively with other spatial mapping support for decision making, the Agricultural Land Bank can be used to prevent unwanted land use change.

Implementation and enforcement of agroecosystem-related policies and legislation

The foundational basis of ecosystem protection is built on having strong policy frameworks and accompanying legislation (Chan *et al.*, 2020). The ratification of the *National Land Policy* in 2022 is a monumental step towards agroecosystem protection and sustainability. Other key frameworks entail the *National Agricultural Plan 2015-2030*, the *National Biodiversity Strategy and Action Plan 2016-2020* and the *National Climate Change Adaptation Plan for Grenada, Carriacou and Petite Martinique*. These frameworks emphasise the importance of biodiversity conservation, climate adaptation and sustainable land management in agroecosystem protection. However, what is re-iterated across policies is the need for policy implementation and accompanying legislation to support the enforcement of related initiatives on the ground (GoG, 2016a; GoG, 2016b; GoG, 2017a). Additionally, steps need to be taken to legally recognise family land tenure arrangements to support agroecosystem protection. Barry and Gahman (2021) also highlighted in their study on women in agriculture in the eastern Caribbean that there is a need for gender-responsive policies that support women in agriculture and reduce the inequalities that they face in their livelihoods. The GoG has taken steps in this direction with the establishment of the *Gender Equality Policy and Action Plan 2014-2024*.

Figure 5.15. Farmers participating in an integrated pest management training on sticky traps (Photo credit: The Ministry of Agriculture and Lands, Fisheries and Cooperatives)

Enabling response options

Multi-sectoral approach and adaptive decision making

Tackling the wicked social-ecological problems contributing to agroecosystem degradation calls for governing across sectors and moving away from State-centric siloed systems (Chan *et al.*, 2020). This requires strong coordination across departments, ministries, civil society and farming associations, policy alignment and consensus on common goals and targets (Chan *et al.*, 2020). It embraces a network governance approach built on inclusivity, equity, flexibility and collaboration (Bixler *et al.*, 2016). The stakeholders, which constitute the network, are the source of decision making (Bixler *et al.*, 2016; Scarlett and McKinney, 2016). Decision making should be based on adaptive thinking. In this regard, the network is proactive and seeks multiple strategies instead of one size fits all solutions to address the various threats facing agroecosystems. For adaptive thinking to work, there should be knowledge sharing and knowledge transfer, including the uptake of ILK, learning, and incorporation of diverse ways people value agroecosystems (i.e. intrinsic, instrumental and relational values). There are various forms of network governance (Provan and Kenis, 2008), and the choice of configuration should be based on the local context. The *Ridge-to-Reef project* is a good example of a multi-sectoral approach at work that should be replicated.

Instrumental response options

Incentives and capacity-building

The success of the above resource options also rely on having the institutional capacities and the right incentives to support agroecosystem transformation (Chan *et al.*, 2020). As discussed, significant instrumental challenges revolve around mechanisms for financing sustainability and human resource and data deficiencies.

One way of financing sustainability to support agroecosystem transformation is through incentives (high agreement, high evidence). Incentive programmes are market-based mechanisms used to galvanise ecosystem service providers (e.g. farmers) to continue providing these services through monetary compensation and are referred to as PES (Farley and Costanza, 2010; Bryan, 2013). As mentioned in this chapter's terrestrial ecosystem section, PES schemes are under-utilised in Grenada. If done correctly, PES schemes provide an opportunity to foster environmental stewardship, encourage inclusive decision making, and support livelihood resilience. However, we will caution that PES schemes not built on principles of inclusivity and equity can lead to elite capture and other perverse outcomes, which undermine long-term sustainability objectives (Pascual *et al.*, 2014). Apart from incentives, subsidies and grants also play a role in sustainable transformation (Chan *et al.*, 2020). The GoG has been supporting farmers through subsidies (e.g. Farm Labour Subsidy programme) and agribusinesses via grants (e.g. Global Environment Facility [GEF] funded Digital Challenge grant) to support transformation and to help build capacity. During the COVID-19 pandemic, the GoG injected US$370,020 into the Grenada Cooperative Nutmeg Association to facilitate payment to farmers for nutmeg due to the supply chain disruption brought on by the pandemic (Wong, 2020).

Regarding building human and data capacities, the response options discussed in the terrestrial ecosystem section (see Section 5.3) are also applicable to agroecosystems. Here, we draw attention to the importance of ILK, which is underutilised currently, in building institutional capacity to engender stewardship initiatives. This requires building mechanisms for knowledge transfer between farmers (especially female farmers) and state actors. It is about "recognizing other ways of seeing, knowing and doing…which can lead to more sustainable and equitable outcomes" (IPBES, 2022, p. 34). ILK can also help overcome scientific data deficiencies as local farmers are good sensors for detecting immediate changes within agroecosystems, for example, new pests, crop stresses, and illegal land use changes in their area. Where human resources are limited to support data collection and programme reporting, citizen science can be used to fill this gap. Through smartphones and apps, local farming communities and agribusinesses can directly engage in reporting information on production, pests and disease and other issues, as well as provide feedback on community projects. At the ministry level, we encourage updating information systems and implementing open data policies to facilitate data

Figure 5.16. Primary school students learning about climate-smart agriculture practices from farmer Ritchie Baptisite (Photo credit:The Ministry of Agriculture and Lands, Fisheries and Cooperatives)

access and transparency between key departments and across local and regional universities, especially regarding land, biodiversity and climate-related data.

Lastly, fostering inter-generational knowledge of agroecosystems and the importance of ecosystem stewardship is another way of building human and institutional capacities. This requires investing in youth education and awareness campaigns on agriculture. Through education and awareness, environmental literacy and sensitisation of the role of ecosystems in daily life are curated in the younger generation. In this regard, stewardship values are cultivated towards nature early on, which supports long-term sustainability. When it comes to agriculture, the GoG, via the agriculture ministry, supports school outreach. NGOs like GRENED also provide support to youth in agriculture.

5.2.3. Freshwater ecosystems

Freshwater is critical for every part of society and the environment and is therefore one of the most important cross-cutting issues. As described in previous chapters, freshwater ecosystems provide a plethora of ecosystem services including supporting, regulating, provisioning and cultural services. However, freshwater quality is increasingly degraded by a wide range of pollutants (Berger *et al.*, 2017). Water quality parameters are therefore fundamentally important as these factors not only determine the health of freshwater ecosystems but can influence the health of most other ecosystems (Shah *et al.*, 2020). Because of hydrology, pollution originating from streams and rivers can be one of the main sources of pollution to marine and coastal ecosystems (Zhongming *et al.*, 2012). In fact, interlinkages between water, food, humans and the environment as a whole, make water pollution a dire threat to society and ecosystem health (Wimalawansa, S. A. and Wimalawansa, 2014). An integrative, holistic approach to management of water resources is therefore necessary.

Challenges

A number of challenges and threats were discussed in previous chapters and summarised in Table 5.2. Overall, Grenada's freshwater challenges are both related to quality and quantity of water resources (Chapters 2-3) (Jackson *et al.*, 2004).

Many of these issues have also been flagged as critical concerns in previous studies. For example, Zhongming *et al.* (2012) listed the following as major threats to Grenada's water supply and recreational water: pollution from agricultural chemicals and waste, especially within watershed areas; siltation of rivers and dams from activities that causes erosion (Box 5.9); pollution from manufacturing plants and garages as a result of improper waste disposal and unauthorised effluent discharge; pollution from inadequate solid waste management and poor sanitation (sewage, greywater, etc.); and unplanned and unauthorised development, indiscriminate land clearing and uncontrolled forest clearance.

Grenada's first *National Water Policy* (NWP) was developed in 2007 but was never implemented. In 2020, an updated policy was approved by the GoG. Issues and challenges cited in this document and others (GEF, 2007; GoG, 2020b) include inter alia, environmental degradation impacting surface and groundwater quality and availability; the lack of comprehensive policy and integrated management; lack of coordination, corporation and integration of stakeholders; poor knowledge of best management practices for water conservation, inappropriate land use, poor enforcement of regulations or lack of regulations specifically targeted at addressing specific water resources and services and inadequate municipal sewage disposal systems.

For this chapter, five challenges facing freshwater ecosystems are that can have far reaching impacts on connected ecosystems and their services. Specifically, problem trees were used to explore the causes and effects of agrochemical pollution (Box 5.10), nutrient pollution, greywater and sewage, sedimentation of waterways and hazardous waste (Figures 5.17- 5.23). Hazardous waste, although not been extensively reviewed in the previous chapters, is an important issue that we also review below.

Table 5.2. Summary of freshwater challenges/threats identified in previous chapters

Drivers	Challenges
Climate change	• Saltwater infiltration • Extreme floods and droughts • Intense storms • Freshwater availability
Deforestation and clearcutting	• Erosion and sedimentation • Poor quality of domestic water supply • Reduced reservoir storage capacity
Farming	• Nutrient pollution • Fertiliser and agrochemical runoff • Sediment runoff (sedimentation) • Poor management of animal waste
Residential activities	• Untreated wastewater (greywater) discharge • Poor sanitary infrastructure leading to sewage seepage • Poor solid waste management • Misuse and storage of hazardous substances
Industrial activities	• Unpermitted* discharge of untreated wastewater (greywater) discharge • Poor sanitary infrastructure leading to sewage seepage • Poor solid waste and (hazardous waste*) management • Misuse and storage of hazardous substances
Other human activities	• Unsustainable harvesting of fauna • Over pumping of lakes and rivers

**Not addressed in previous chapters*

Box 5.9. Challenges at NAWASA's water catchment areas

Siltation due to poor soil management in upper watersheds has dramatic impacts on water quality. As reported in Jackson *et al.* (2004), the Concord watershed provides a typical example in Grenada, with sedimentation, agrochemical pollution, extensive soil erosion due to agricultural activities occurring near a NAWASA abstraction location. Related impacts include dam sedimentation and higher cost associated with silt removal through water treatment. These issues are common occur and continue to occur at the majority of surface dams and water catchment areas across the country (Box 5.10; Chapter 2) (Jackson *et al.*, 2004).

Problem Trees:

Agrochemical Pollution

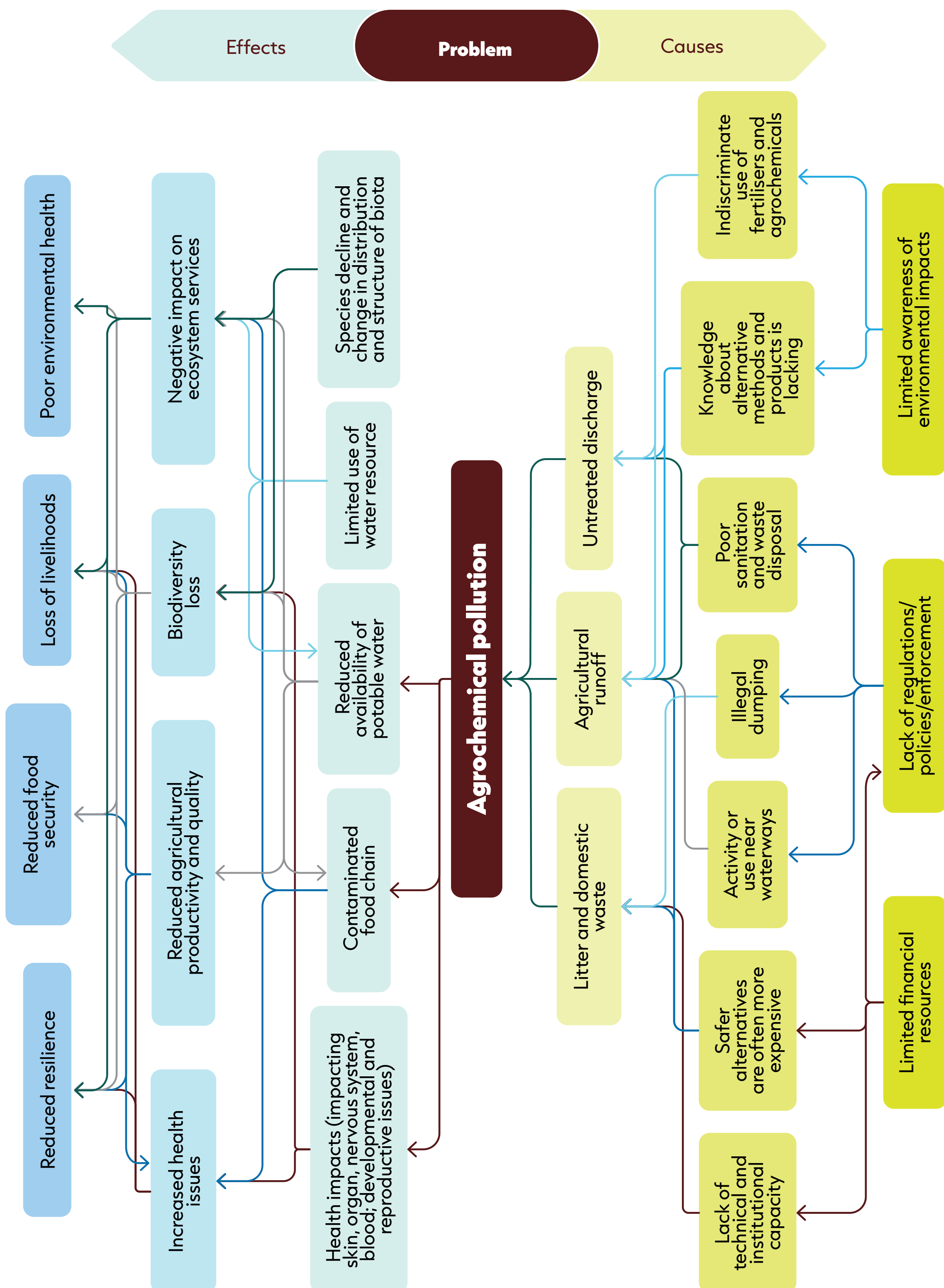


Figure 5.17. Problem tree: Factors leading to agrochemical pollution and the effects on freshwater ecosystems

Box 5.10. Challenges associated with agrochemical use in Grenada

Agrochemicals include those chemicals used in the agricultural industry such as pesticides (herbicides, insecticides, fungicides, rodenticides, nematicides etc.), synthetic fertilisers and plant growth stimulators (Majeed, 2018; Kumar, 2021). Increasing demand for food has led to increased pressure and the need to boost agriculture yields. Often, unsustainable practices (over application of fertilisers and pesticides) are utilised leading to occurrences such as runoff of excess products into freshwater ecosystems. One example is Lake Antoine (Figure 5.18), a 6.5ha lake deemed unfit for use as a source of water supply due to agrochemical contamination from agricultural practices in surrounding areas (FAO, 2015).

Figure 5.18. Photograph of Lake Antoine, St. Patrick, Grenada (Photo credit: Judlyn Telesford-Checkley)

Agrochemical pollution can lead to eutrophication (Figure 5.14 on page 363), biodiversity loss and change in species diversity (desirable species are replaced by less desirable ones with a higher tolerance for the particular environmental condition (Lemaire *et al.*, 2022; Sures *et al.*, 2023). Pesticide toxicity in fish and other aquatic organisms (Rohani, 2023), impacts growth, physiology, reproduction, immunity, hemato-biochemical profile and causes histopathological alterations of tissues (Santana *et al.*, 2021; Rohani, 2023;). A study conducted in Costa Rica on the impacts of pesticide use in pineapple crop production found high correlation between fungicide and herbicide use and ecological impacts on macroinvertebrate communities (Echeverría-Sáenz *et al.*, 2012). Human impacts are also a concern. Based on their chemical configurations, pesticides can bioaccumulate in fish tissue and cause health complications for consumers, including humans. Pesticide use is, therefore, a serious concern worldwide (Bourguet and Guillemaud, 2016; Sharma *et al.*, 2019). Health-related impacts are broad, including organ failure, cancers, and skin irritations (Bourguet and Guillemaud, 2016; Marete *et al.*, 2021).

Nutrient pollution

Globally, nutrient pollution is one of the most costly and challenging environmental problems. Excess nutrients in the air and water have the potential of significantly changing aquatic biodiversity, impacting ecosystem and human health, the environment and the economy (USEPA, n.d.; Woodward *et al.*, 2012; Shortle and Horan, 2017). According to the United States Environmental Protection Agency (USEPA), nutrient pollution causes billions of dollars every year for drinking water treatment, tourism and fishing industry losses and real estate (waterfront properties) (USEPA, 2015).

Studies conducted by Silbiger *et al.* (2018) found negative impacts of nutrient pollution and pH on the ecosystem functioning of coral reefs. Due to these observed impacts, the authors concluded that nutrient pollution can make reefs more vulnerable to climate change related impacts associated with ocean acidification.

Although Grenada-specific studies were not found, research by Lapointe (2019) and a review conducted by Rawlins *et al.* (1998) associated the degradation of coastal resources in the Caribbean to the potential impacts of agricultural pollution. Other reported impacts include eutrophication, algal blooms and loss of biodiversity. The increasing influx of Sargassum into the Caribbean region is also believed to be a result of eutrophication due to increasing nutrients in the Atlantic Ocean. There is therefore a need for more research on declining coastal ecosystem health to upland watersheds to better understand nutrient pollution in the Caribbean. Figure 5.19 shows some key factors leading to nutrient pollution.

Greywater and sewage

Greywater refers to used water from bath sinks, showers, and washing machines. Challenges associated with greywater and sewage (Figure 5.20) include skin irritation, chronic diseases, and diarrhoea, to name a few. Banaszak (2021), discussed water quality decline due to inadequately treated wastewater effluent and its impact on Mexican Caribbean coral reefs and the increased prevalence of Sargassum blooms on the coastline leading to a further reduction in water quality due to decomposition. Häder *et al.* (2020), looked at the impacts of sewage and nutrients among others, on marine and freshwater ecosystems. The authors concluded that even when the pollutant source is distant from the sink, the impacts can be just as significant.

DeGeorges *et al.* (2010), looked at domestic sewage in the Caribbean and discussed this type of pollution resulting in widespread impacts on ecological and public health. One of the most noteworthy impacts was the deleterious effects on coral reefs which resulted in a chain reaction of ecological problems such as beach erosion, habitat loss and the collapse of fisheries.

The paucity of data on related issues in Grenada is concerning, since failure to address these problems can severely impact the nation's economy and increase its vulnerability to climate change impacts.

Sedimentation of waterways

Sedimentation of waterways is the process of soil, sand, silt, and other particulate matter settling and accumulating in rivers, streams, lakes, and other bodies of water. Sedimentation of waterways primarily occurs from terrestrial or stormwater runoff. Although sediment is a natural component of aquatic ecosystems, the process can lead to a range of environmental and health problems (Figure 5.21) (Julien, 2010).

Hazardous Waste

Among all the threats impacting freshwater ecosystems discussed in this chapter, hazardous waste pollution could be considered the most serious in that its impact on humans and the environment can be detrimental (Kumaraswamy *et al.*, 2020; Bhat *et al.*, 2022). Leachate generated from untreated hazardous waste ultimately reaches water resources and can cause a wide range of ecological impacts including changes in species diversity, impaired growth and reproduction rates of aquatic organisms (Bhat *et al.*, 2022; Häder *et al.*, 2020). Ita-Nagy *et al.* (2022), in their review, looked at the prevalence of microplastics in the ocean in Latin America and the Caribbean and reported that microplastics were widespread, including on beaches, mangroves, and even unpopulated and remote areas. Overall, more data is needed to establish linkages between microplastics and their impact on local marine biota and human health. A well-known fact is that most marine pollution originates on land; mitigating impacts, therefore, requires a coordinated effort. Figure 5.23 illustrates the major factors leading to hazardous waste pollution and the serious impacts on freshwater ecosystems.

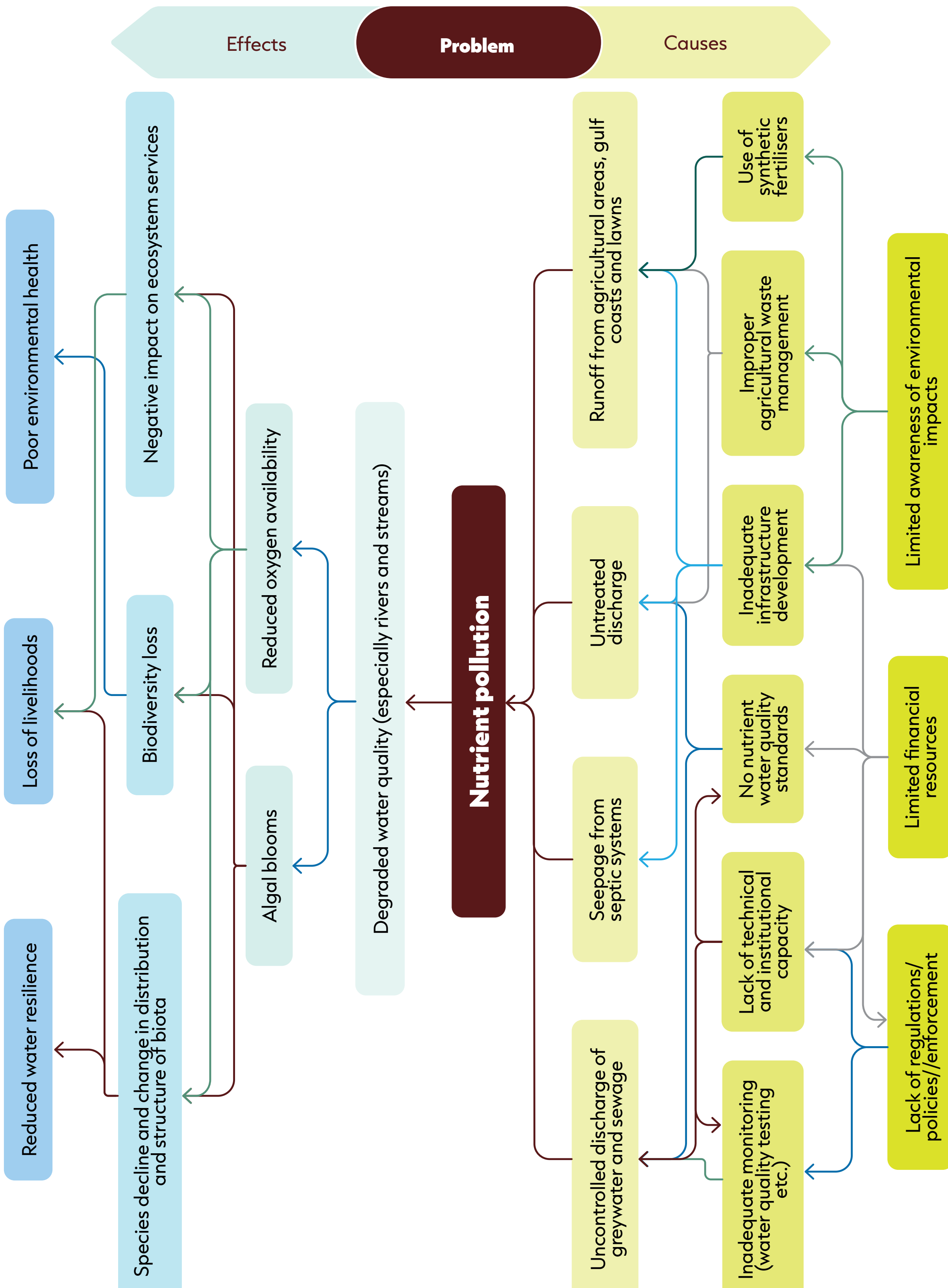


Figure 5.19. Problem tree: Factors leading to nutrient pollution and the effects on freshwater ecosystems

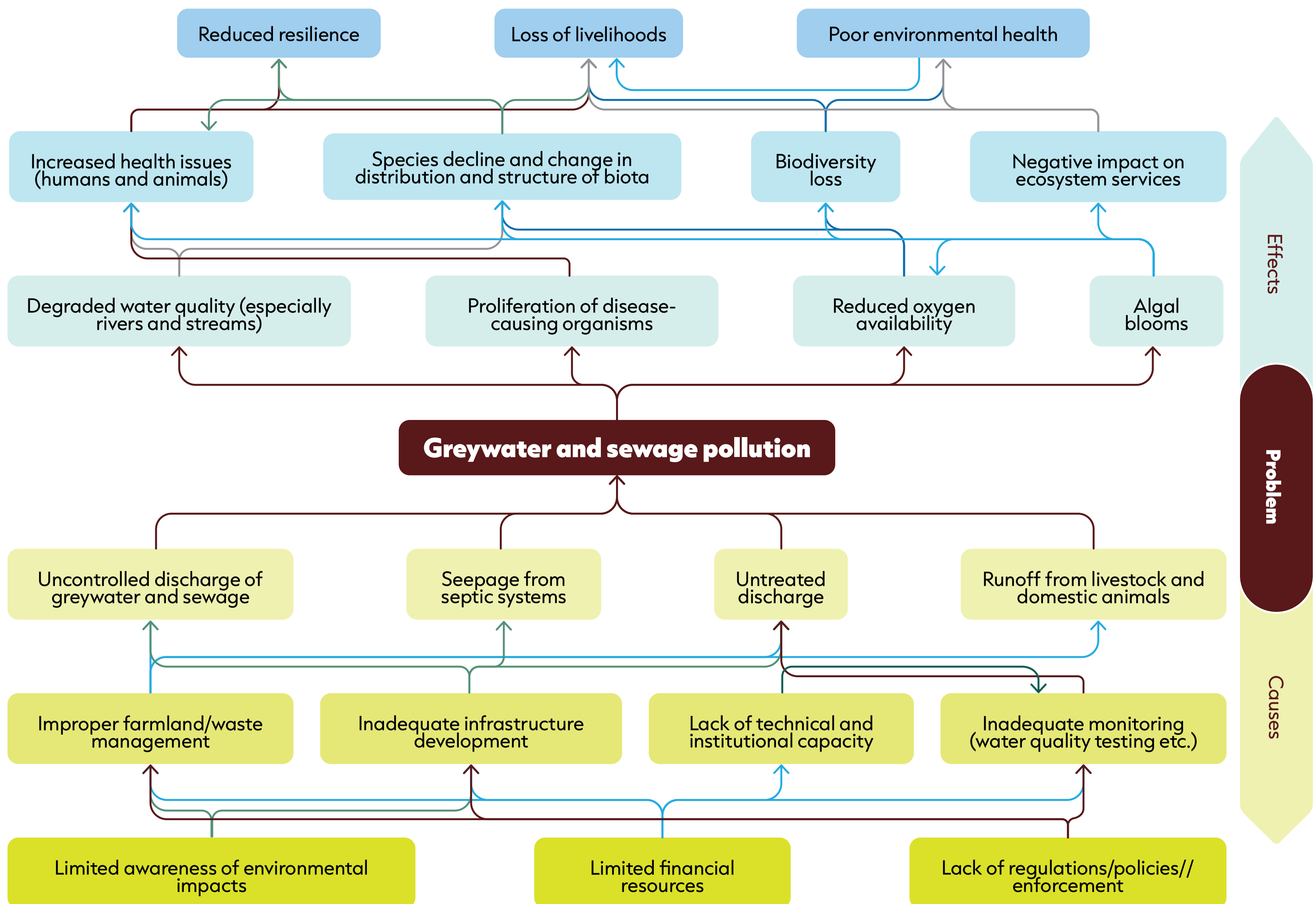


Figure 5.20. Problem tree: Factors leading to the sedimentation of waterways and the impacts on freshwater ecosystems (see Box 5.11)

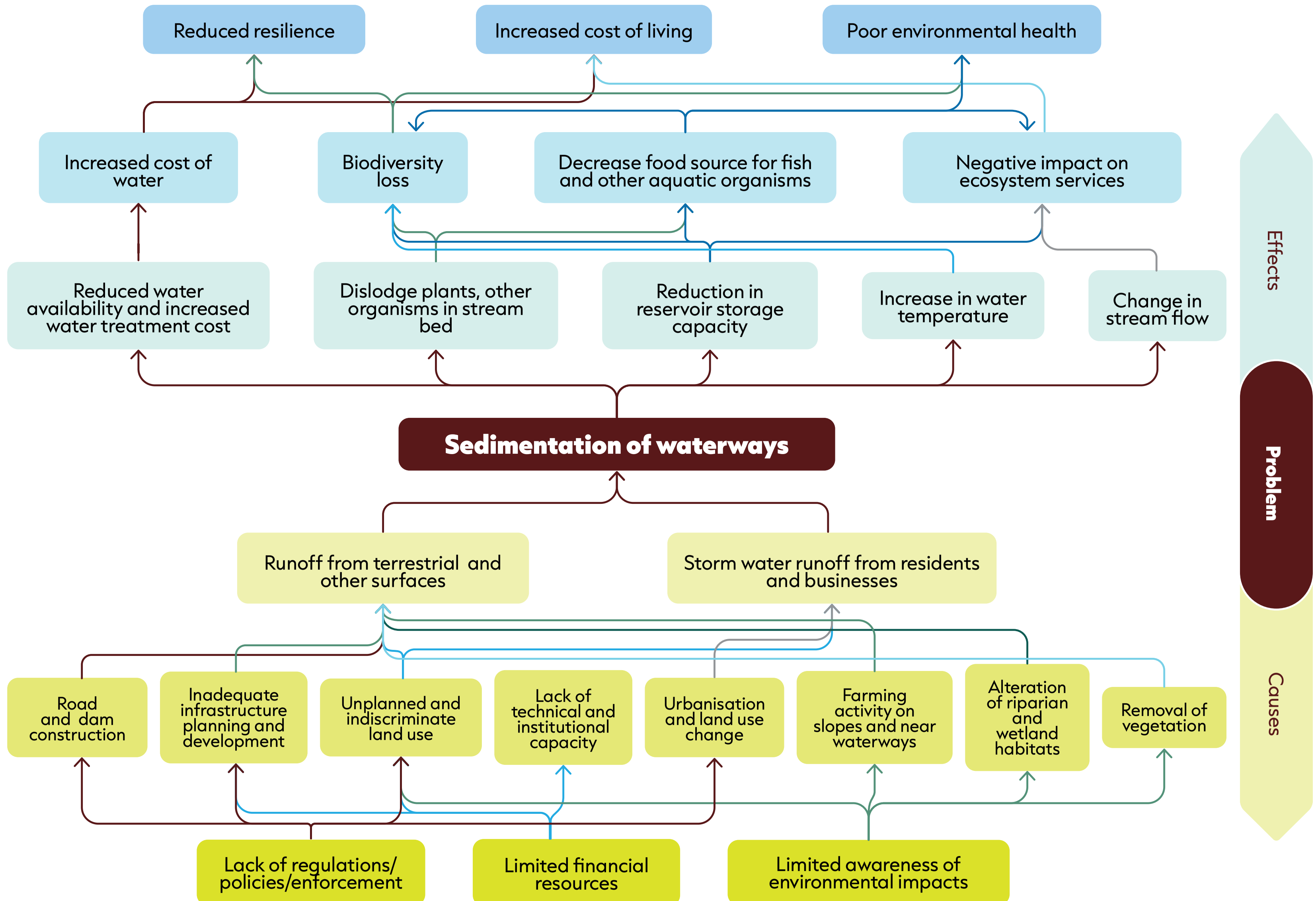


Figure 5.21. Problem tree: Factors leading to the sedimentation of waterways and the impacts on freshwater ecosystems (see Box 5.11)

Box 5.11. Challenges associated with sedimentation of Grenada's waterways

As discussed here and in other chapters, sedimentation caused by factors, including inadequate land use and habitat degradation, is a recurring challenge in Grenada. The chart below illustrates the one example of the far-reaching impacts on NAWASA in being able to supply potable water. Figure 5.22 below is an example of the resulting impact of sedimentation due to runoff.

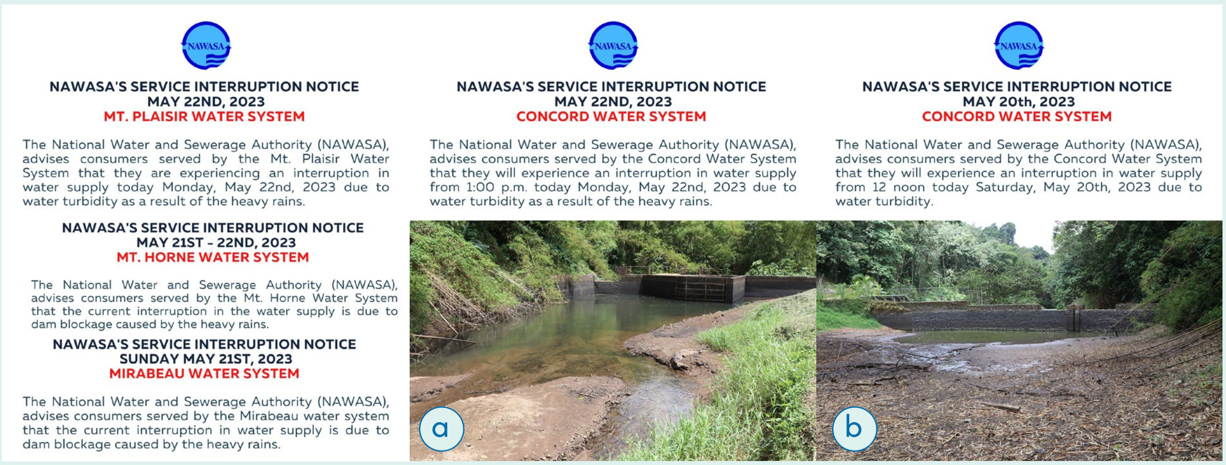


Figure 5.22. Photographs showing a series of NAWASA's service interruption notices issued within hours of a significant rainfall event. The photographs (a and b) illustrate the sediment and water levels in two of NAWASA's dams (Photo credit: NAWASA)

Foundational

As described earlier, a variety of knowledge frameworks and initiatives were used to examine the state of Grenada's freshwater ecosystems and determine the most suitable kinds of interventions needed to enhance its ecosystem services. Analysing the country's governance structure (agencies, departments, ministries etc) also provided the understanding needed to decipher current gaps and what's needed for overall improvements (Figure 5.24). Appendix 5 provides a catalogue of the agencies/departments/ministries with direct or indirect responsibilities for the management of Grenada's water resources.

A common challenge encountered throughout this assessment was the paucity of, and lack of public access to important knowledge resources related to water quality (Figure 5.24). In addition to those mentioned earlier in this chapter, during drafting of this chapter, access to water-quality data from the relevant State authority was not shared with the team, even after multiple formal requests from a government official with authority to do so. Instances where data was available from local studies, such data were limited and not collected in a consistent manner to yield statistically significant patterns.

Knowledge gaps that impact the assessment of freshwater ecosystems include water quality data from constant monitoring of the nation's water resources. Such information is necessary to accurately determine the factors such as types and concentrations of contaminants, seasonality and trends of contamination events and locations needing

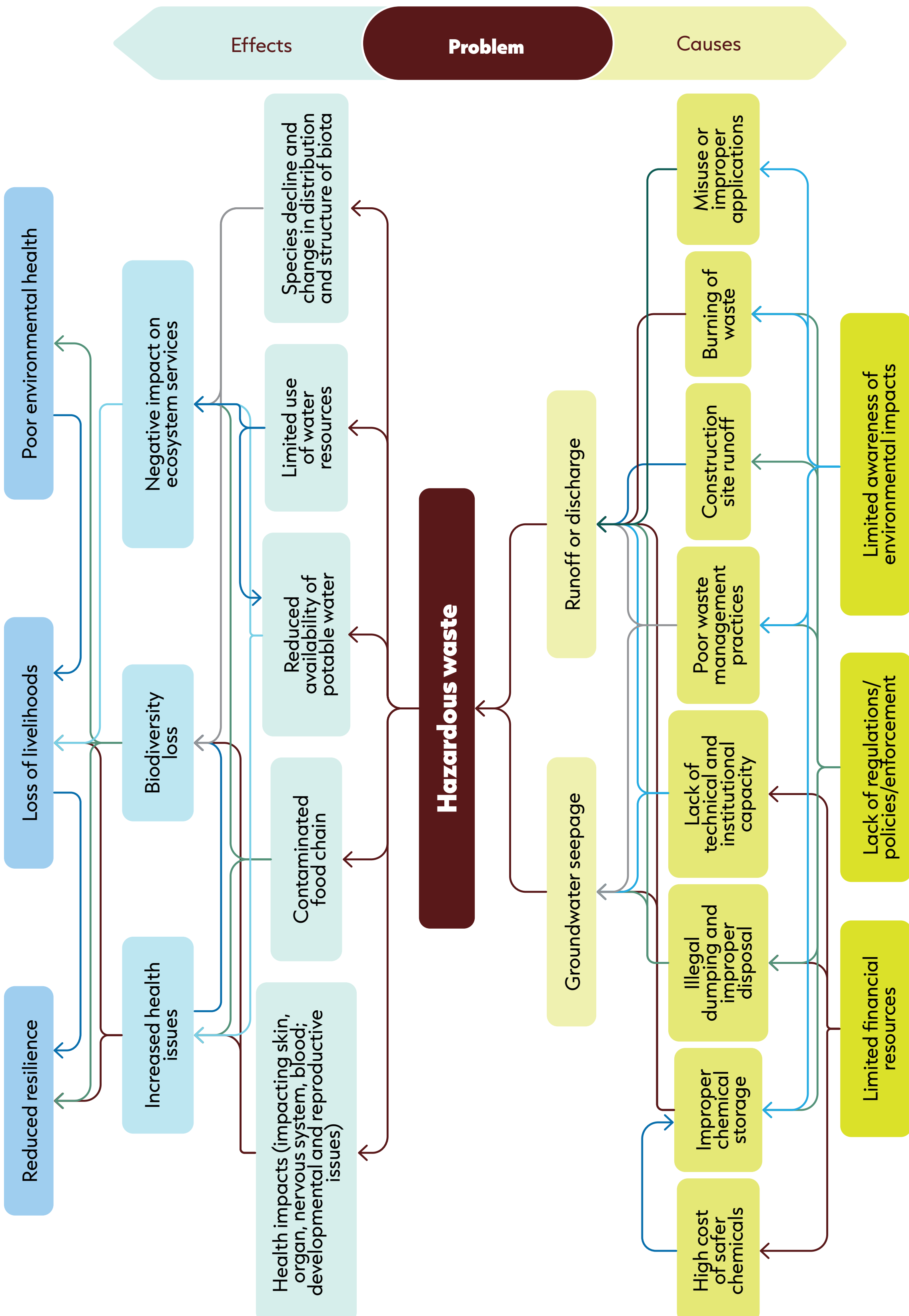


Figure 5.23. Problem tree: Factors leading to hazardous waste pollution and the effects on freshwater ecosystems

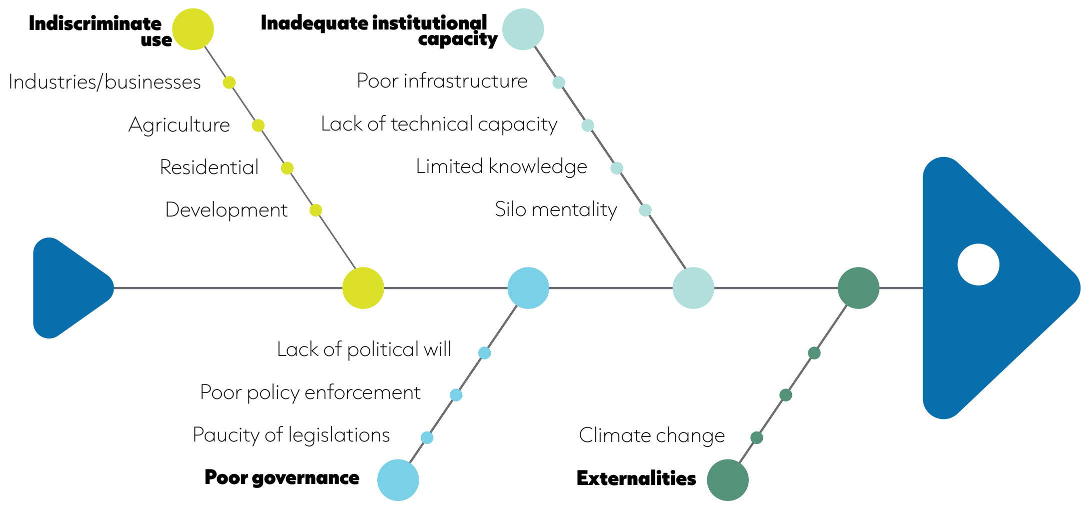


Figure 5.24. Diagram illustrating four common factors responsible for the pollution/contamination of Grenada's freshwater ecosystems

priority for mitigation action. What is especially lacking is data studies correlating human and/or ecological health to water quality standards. This is an area in which public health research entities can become involved. Arrangements, however, must be that findings must be made publicly available to facilitate knowledge building across sectors and accountability to stakeholders.

Instrumental

Management instruments

A recurring theme through the development of all the problem trees is relatively indiscriminate use in agriculture of agrochemicals such as synthetic fertilisers and pesticides. This has been shown to have detrimental impacts through domino effects from land application to watersheds via runoff, to marine and coastal ecosystems (Majeed, 2018; Kumar *et al.*, 2021). Similarly, unplanned and/or uncontrolled land clearing, alteration of riparian and wetland areas for development or farming purposes can result in erosion and siltation of waterways (Wimalawansa and Wimalawansa, 2014).

Capacity building

Many of the challenges within the freshwater management sector stem from a lack of capacity across the stakeholders in the sector. These gaps include:

- poor infrastructure in public sector: monitoring, sewer and water treatment etc;
- poor infrastructure in private sector;
- lack of technical capacity: qualified staff, number of staff;
- limited knowledge and training; and
- silo mentality: lack of cooperation among ministries/agencies, acting alone.

Response options

The following are objective trees developed from each problem tree in the previous section:

- *Agrochemical pollution*
- *Nutrient pollution*
- *Greywater and sewage*
- *Sedimentation of waterways*
- *Hazardous waste*

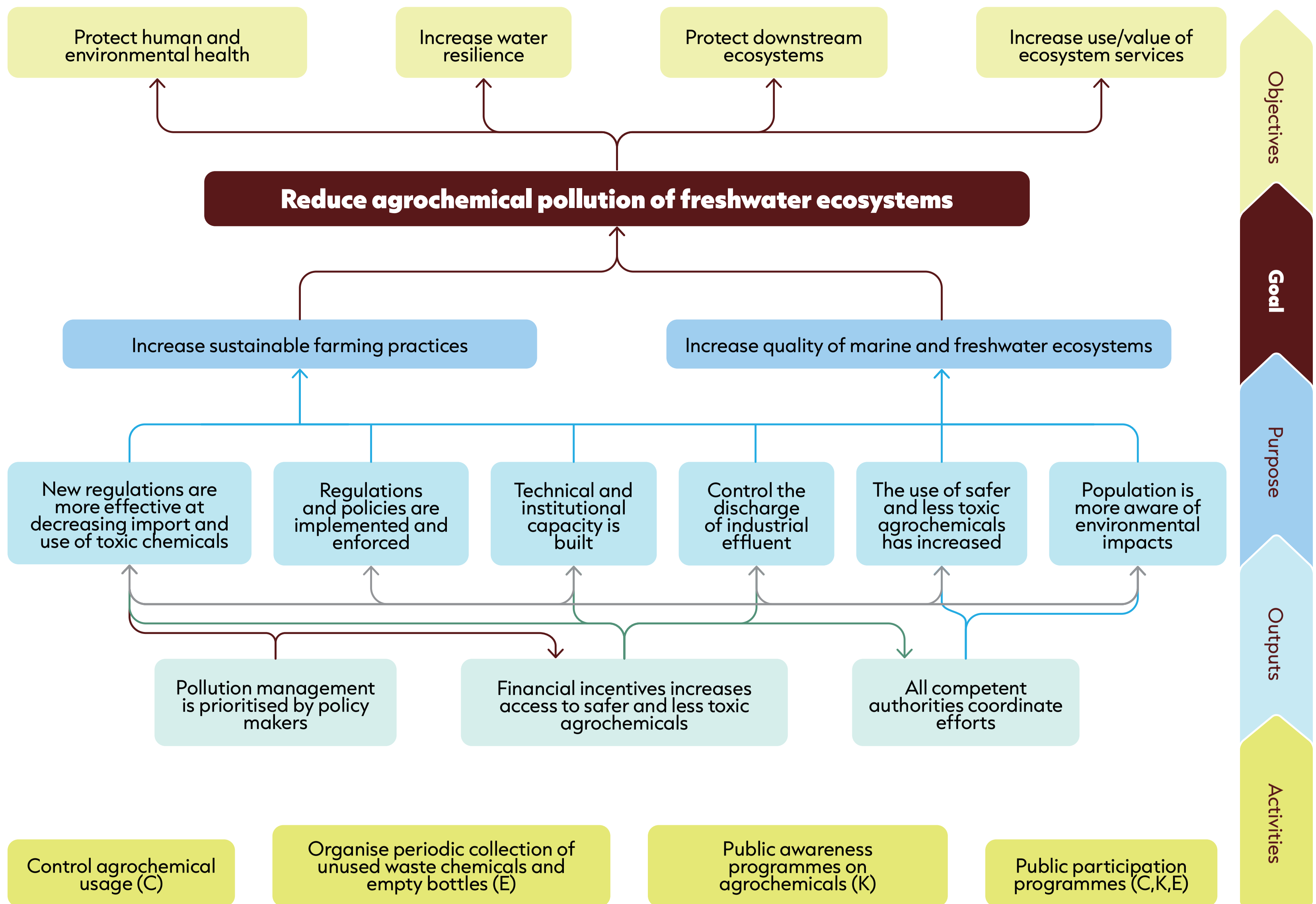


Figure 5.25. *Objective Tree: Responses to agrochemical pollution* (see Box 5.12) [Activities classified as K (Knowledge/Foundational), E (Enabling), C (community)]

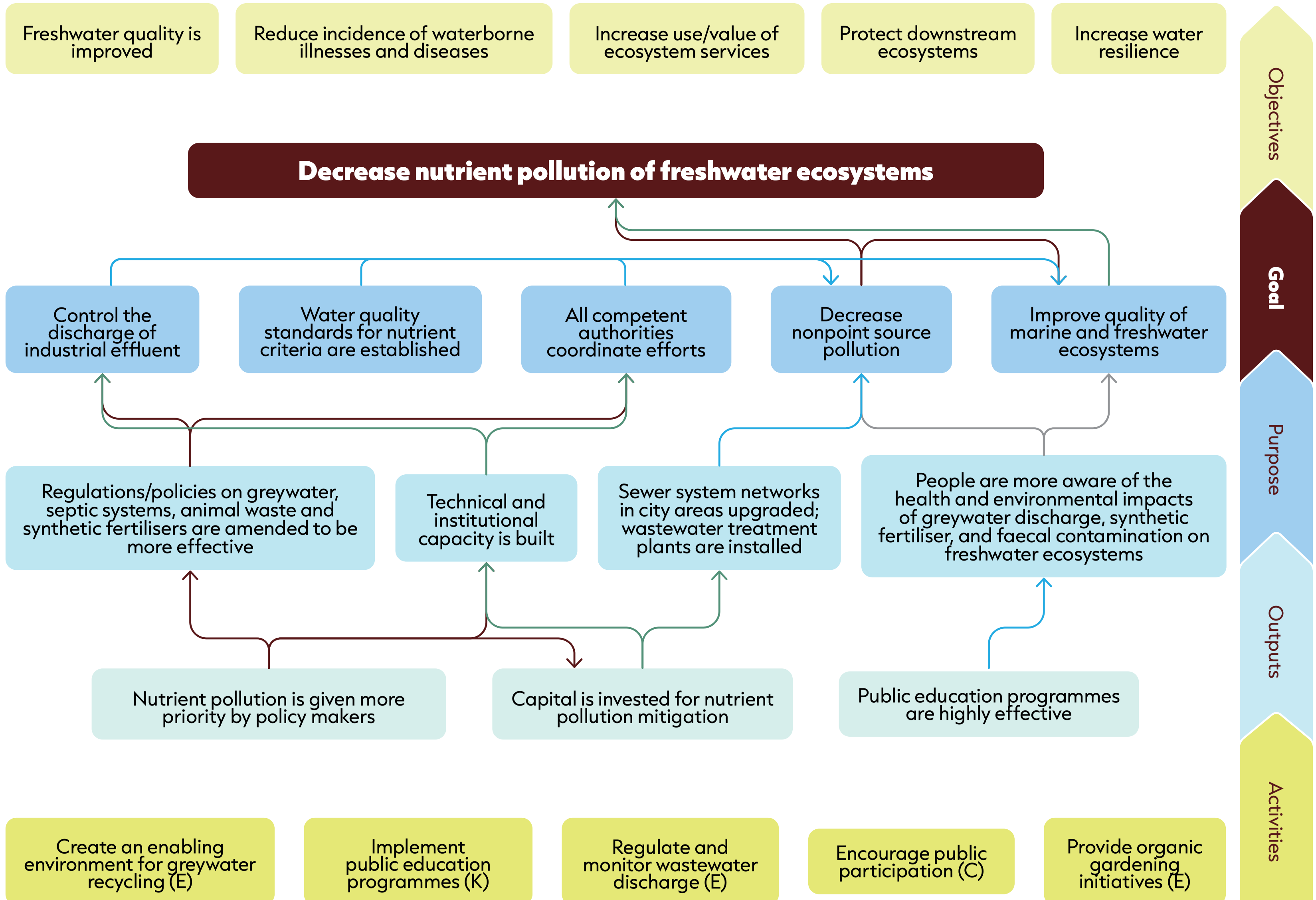


Figure 5.26. *Objective Tree: Responses to nutrient pollution [Activities classified as K (Knowledge/Foundational), E (Enabling), C (community)]*

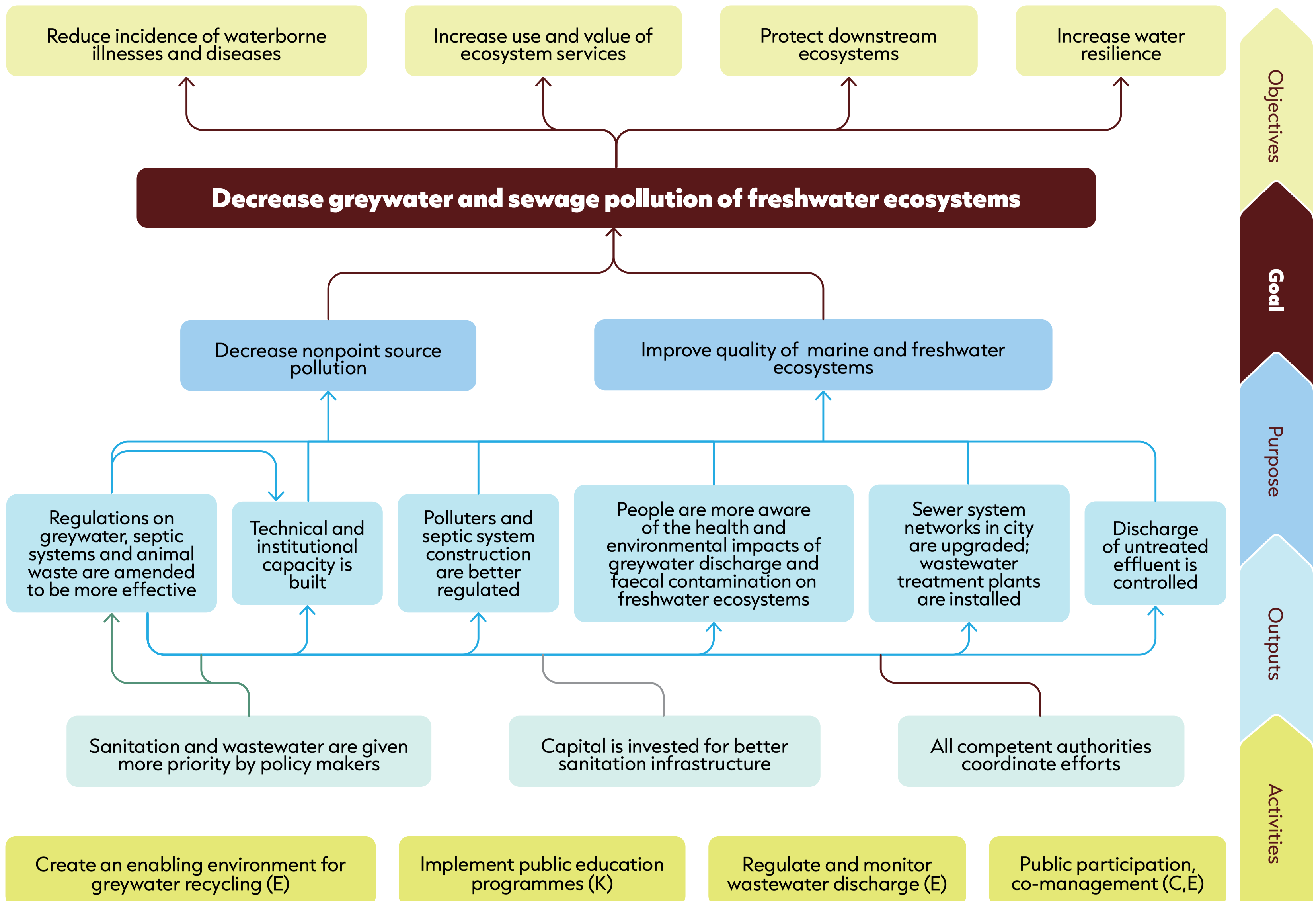


Figure 5.27. *Objective Tree: Responses to greywater and sewage pollution* (see Box 5.13) [Activities classified as K (Knowledge/Foundational), E (Enabling), C (community)]

Box 5.12. Reducing agrochemical pollution

Reducing agrochemical pollution (Figure 5.25 on page 377) requires a systematic and holistic shift in the current culture around agrochemical use starting from the update, enactment and enforcement of applicable regulations to changed mindsets and practices among stakeholders to using substances that are less toxic and more environmentally friendly. It also involves better adherence to application rates and waste disposal standards. The government can enable such practices by offering financial incentives such as reduced tariffs on organic brands or through knowledge transfer, including training and workshops about sustainable practices.

Foundational response

A possible solution to the data gap challenge discussed throughout this NEA, is a collaborative approach between academia and government (high agreement/medium evidence). The government can leverage the expertise of faculty and fresh perspectives of students while helping the universities to meet their research and educational goals. Another advantage is provided by the technological resources available at universities. Examples of government funding to support this initiative are research grants, funding for lab equipment or funding for scholarships. Community engagement is also important. By engaging the community, it identifies within the management process the importance of community buy-in and allows for ownership of responsibilities (medium agreement/medium evidence).

Enabling

Legislative and Policy Response

A well-structured policy framework is of utmost importance in addressing all water quality related issues including those discussed in this chapter. The government must, therefore, ensure that the relevant policies are implemented and that stakeholders are educated on the importance and relevance to economic and environmental health (high agreement/high evidence). Regulations should include the setting of standards (drinking water, water bodies for bathing etc.), monitoring and effluent/discharge limits.

The Caribbean Public Health Agency (CARPHA) is responsible for coordinating and advising national governments within the OECS, on water quality and pollution issues. The GoG in its *2020 National Water Polic*y, has committed to ensuring that arrangements are in place to facilitate a coordinated approach to water quality management (GoG, 2020b).

Permitting requirements related to environmental management (effluent discharge, stormwater retention etc.) for farms and other businesses should be established (high agreement/high evidence). Periodic monitoring/inspections by field officers are needed for oversight (high agreement/medium evidence). Noncompliance should result in penalties and remedial action plans.

Institutional and governance response

According to Grenada's 2020 NWP, "The day-to-day management of Grenada's water resources in their entirety: surface waters (streams, rivers, lakes, other natural reservoirs), ground waters (natural aquifers, wells), water stored as part of municipal/community supplies from rainwater harvesting or other sources, estuarine waters and waters along the coast that are subject to use (recreation, supply for desalination and receiving environment for effluent discharge) shall be the responsibility of a Water Resources Management Unit (WRMU)" (GoG, 2020b).

The WRMU's role is to ensure the adequate management and maintenance of Grenada's waters "for present and future generations and for the continued provision of environmental services".

Listed in the NWP, whose implementation status is unknown, are key actions for recommendation. It is hoped that these actions are well structured, coordinated and implemented in the near future. Planned actions include *inter alia*:

Box 5.13. Reducing greywater and sewage pollution of freshwater ecosystems

Greywater is water that does not include faeces or urine. Greywater and sewage pollution are widespread issues across the tri-island state. Reducing such pollution (Figure 5.27) requires coordinated efforts between the physical planning department's approval process for development, to the department of environmental health's (Appendix 5) inspections and monitoring, and stakeholders' understanding of the health and environmental impacts of releasing greywater and sewage into our waterways. Policy recommendations include banning the direct discharge of greywater from residential dwellings and businesses. Additionally, industrial wastewater should be treated in holding ponds to set standards prior to discharge. Discharge permits should also be required. Positive actions can be enabled by hosting community level greywater recycling workshops and initiatives. For the most part, if properly conducted, greywater can be treated using natural processes (sand, gravel) and reused for purposes such as gardening and flushing toilets. The image below shows an example of a simple greywater recycling system (Figure 5.28). Additionally, laundry water can be recycled depending on the types of detergent and additives used. Therefore, educational programmes about eco-friendly laundry products (vinegar, baking soda etc.) can also be beneficial.

Although grease waste has not been discussed in this NEA due to lack of supporting data, it is important to include it here as part of the overall wastewater management process. This is especially relevant to restaurant and hotel industries but households should also be encouraged to use best management practices. Fats, oil and grease (FOG) pollution in addition to clogging drains and sewer lines, can be detrimental to plants and wildlife and also diminish the quality of ecosystem services (Islam *et al.*, 2013; Masifwa *et al.*, 2020). Actions for preventing FOG pollution include requiring businesses producing food for sale to install grease traps (small containers/vessels incorporated into wastewater piping systems) that retains FOG for subsequent proper disposal. FOG can be recycled into biodiesel and compost. A FOG prevention policy that is properly implemented and enforced can provide an avenue for the formation of a circular business.

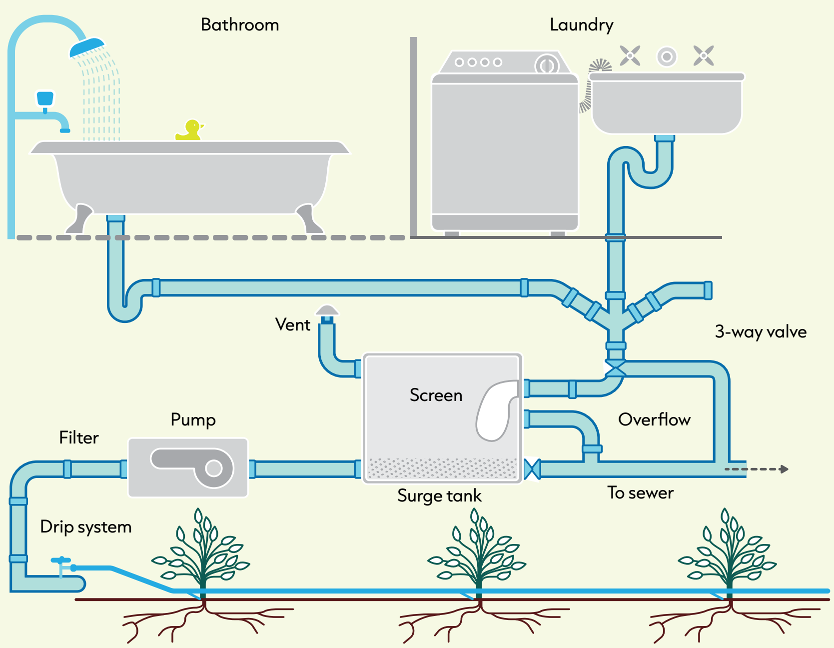


Figure 5.28. A simple greywater recycling system (Green, 2015)

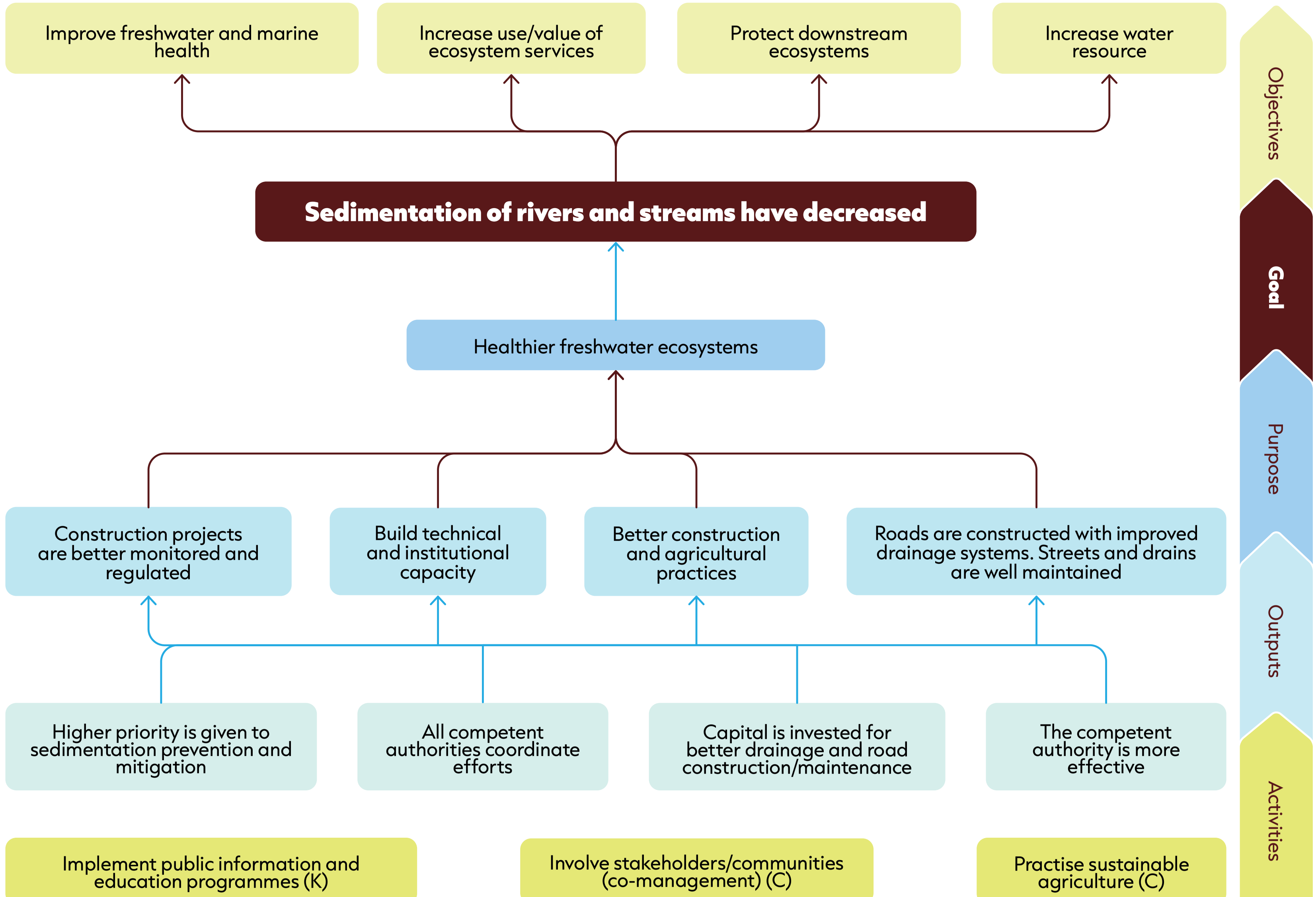


Figure 5.29. Objective Tree: Responses to sedimentation of waterways (see Box 5.14). [Activities classified as K (Knowledge/Foundational), E (Enabling), C (community)]

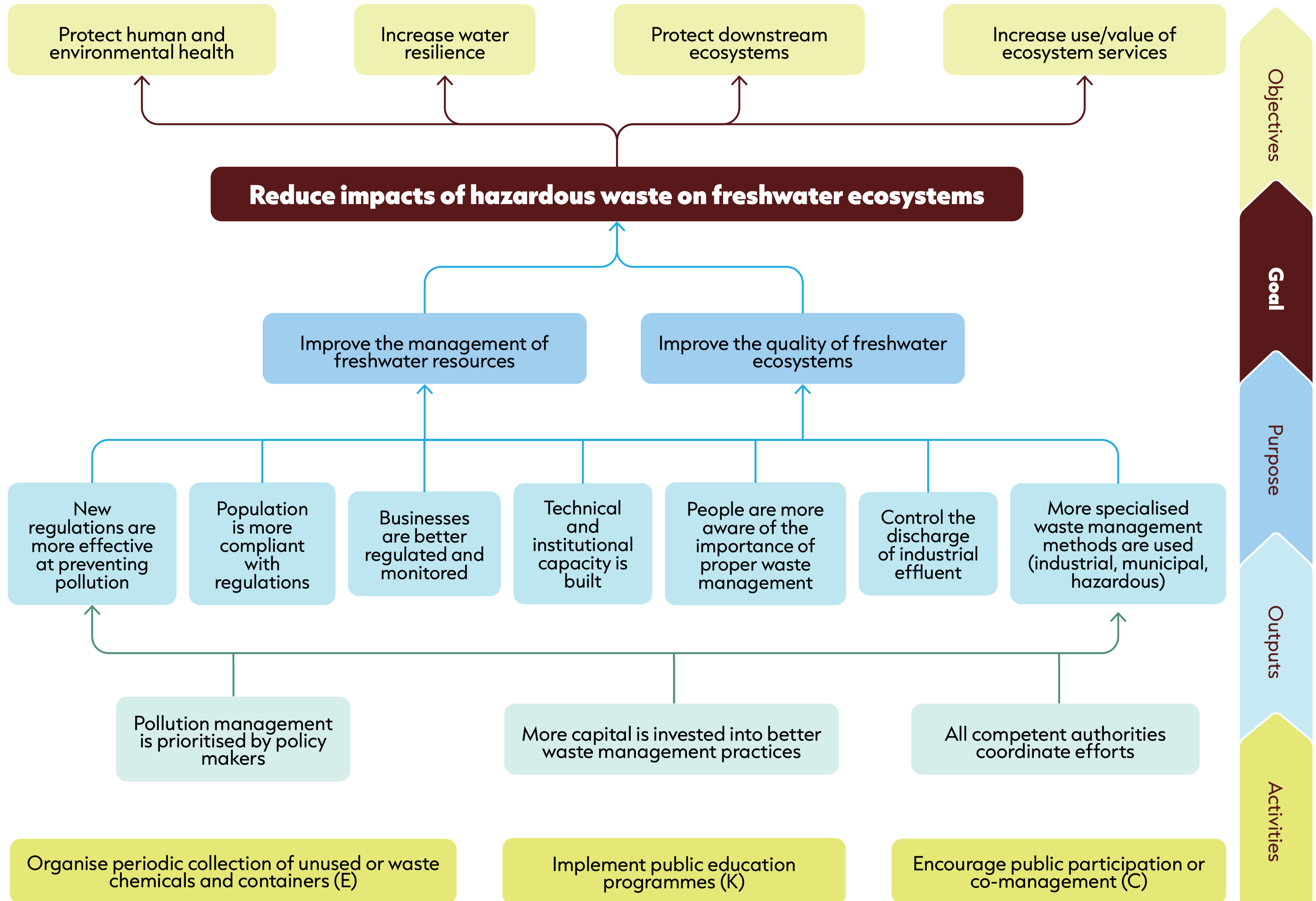


Figure 5.30. *Objective Tree: Responses to hazardous waste pollution* (see Box 5.15). *[Activities classified as K (Knowledge/Foundational), E (Enabling), C (community)]*

Box 5.14. Preventing sedimentation of waterways

As discussed elsewhere, sedimentation of waterways is directly linked to land-based activities or practices. Preventing such occurrences (Figure 5.29) requires multi-sectoral collaboration. Land-based activities such as land clearing, farming on slopes, poor road construction, land clearing for development projects, inadequate site runoff abatement and poor debushing practices, all require monitoring and the use of best management practices. Some prevention mechanisms include incentivising sustainable farming practices, implementing construction site inspections and enforcement and creating education programmes (high agreement/ medium evidence).

- the development of a permit system for access and use of water (water diversion/abstraction, effluent discharge, pollution control and quota allocations); and
- collaborative work with water sector stakeholders, other stakeholders, Grenada Water Stakeholder Platform (G-WaSP) and the Public Utilities Regulatory Commission (PURC) for activities including: water use/loss estimations, water reuse considerations, rainwater harvesting, climate change and vulnerability studies, and public education and awareness programmes, among others.

Instrumental response

Technology and practices response

Changes in everyday practices and routines are also necessary for impactful and long-lasting change. The following are recommended:

- safer/healthier chemical options should be promoted and used; incentives should be used to encourage more sustainable farming practices (high agreement/medium evidence);
- there should be more stringent water quality monitoring where technology for efficiency and effectiveness (easier pollution detection, time-saving practices etc) is used (high agreement/ medium evidence);
- organic farming should be encouraged and incentivised;
- access to water quality data should be improved by creating one central database which can be accessed remotely (medium agreement, low evidence); and
- recycling programmes should be introduced and upgraded according to international best practice (high agreement/medium evidence).

Box 5.15. Reducing impacts of hazardous waste on freshwater ecosystems

Among all the threats impacting freshwater ecosystems discussed in this chapter, hazardous waste pollution can be considered the most serious. Reducing such impacts (Fig 5.30) should therefore be of high priority. Research and data collection is a fundamental starting point to gain a general understanding of the extent of the problem in the tri-island state. Collaborative efforts with academia and other relevant institutions or stakeholders could be used for this purpose (high agreement/ medium evidence). Other necessary responses include update/enactment and enforcement of legislations, monitoring and evaluation (M&E) of industrial facilities through operational permits, increasing technical and financial capacities and educational programmes formatted for all segments of society (high agreement, medium evidence).

5.2.4. Marine and coastal ecosystems

Challenges

Coastal and marine ecosystems in Grenada are under threat from multiple natural and anthropogenic stressors. Chapter 2 of this report has indicated that specific threats to these ecosystems include 1) diseases, 2) habitat loss and degradation, 3) invasive species, and 4) pollution. These stressors collectively compromise the delivery of ecosystem services, negatively affect human health and well-being and disrupt activities (e.g. fishing, tourism, etc.) that are integral to the social and economic well-being of Grenadians.

Since 2011 to now, the Caribbean region has experienced abnormal influxes of Sargassum (Figure 5.31). Satellite imagery suggests that this pelagic Sargassum originated primarily from the Atlantic Ocean (Wang *et al.*, 2019). These blooms of Sargassum may be connected to nutrient enrichment (possibly arising from Amazon River discharge and upwellings off the western coast of Africa) and climatic variations (Wang *et al.*, 2019). It has also been suggested that if nutrient enrichment continues and seed populations of Sargassum persist, recurrent blooms in the tropical Atlantic and beaching events in the Caribbean Sea may become the new norm (Wang *et al.*, 2019). Although researchers are unable to predict future Sargassum influxes to the Caribbean due to insufficient monitoring data (Oxenford *et al.*, 2021), it is likely that abnormal influxes of Sargassum is an issue that will persist for Grenada during the next decade (high agreement/high evidence).

Grenada has experienced abnormal influxes of Sargassum within the last decade, with hotspots being identified along the east coast between Telescope to Soubise (Toby Calliste, 2023, personal communication). Recent hazard exposure maps, based on data from 2011-2021, have indicated that Sargassum inundation frequency is medium (sub-area 2) to high (sub-area 1) on the east coast of Grenada and Carriacou (Degia *et al.*, 2022). These Sargassum influxes have posed threats to biodiversity and humans that depend/use coastal/marine environments (Toby Calliste, 2023, personal communication; Caribbean Regional Fisheries Mechanism [CRFM] 2019) (Figure 5.32 and Figure 5.33).

Abnormal quantities of pelagic Sargassum in coastal waters of Grenada pose a threat to coastal ecosystems such as seagrass beds and coral reefs by disrupting light availability. When pelagic Sargassum sinks to the seafloor, there is also a risk of smothering of marine flora and fauna. In some areas, mortality of benthic organisms, coral and seagrasses have been reported (CRFM, 2019). Some Grenadian stakeholders were particularly concerned about the disruption of the nursery function of seagrasses and coral reefs and the subsequent impact on the recruitment of shrimps,

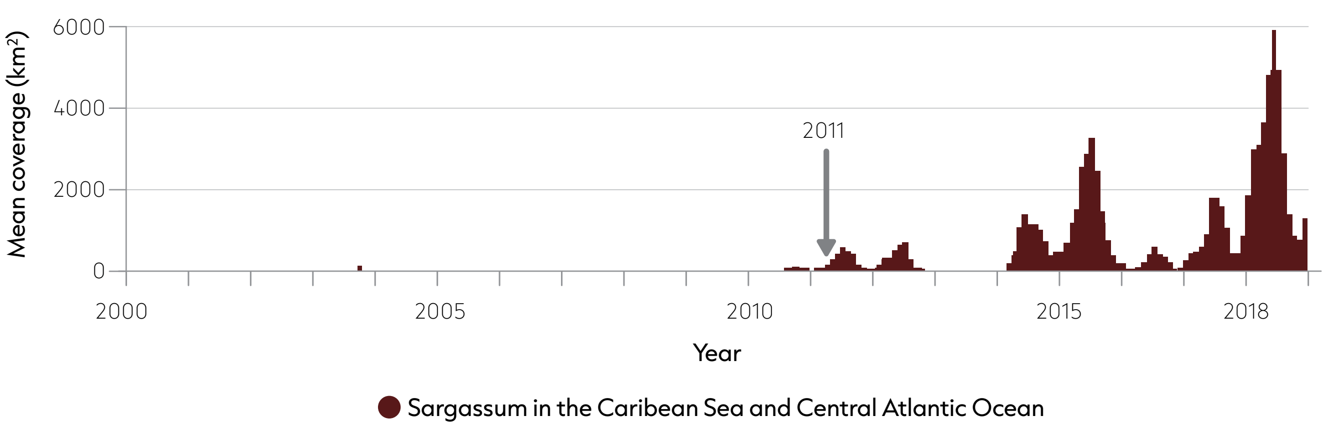


Figure 5.31. Monthly mean Sargassum area coverage in the Caribbean Sea and the central Atlantic Ocean between 2000 to 2018. (Wang et al., 2019)

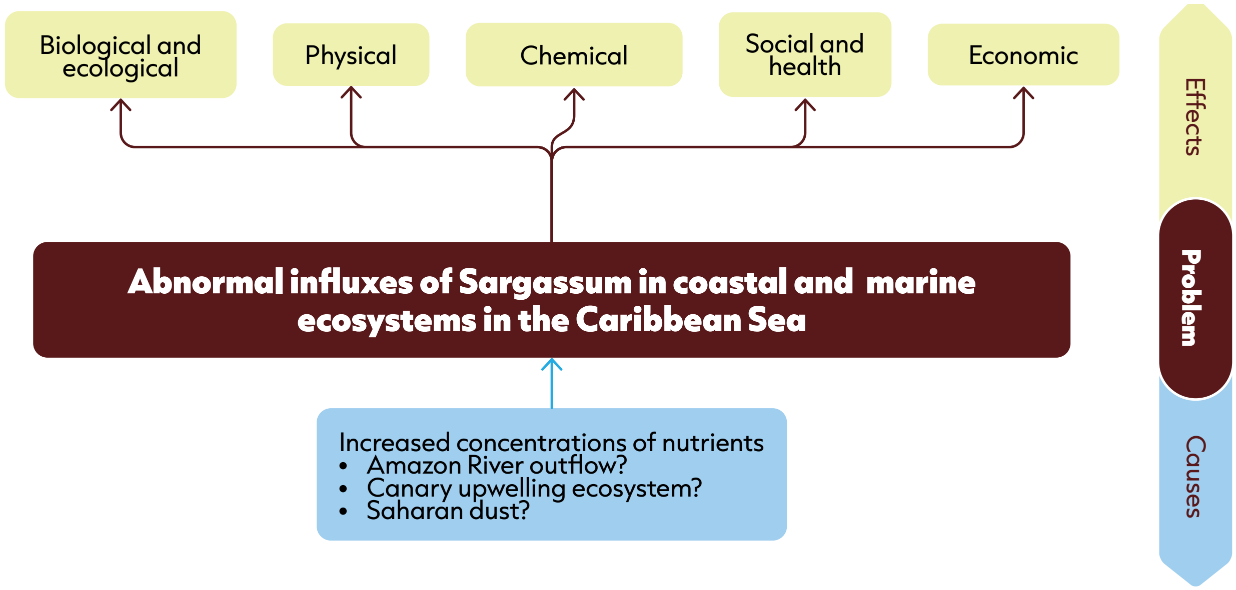


Figure 5.32. Problem tree for Sargassum influxes in Grenada

lobsters, conch and snappers (CRFM, 2019). Once Sargassum strands on beaches, there is mortality of marine fauna that have become entrapped within its dense mats. Stakeholders have reported fish kills in certain areas (CRFM, 2019). Sargassum stranding on beaches have disrupted sea turtle access to nesting sites and the ability of sea turtle hatchlings to escape their nests (CRFM, 2019). Due to the fact that Sargassum is positively buoyant and is transported by oceanic currents, non-native species may 'hitch a ride' on Sargassum, thereby introducing the possibility of IAS, (CRFM, 2019). Clean-up operations at specific sites in Grenada (Pearls Airport/Great River Bay and Soubise Beach) have resulted in significant beach erosion and loss of sand (CRFM, 2019). Specifically, sand was lost once heavy equipment was used to remove stranded Sargassum (CRFM, 2019).

Sargassum also burdens the social, health and economic sectors of Grenada as both pelagic Sargassum as well as those stranded on beaches pose a threat to humans. Sargassum stranded on beaches impede recreational and tourism activities (The Guardian, 2015). Once stranded, Sargassum eventually starts to decompose and release hydrogen sulphide gas. This can act as an irritant and pose respiratory problems for beach goers, tourists, fisherfolk and nearby residents. Specific groups of stakeholders such as fisherfolk have reported that Sargassum in nearshore coastal waters entangles their fishing gear, damages their outboard engines and boats, disrupts access to their boats and landing sites (CRFM, 2019; Now Grenada, 2019). One of the coastal communities along the east coast of Grenada that has been particularly affected is Soubise (Toby Calliste, 2023, personal communication). Sargassum influxes have both a social and economic impact on fisherfolk as they report decreased numbers of fishing days, reduced catches and an overall loss of livelihood (CRFM, 2019). Fisherfolk have reported that for certain species, such as dolphinfish or mahi-mahi (*Coryphaena hippurus*), Sargassum influxes have resulted in there no longer being a clearly defined season (Toby Calliste, 2023, personal communication). For some species, such as crevalle jack or cavalli (*Caranx hippos*), Sargassum influxes have been associated with increased catches (Toby Calliste, 2023, personal communication). In 2018, it was estimated that the total cost of beach clean-up operations was approximately US$370,000, (Now Grenada, 2019).

Figure 5.33. Exposure of Grenada's coasts to Sargassum inundation (Degia et al., 2022)

Response options

Coastal and marine ecosystems (e.g. beaches, mangroves, seagrass beds, coral reefs) in Grenada are responsible for the delivery of a suite of ecosystem services. During the past decade, Grenada has experienced abnormal influxes of Sargassum in its coastal/marine ecosystems. In order to ensure that Grenadian coastal/marine ecosystems are sustainably managed, human health, well-being and livelihoods are protected, it is suggested that efforts are directed to the effective management of Sargassum influxes in specific coastal areas (Figure 5.34). In order to accomplish this, it is proposed that Grenadians employ a suite of response options: 1) Foundational, 2) Enabling, and 3) Instrumental.

Foundational

Firstly, under the category of Foundational Responses, it is proposed that efforts be directed towards the generation and distribution of knowledge and information (high agreement/high evidence). Presently, there is only informal data collection about Sargassum influxes in Grenada and its impacts on ecosystem health and human well-being. In order to improve data collection efforts, a participatory community-based approach can be taken. Stakeholders that are on the ground, e.g. fishers can be trained to assist with data collection. New technology tools can be utilised e.g. cameras and drones to monitor Sargassum stranding.

Enabling

Secondly, under the category of Enabling Responses, efforts can be directed to the establishment of a multisectoral task force/committee on Sargassum (high agreement/high evidence). Already, this has been proposed under the draft protocol for the management of extreme accumulations of Sargassum in Grenada. Within this task force, some of the stakeholders that could be involved include:

- Government: (i) Ministry of Sports, Culture, the Arts, Fisheries and Cooperatives (ii) Ministry Tourism, Civil Aviation, Climate Resilience and the Environment (iii) Ministry of Agriculture, Lands and Forestry (iv) National Disaster Management Agency (NaDMA), (v) Ministry of Communications, Works, Physical Development, Public Utilities, ICT and Community Development (Physical Planning Unit), (vi) Ministry of Health (Environmental Health Division), (vii) Grenada Ports Authority, (viii) Grenada Tourism Authority, (ix) Grenada Solid Waste Management Authority, (x) Ministry of Carriacou and Petite Martinique Affairs, (xi) Ministry of Infrastructure Development, Public Utilities, Energy, Transport and Implementation
- Academia: St. George's University
- Non-Governmental Organisations: SusGren, Grenada Coral Reef Foundation, Trust for Sustainable Livelihoods, The Nature Conservancy, Grenada Community Development Agency, Soubise Fishermen Cooperative Society, Ocean Spirits
- Regional Stakeholders e.g, Academia: The University of the West Indies, Cave Hill, Centre for Resource Management and Environmental Studies (CERMES)
- International stakeholders: FAO

Within this Multi-Sectoral Task Force, could include several different Working Groups, such as: 1) Research, Data and Monitoring, 2) Response and Management, and 3) Communications (Education and Outreach).

Instrumental

A third category of response options that can be employed to effectively manage Sargassum influxes to Grenada is Instrumental, whereby attention could be directed to new technologies and practices, voluntary actions, markets and incentives, etc (high agreement/high evidence). When managing adverse impacts, a suite of approaches can be utilised 1) avoidance, 2) mitigation, 3) remediation, and 4) compensation. Since it is not possible to avoid influxes of Sargassum to the Caribbean region, efforts can be directed towards mitigation at specific coastal locations. Considerations can be given to: 1) coastal/marine areas (e.g. Levera Proposed National Park, Woburn Clarks Court Bay Marine Park, areas with mangrove/seagrasses/coral reefs, [Box 5.16]), 2) key coastal communities and areas with key fish landing sites (e.g. Soubise, Bathway, Marquis, etc.), 3) seamoss

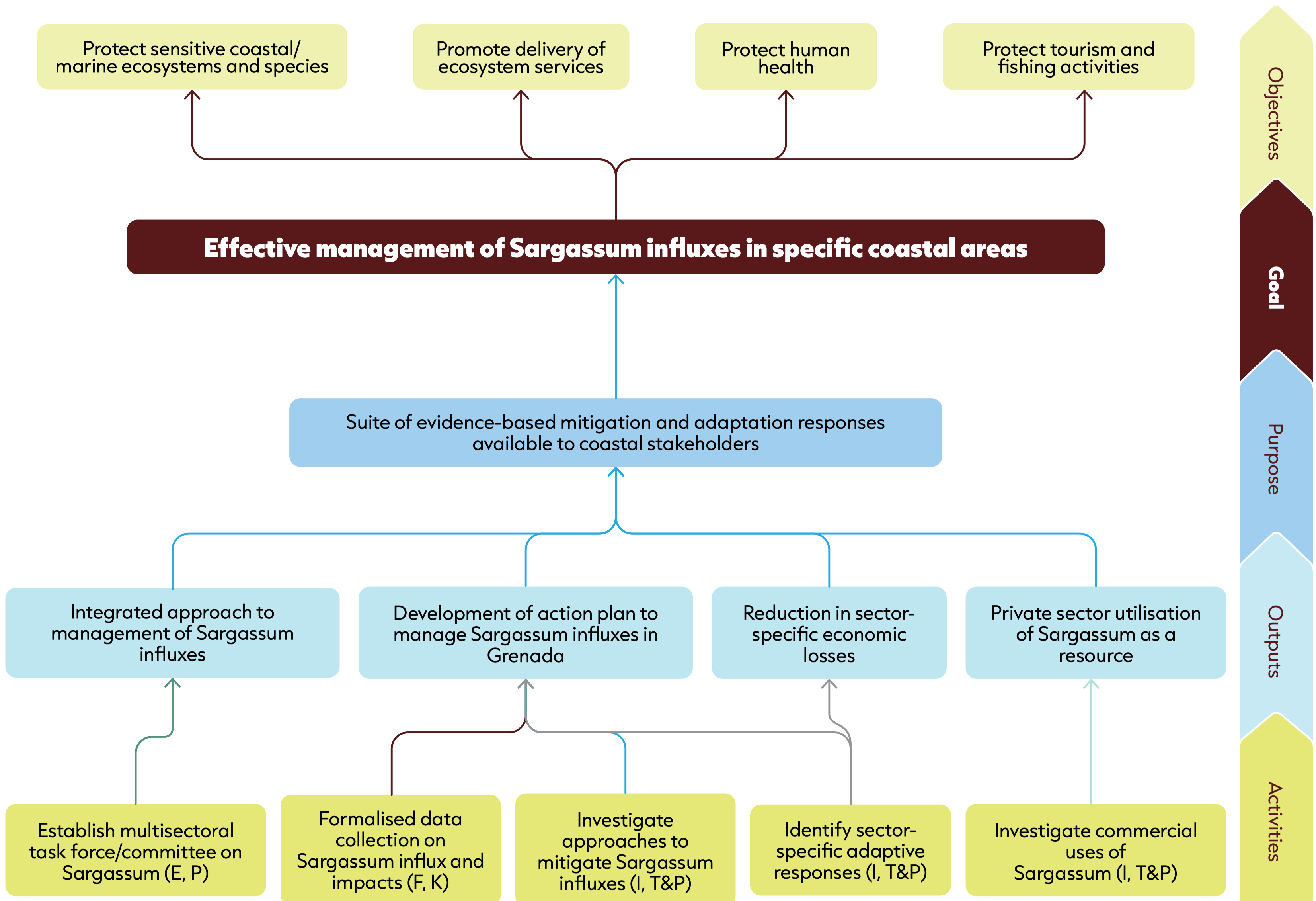


Figure 5.34. Objective tree for Sargassum (Note that Response Options were categorised into (i) Foundational (F) e.g. Knowledge/Foundational (K), (ii) Enabling (E) - Policies (P), (iii) Instrumental (I) -Technologies and Practices (T and P)

farming locations on east/south-east coast (Grenville Bay-specifically Telescope and Soubise, Petit Bacaye, and Woburn) and 4) key turtle nesting beaches (e.g. Levera Beach, etc). New technologies and practices that are employed elsewhere in the Caribbean can also be investigated for Grenada (see Section 5.4). Additionally, efforts could be directed towards sector-specific (fisheries, tourism, maritime transport) adaptive responses to Sargassum influxes. This may involve the utilisation of new technologies or a change in practice by stakeholders. Efforts can also be directed towards investigating the commercial uses of Sargassum in Grenada. Once Sargassum is embraced as a resource, the private sector can drive removal efforts from the natural environment.

Box 5.16. Marine Protected Areas in Grenada

Grenada has already designated several Marine Protected Areas (MPAs): 1) Woburn Clarks Court Bay, 2) Grand Anse Marine Protected Area, 3) Moliniere-Beausejour Marine Park, 4) Sandy Island/Oyster Bed Marine Protected Area. Furthermore, there are also several proposed MPAs for which draft management plans have been prepared.

Actively managed MPAs provide Grenadians with an opportunity to protect sensitive coastal and marine ecosystems and ensure the continued delivery of provisioning, regulating, supporting and cultural services. Fisheries can benefit since specific life stages will be protected, feeding grounds and spawning grounds can also be protected, with potential spill-over effects that can benefit fishers. Tourism can also benefit as there may be an increase in the number of visitors engaging in snorkelling, scuba diving, and tours. Multiple use MPAs allow diverse stakeholders to benefit. However, it also provides an opportunity to ensure that adverse impacts of anthropogenic activities are avoided and minimised.

Model MPAs in other Caribbean countries have successfully implemented (i) co-management schemes, whereby multiple stakeholders (especially local communities) are involved in management, (ii) self-sustaining MPAs via user fee collection.

5.3. Policy instruments: status and opportunities

Policy and the arising legislative frameworks that translate such policies into coordinated State and non-State action on the ground, are central tools for ecosystem service optimisation. Such policies become reality through the adoption by the State of explicit budgeting, operational strategies, programmes, action plans and projects that direct on-the-ground management and conservation. As a result, the policy process is central to development of a synergistic and coherent enabling landscape for ensuring the people of Grenada benefit from their ecosystem services. The existing and draft environmental legislation and policies have been identified above and in previous chapters (Chapters 1-4).

A review of these policies pertaining to Grenadian biodiversity conservation (GoG, 2014) concluded that biodiversity conservation was being addressed by existing policy, planning and legislative frameworks, and to a large degree, the policy framework for biodiversity in the country has been evolving to reflect the global environmental consensus and priorities. However, as with that review, the underlying theme in the ecosystem reviews of this chapter is a broad lack of decision making with regard to adoption and implementation of policy.

Here the suite of existing draft environmental-related policies (e.g. *Plan and Policy for System of National Parks and Protected Area, Land Use Policy* etc.) that are yet to be officially adopted and enabled through relevant legislation (e.g. the *Draft Environmental Management Act*), speaks to a critical governance bottle-neck plaguing ecosystem service management in Grenada. In this situation, a key action is the need for leadership among the State actors to identify where in the policy cycle, there is a process failure that is inhibiting policy adoption and implementation. This should be considered to be a fundamental governance priority. Unless this issue is addressed, the rate of policy development, adoption, and implementation will remain greatly suppressed and dysfunctional.

5.3.1. Terrestrial policy responses

It is notable that there has been only limited enactment or revision of terrestrial-related environmental legislation since the 1990s. This lack of action on enabling legislation is paradoxical in light of increasing knowledge of the importance of climate change and ecosystem services for the Grenadian population (Chapter 3). The lack of movement on an enabling policy environment for terrestrially focused issues lies at the base of this failure to evolve the legislative environment. The Acts that are particularly important for managing terrestrial systems (Appendix 2) include:

- *Forest, Soil and Water Conservation Act,*
- *Birds and Other Wildlife (Protection) Act, National Parks and Protected Areas Act*
- *Physical Planning and Development Control Act*

To improve the enabling environment for terrestrial systems we focus on several cross-sectoral policy gaps and needs, which if addressed would promote sustainable land management practices and deliver more sustained ecosystem services (Table 5.3 on page 394). We present those options predicted to have the greatest potential for amplification of ecosystem services i.e. policy activities with the highest number of connections to outputs, within and between the three terrestrial objectives trees (Appendices 4 and 6), as well as other ecosystems in this chapter review. Among those approaches which stand out as providing multi-sectoral improvements, the adoption of a land use policy is a priority (Box 5.17).

Box 5.17. Land use policy

The adoption and implementation of a national land use policy and plan has been identified as a central action to facilitate many of the positive ecosystem futures identified in this National Ecosystem Assessment. As stressed throughout this document, the constraints of being a small island, with economic activity centred on the natural environment and the complexity of threats to ecosystems, demand that the highest priority be placed on holistic and proactive management of Grenada's natural land areas. Adoption of a land use policy that has been co-created, reflecting multi-stakeholder engagement and values, can provide an important framework for managing the country's limited and valuable land-based resources.

Multiple unsuccessful attempts have been made to implement a Land Use Plan in Grenada. At the time of writing, the *2016 Land Use Policy* has been ratified by the country's Cabinet but remains to be implemented. While revision is necessary to address weaknesses in the current version (e.g. lack of zoning), the need for such revisions does provide an opportunity to mainstream ES in the policy, as suggested in this NEA. Nonetheless, it is clear that prioritising a land use policy, even one with shortcomings, is critical to ensure sectoral activities (e.g. in tourism, agriculture, energy, transport) explicitly support sustainable management of ecosystems and their services.

To support implementation of land use planning and physical development, enacting the *Draft Environmental Management Act* would cut across multiple sectors to instil sustainable practices in built infrastructure development. For example, ensuring a robust, transparent EIA process, which could allow for an explicit recognition of the costs, benefits and trade-offs inherent in physical development processes. Such a robust process would include mechanisms for legal public challenge of EIA processes, and a more prescriptive approach to controlled activities and ecological systems and processes that should be included in an EIA. This action would allow for improved communication and coordination across the stakeholders and so address multifaceted threats such as habitat degradation.

Development of a harmonised protected areas policy, legislation and management framework to clarify roles and responsibilities, is a fundamental step to ensuring a transparent and efficient framework for management of protected areas in the country and have considerable impact on the pressures underpinning habitat degradation and unsustainable use (Table 5.3; Appendix 6). This would require revision and enabling of the draft *Forest Policy and draft Protected Areas, Forestry and Wildlife Bill*. Full engagement of all stakeholders, including local communities and NGOs in the drafting and finalisation of protected areas legislation, would be critical given the previously identified challenges around private land ownership and landowner engagement. The form of implementation of any new protected areas policy should be determined through dialogue with local communities and NGOs. One option worth pursuing is the establishment of the Protected Area Advisory Council as set out in the *Environmental Management Act*, noting that the Sustainable Development Council has already been established without implementation of the Act (GoG, 2016b).

Amplifying landscape-level delivery of ecosystem services beyond protected areas requires engaging private landowners. Options with potentially high benefits include feasibility assessments of the policy and legislative mechanisms for enabling OECMs, as well as for PES to keep land under natural cover and promote behaviour change to mainstream sustainable land management practices (Appendices 4 and 6). Likewise, creating an enabling policy environment for a green and circular economy offers an incentive for empowering private landowners to develop sustainable sources of income.

Strengthening policy mechanisms for public participation in environmental decision making provides a means to address inequality in ecosystem service provision, especially for women and rural communities, and aligns with the strong focus in the GBF on the human right to a healthy environment. The opportunity exists to focus on environmental justice through:

- implementation of the *Escazú Agreement*, recently ratified by Grenada, to empower local communities and encourage pride in natural resources (Table 5.3; Appendices 4 and 6);
- access to open and transparent data sharing systems, for which provision is missing from many policies and strategies, would provide civil society with direct access to information and so play a role in facilitating meaningful and equitable public participation; and
- provisions for Access and Benefit-Sharing (ABS) for communities are a weakness across many national sectoral policies. The *Nagoya Protocol* provides a supporting mechanism that would lead to further empowerment of local communities.

The importance of these elements can be illustrated with examples from policy responses to overexploitation. For example, establishing a permitting system to address overexploitation of game species would require a public consultation process to maximise buy-in and require knowledge of island-specific differences in natural resource use across Grenada, Carriacou and Petite Martinique. Similarly, a functioning CITES system with relevant legislation and clarifying reporting processes will be necessary to manage ABS given the potential for bioprospecting from exploited species.

5.3.2. Freshwater policy responses

As discussed throughout the chapter and as was made evident in the problem trees, many of the threats/challenges related to water stem from inadequate governance due to either the absence of adequate legislation or the lack of enforcement. One of the primary acts that has the potential to significantly reduce water pollution is the draft *Environmental Management Act* (Table 5.3).

Other legislations or policies that can be beneficial if updated and enforced are:

- *The Pesticide Control Act Cap 238 (1973)*: control importation and use of substances that are banned in other developed countries; promote environmentally friendly alternatives
- *Public Health Act, Cap. 263 (2012), Waste Management Act, Cap. 334A (2001), Water Quality Act, Cap. 334B (2005)*: enhanced protection of waterways
- *NAWASA Act (1990) and Amendments (1991 and 1993), Cap. 208*: improved sewerage infrastructure, consistent water quality monitoring, data sharing and transparency
- *Physical Planning and Development Control Act 23 (2016)*: completion of the national physical plan that provides for inter alia, the allocation of land for prescribed purposes such as coastal zone protection, controlled sewage disposal, and overall the pollution of water bodies (draft review of Grenada's Water Legislation, February 2019)

Improvements in the institutional arrangement for freshwater management have already been proposed by the Grenada's *2020 National Water Policy* (GoG, 2020b). Here, in inter-related functions associated with this framework policy direction and coordination,

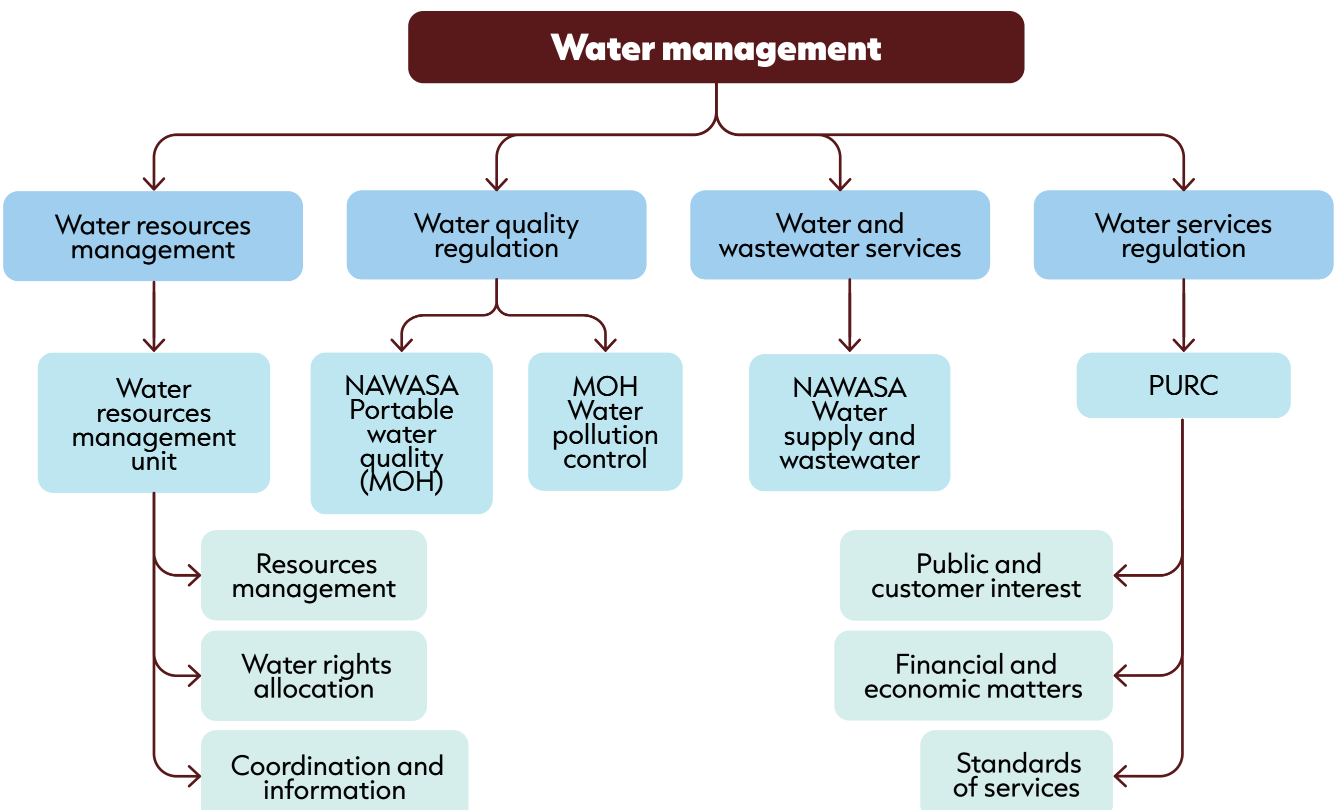


Figure 5.35. Functional chart of Grenada's water sector adopted from GoG 2020b.

regulation and service provision are illustrated in the proposed institutional arrangement for the management of Grenada's water resources (Figure 5.35).

5.3.3. Coastal policy responses

Grenada, Carriacou and Petite Martinique like other states in the Caribbean have heavily populated urban coastal regions and as a result there is intense demand on ecosystem services to support local livelihoods. Furthermore, with most of the major infrastructure and economic activities within the urban coastal zone (e.g. tourism, light industry, housing and transportation networks) human activity from these development sectors has led to the destruction of vital coastal ecosystems such as coral reefs, seagrasses, beaches and mangroves through overfishing, unregulated development activities, inadequate solid waste disposal and treatment of wastewater, as well as up-stream watershed pollution.

Such degradation threatens the sustainability of existing coastal marine assets and ecosystem services. These threats are increasingly exacerbated by climate change (e.g. coastal lowland attrition due to sea level rise) and increase existing vulnerabilities to extreme weather events and volcanic disturbance.

Addressing the challenges that originate within the national jurisdiction provides a means of increasing overall resiliency within these marine systems. Such resiliency is critical in providing a buffer to externally originating challenges in the marine ecosystem, including transboundary movement of IAS (e.g. lionfish), disease spread (e.g. stony coral loss disease), Sargassum influxes, and climate stressors (e.g. ocean acidification, sea level rise, heat stress). Therefore, in seeking to mitigate and adapt to these issues, the State should facilitate policy responses that strengthen cross-sectoral linkages, and so increase ecosystem service resiliency (Table 5.3; Box 5.18).

Table 5.3. Solutions mapping to the existing enabling policy environment for the delivery of ecosystem services across all ecosystems

Approach	Policy area	Ecosystem (problem)	Agreement	Evidence
Develop enabling policy environment for green/ circular economy	Finance, environment, forestry, fisheries, agriculture	Terrestrial- habitat degradation and overharvesting Freshwater, marine and coastal- water pollution (agrochemicals)	Low	Medium
Adopt *Forest Policy* and *Draft Protected Area, Forestry and Wildlife Legislation 2003*	Forestry, environment, agriculture, land use, physical planning	Terrestrial- habitat degradation and protected areas Freshwater- sedimentation	High	High
Implement *Environmental Management Act*	Environment, forestry, agriculture, water, fisheries, physical planning	Terrestrial- habitat degradation, IAS, over exploitation Freshwater, marine and coastal: water pollution (agrochemicals, hazardous waste, microplastics)	High	High
Implementing land use plan	Land use, physical planning, forestry, environment, agriculture,	Terrestrial- habitat degradation, over exploitation Freshwater- sedimentation, water pollution	High	High
Integration of ES in national planning and projects	Cross-sectoral	All ecosystems	Medium	High

Identify Cabinet-level role for cross-sectoral integration	Cross-sectoral	All ecosystems	High	Medium-High
Strengthen mechanisms for public participation in environmental decision making	Environment, forestry,	All ecosystems	High	High
Undertake new NBSAP	Environment, forestry, fisheries, agriculture, water	All ecosystems	Medium	High
Harmonise and adopt protected areas policy, legislation and management frameworks to clarify roles and responsibilities	Forestry, environment, water, physical planning	Terrestrial- habitat degradation, over exploitation, tourism, recreation, sustainable livelihoods Freshwater- sedimentation, water pollution	High	High
Policy and legislative mechanisms to enable PES to maintain natural cover	Finance, environment, forestry, agriculture, water	All ecosystems	Medium	High
Ratify *Nagoya Protocol* and implement *Escazu Agreement*	Environment, forestry, agriculture, fisheries, justice	All ecosystems	Medium	High
Implement the International Convention for the Prevention of Pollution from Ships (MARPOL)	Environment, transport, ports, fisheries	Marine and coastal ecosystems	Medium	High
Implement the Basel, Rotterdam, Stockholm and Minamata Conventions	Cross-sectoral	All ecosystems	Medium	High
Update *Waste Management Act* to include climate responsiveness	Environment	All ecosystems	High	High

Box 5.18. Harmonising cross-sectoral ecosystem service policies - the case of the coastal zone

Two examples illustrate how coastal and marine threats can be addressed by cross-sectoral integration of the enabling policy environment (Table 5.3):

Pollution in the marine environment

It is important to note that pollution within this ecosystem originates not only from the local marine environment but from the terrestrial as well as transboundary international sources. The range of such sources include from upper-watershed point and diffuse commercial, farm and domestic pollution, industry, sewage, littering, and ship waste (heavily affected locations include St. George's, Clarks Court Bay, Hog Island). Potential policy interventions here include:

- implement *Environmental Management Act* e.g. expand levy to tourists and yachts to fund prevention and control of marine and coastal waste;
- update *Waste Management Act* e.g. strengthen polluter pays principle to mitigate against coastal and marine degradation;
- ratify and implement MARPOL, Stockholm, Basel, Minamata Conventions e.g. strengthen hazardous waste management both on land and at sea;
- enabling policy for circular economy e.g. provision for waste recycling to reduce pollution and littering, through biofuel, right to repair, banning polystyrene etc.;
- strengthen mechanisms for public participation in environmental decision making e.g. to utilise human capital to generate solutions for a circular economy; and
- utilisation of citizen-science or citizen-observation systems to monitor and evaluate effectiveness of policy and law enforcement in the coastal zone.

Coastal development

Coastal development represents one of the most challenging sectors for governance and management trade-offs given the range of stakeholders, economic sectors and political actors involved. Decisions on prioritisation of competing incompatible land uses in this space contribute significantly to impacts on livelihoods, public health, economic activity, and conservation of unique natural resources (e.g. through pressures on critically endangered species through habitat loss and degradation). Here hotel, marina and housing developments are the most visible examples of the challenge involved. At present, key affected locations include Woodlands, Woburn, La Sagesse, Levera, Mt. Hartman, Calivigny and Sandy Island. Potential policy interventions here include:

- implementing *Land Use Plan* (Box 5.17 on page 391) e.g. promote integrated management and development and sustainable land use practices to mitigate against habitat degradation;
- implement *Environmental Management Act* e.g. strengthen EIA process to encompass more activities and be more prescriptive (e.g. set back distances, erosion control);
- enabling policy for PES e.g. provide financial incentives to keep land under natural cover for ecosystem services provision rather than develop;
- integration of ecosystem services in national planning and projects e.g. incorporate true value of mangroves (e.g. coastal protection and fish nurseries, protection against sea level rise) into national budgeting;
- harmonise PA legislation e.g. strengthen PA management to maintain natural cover and mitigate against habitat degradation and climate change (e.g. erosion control, protection of mangroves, reduce sedimentation); and
- strengthen mechanisms for public participation and transparency in environmental decision making e.g. to provide civil society with a voice on the future of Grenada's natural patrimony.

5.4. Finance instruments: status and opportunities

Developing sustainable funding mechanisms that incentivise rational choices that maximise the use of ecosystem services whilst simultaneously ensuring the long-term viability of these resources, is a central challenge for the stakeholders on Grenada. With much of the development funding for environmental management in the country originating from multilateral, bilateral and foundation donors, and the recurrent State budget, the funding environment for implementation of the activities described in this chapter, can appear daunting.

As with many SIDS, the Grenadian economy is reliant largely on external drivers (Chapter 1). Grenada has a history of a high debt-to-GDP ratio that undoubtedly influences the allocation of spending on the environment. The downturn in global tourism due to the COVID-19 pandemic has further exacerbated national debt (Seerattan, 2023). Prior to the pandemic in 2019, government policy adjustments and reforms had reduced national debt to 59.7% of GDP. However, since the pandemic this has now risen to over 70% of GDP (Seerattan, 2023). As indicated in Chapter 4, the country's various natural ecosystems provide significant tangible inputs to the national economy. Examples include the contribution to the environmental ambience to the tourism industry, the over US$185 million received in the past 40 years from pelagic fisheries, and the estimated US$0.48 billion in avoided damage provided by coral reef protection. In spite of these multiple benefits, State-level investment in these ecosystem services remains limited.

Given the fragility of the economy to external shocks (Chapter 1), incorporation of biodiversity and ecosystem services in national accounting represents an opportunity to be more deliberate in assessment of the costs and benefits of specific development pathways currently being considered by the nation, as well as investment priorities. As emphasised in Chapter 4, achieving this requires increasing our

Box 5.19. Payment for Ecosystem Services - watershed protection in Latin America

Payment for Ecosystem Services (PES) is a mechanism that generates private and public funding which can be used to incentivise landowners and communities to maintain a specific ecological service. By developing a market for ecosystem services, it adds economic value to the services that currently lie outside human economic systems and outside of formal protected areas. PES has been particularly effective for conserving water and watersheds in Latin America, including Costa Rica, Mexico and Chile (Grima *et al.*, 2016). Multiple financial instruments exist to implement PES, such as user fees or private funding, that is then re-distributed to landowners to protect an ES (Martin-Ortega *et al.*, 2019).

To date, PES is under-utilised in the Caribbean, although there have been economic valuation and feasibility studies of PES for Marine Protected Areas in Grenada (Monnereau, 2017). Criteria for success in Latin American PES schemes include (Grima *et al.*, 2016; Martin-Ortega *et al.*, 2019):

- Positive contribution to local livelihoods while ensuring continued provisioning of ES
- Long-term (10+ years) local or regional scale projects
- Including in-kind contributions rather than cash-only transactions
- Inclusion of private actors (including NGOs), and removal of intermediaries between seller and buyer
- Increased stakeholder participation in price-setting processes

Box 5.20. The example of the Trinidad and Tobago Green Fund

The Trinidad and Tobago Green Fund was initiated in 2001 under that country's *Miscellaneous Taxes Act* for the purpose of the maintenance, restoration and conservation of the environment (GoTT, 2023). The Fund levies 0.3% on the gross income of all companies and businesses in Trinidad and Tobago (GoTT, 2023), and is maintained separately from other taxes, with its balance reported in the National Budget. Administered by the Ministry of Planning and Development, project approval is overseen by a Green Fund Advisory Committee (GoTT, n.d.). In 2021, the Green Fund stood at nearly US$1.19 billion, available for NGOs and CBOs to apply for project funding (GoTT, 2023). Although there have been challenges with accessibility to the fund, and the capacity of NGOs and CBOs to complete the application process, to date 29 projects valuing over US$148 million have been certified, including reforestation and restoration, recycling, solar energy and ecotourism projects (GoTT, n.d.). Such a fund could provide another valuable financial model for adoption by Grenada to encourage NGO/CBO-led management of ecosystem services.

knowledge and providing an enabling environment, and instrumental tools for valuing and protecting the natural environment.

In parallel, there is today a heightened realisation by the global community of the need to dramatically increase the funding available to manage biodiversity, as signalled at the recent COP15 of the CBD. Today, diverse innovative financing approaches are being developed, which go beyond traditional grant financing. These encompass instruments as diverse as return based investments (e.g. microfinance, peer to peer investing, sovereign bonds), risk management tools (environmental insurance and pay for success vehicles) to leveraging financing through

Box 5.21. Green Bonds - Fiji leading the way

According to the World Bank (2017), in 2016 green bonds issued by the Bank totalled US$81.6 billion while in 2017, over US$130 billion was issued in green bonds, across the sector. These bonds are attractive to investors because they provide investors an opportunity to invest in businesses focused on climate resilience. In addition, green bonds are attractive to investors because of the monitoring requirements of the Green Bond Principles (World Bank, 2017). Green bonds have been used in other SIDS. For example, in November 2017, the Government of Fiji became the first state in the world to issue a green bond, pioneering the issuing of a sovereign green bond, with the objective of raising US$44 million dollars to help Fiji in meet its climate-resilient infrastructural and sustainable development targets (Fiji Ministry of Economy, 2019).

Environmental, Social and Governance (ESG) and economic instruments not currently used by the State (e.g. deposit-refund schemes, compensation and offsets). An example of a new financing instrument, is the creation of a special financing facility being adopted in South Africa. Here, the Development Bank of Southern Africa has created a climate finance facility with US$171 million in financing from the Green Climate Fund for the implementation of climate adaptation projects. Such a model might provide a useful approach for Grenada.

There are several approaches that can be taken by the State to facilitate a broadening of income streams for supporting improved management of the country's ecosystem services (Table 5.4 on page 402). These include integrating the Natural Capital Accounting system in fiscal decision making, development of PES (Box 5.19), Green Funds (Box 5.20) and the use of blue and green bonds (Box 5.21). Debt for nature swaps may also provide an avenue for some fiscal relief. Despite two debt restructurings and although it continues to have unsustainable external debt, the country could take advantage of the structure of this debt that would allow it to develop a green and blue economy (Rambarran, 2018).

5.4.1. Terrestrial financial responses

Given the backdrop of Grenada's current financial status, maintaining ecosystem services for the population is dependent on generating diverse and sustainable sources of funding. One option is to strengthen existing finance options (Table 5.4). Grenada has current or draft mechanisms that offer possibilities for generating ongoing funds, if they are updated and implemented:

- the Environmental Levy is one such tool to address terrestrial pollution. However, weaknesses in enforcement and lack of updating since 1995 mean that not only does it now not reflect changes in consumption, but the absolute cost of polluting would have increased; and
- the management of Terrestrial Protected Areas suffers from a lack of funding, in part since the mechanism proposed to raise funds, the National Parks Development Fund, has not been operationalised. The enabling legislation for this fund now requires updating e.g. to consider current best practices for charging user fees. While the exact nature of how such funding mechanisms are operationalised will depend on stakeholder consultation, a key issue remains the ring-fencing of such funds for environmental management.

Competing interests for limited land and resources are key drivers for the erosion of ecosystem services on Grenada. It is hard to see how the pressure on ecosystems and their services can be lessened without reducing financial incentives and disincentives that conflict with preservation of functioning ecosystems (Table 5.4). One option is to reform taxes (e.g. to strengthen the polluter pays principle), which would encourage behaviour change, as would rewarding land owners for good land use practices that lead to nature-positivity (e.g. maintaining natural cover, reduced grazing, SLM and climate-smart agriculture). Options to generate and redirect funding to encourage nature-based practices include developing budgetary allocations specifically for mainstreaming ecosystem services, exploring opportunities for PES and increasing access to micro-financing. Such finance instruments are effective tools for scaling-up restoration and ecosystem-based approaches. However, for this to be successful, secure land tenure is critical for engaging private landowners

Box 5.22. Investing in land use change and forestry through REDD+

Reducing Emissions from Deforestation and Forest Degradation (REDD+) is a blended finance mechanism for forest landscape restoration and conservation. The REDD+ framework was adopted as the *Warsaw Framework for REDD+* at COP 19 and subsequently taken up in Article 5 of the *Paris Agreement*. It is a results-based financing tool which provides payments to countries for meeting commitments. There are 47 participating countries and 17 donor countries and organisations. Funding is provided via the Forest Carbon Participation Facility (FCPF), which comprises two funds: 1) FCPF Readiness Fund of approximately US$400 million, and 2) the FCPF Carbon Fund with an estimated value of US$900 million.

Within the Caribbean, Guyana has earned approximately US$190 million via the REDD+ finance arrangement between the Governments of Guyana and Norway. Of the US$190 million, US$70 million was deposited into the Guyana REDD+ Investment Fund while US$5.8 million was disbursed into the Guyana Forestry Commission to assist with development of a monitoring, reporting and verification system (Laing, 2015). Such funding mechanisms are important, as more than 15 times more public finance is currently provided to the agriculture sector in tropical countries by international donors than climate mitigation finance related to forests (UNEP, 2020).

so as to reduce their investment risk and incentivise long-term planning.

In a post-COVID-19 world where small islands face a suite of challenges exacerbated by the climate and biodiversity crises, re-thinking finance options will be necessary to develop innovative and exploit emerging instruments (Table 5.4) for the green, blue, orange and circular economies that will increase the resiliency of Grenada to external shocks. To assess the relative potential of these new and innovative instruments for generating sustainable financing and returns on investment, whole value-chain assessments (e.g. of NTFPs, enrichment planting) form a necessary part of the process. The importance of leveraging private sector capital for scaling up forest and landscape restoration projects is increasingly recognised and moving beyond a niche market (Löfqvist and Ghazoul, 2019). For example, the *Ridge-to-Reef* project as generally perceived as successful but was limited in geographic scope and duration and thus an opportunity exists here to scale up an established approach.

The high contribution of private sector investment in Grenada offers an opportunity to channel these funds towards such nature-based projects, e.g. through green bonds, debt-for-nature, carbon markets, and ESG. Frameworks for conservation finance are rapidly advancing, reducing the risks and transaction costs for private investors, whilst safeguarding local communities and landowners and thus it is pertinent for the government to take full advantage of emerging opportunities. Grenada's leadership in the restructuring of the hurricane insurance clause (Seerattan, 2023), demonstrates the potential for negotiating these innovative and emerging mechanisms and instruments. So too does Grenada's history of leveraging MEAs to access financing, which should be explored to further capitalise on existing and new funds for forest and landscape restoration (e.g. Global Forest Finance Pledge, REDD+ (Box 5.22), LDN, Caribbean Biodiversity Fund (CBF), Loss and Damage Fund, Caribbean Community Climate Change Centre (CCCCC). The complexities and opportunities of these new and emerging finance tools, as well as existing barriers to their implementation, means that success is dependent on building partnerships between the government, private sector, education (e.g. SGU), NGOs and individual landowners.

5.4.2. Freshwater financial responses

Lack of financial resources is arguably a core cause of all the freshwater challenges discussed in this chapter. Even with adequate legislation, money is necessary for technical and institutional capacity building and using an integrated approach to governing of businesses where fee-based operation permits are required. Fees are determined by the risks posed on different ecosystems and are used towards that ecosystem protection programme. For example, a company that discharges effluent as part of its daily operations, in addition to ensuring the water is treated prior to release, a discharge fee could be incorporated into the overall permit fee. Permits should therefore have an expiry date and the fees subject to change based on current status of operations (high agreement, medium evidence).

Other financial responses for fee-based operation permits for businesses using ecosystem services are presented at Table 5.4. Economic modelling can also be useful. For example, Lupi *et al.* (2020) developed an integrated assessment model that couples economic and biophysical models to determine the impacts of agri-environmental policies on the value of freshwater ecosystem services. The model links "changes in phosphorus-related management practices on farms…to changes in the value of key freshwater ecosystem services, including biological condition, water clarity, species-specific fish biomasses, and beach algae". According to the authors, the use of the model will facilitate the correlation between policies and conservation programmes on ecosystem services and values. It is anticipated that the results can help show policy makers the importance of supporting budget allocations for water quality management, enhancing ecosystem services, and promoting more sustainable agricultural practices.

5.4.3. Agriculture financial responses

There is a key strategic focus on agriculture by the current GoG (GoG, 2022). This is reflected in one of the largest large budgetary allocations to agriculture in recent times of US$20.1 million for the fiscal year 2023 (GoG, 2022). Of this amount, around 49.7% of the budget is earmarked for the *Food Security Enhancement Project*, which will target increasing the production of crops and livestock, making improvements to fisheries, equipment and training, food quality and health, provision of farm infrastructure and investment in sustainable practices within agriculture (GoG, 2022). While the value of the private sector contribution to agriculture is unknown, there is evidence of private sector investment in sustainable agroecosystems, for example, the Belmont Estate, which specialises in organic tree-to-chocolate production and agrotourism (World Bank *et al.*, 2014).

To aid public and private sector funding, multilateral and bilateral partnerships also serve as an avenue for financial support. Throughout the years the sector has received financial investments in the form of grants from the Government of Japan, the Government of Morocco, GI), United Nations Development Programme (UNDP), the Global Environment Facility (GEF) and FAO as well as loan facilities from the International Fund for Agricultural Development (IFAD) and the Caribbean Development Bank (CDB) (World Bank *et al.*, 2014). In the past two decades, Grenada has benefited from specific international funding for climate change adaptation. For example, Grenada has been a recipient of GEF-4, GEF-5, GEF-6, GEF-7 and GEF-8 funding that targets global challenges of climate change, biodiversity loss and land degradation. Under the latest GEF-8 arrangement (2022) that is geared towards green, blue and resilient recovery, Grenada has been allocated approximately US$8 million (GEF, 2022).

While important strides have been made towards agricultural investments, the GoG and the private sector must have an outlook on new streams of financing to support sustainability initiatives within agroecosystems and other ecosystems (Table 5.4). Possible avenues can entail:

- designing local PES schemes that rewards farmers for their ecological stewardship (Box 5.19). These schemes can be funded publicly, privately or via PPP;
- participating in the UNFCCC REDD+ (Box 5.22);
- establishing PPP to support climate-smart agriculture initiatives;
- support farming associations to access voluntary carbon markets;
- support farming associations and agri-businesses in participating in certification schemes; and
- exploring social impact investments and green bonds (Box 5.21).

5.4.4. Coastal and marine financial responses

Grenada, like many SIDS, has limited financial resources and therefore must find creative ways to support those response options that it chooses to implement for coastal and marine ecosystems (Table 5.4).

Response options are needed to fund knowledge generation that is underpinned by participatory, community-driven science. Regional academic institutions can partner with relevant Grenadian stakeholders to co-design such initiatives, since it is Grenadians on the ground that will drive data collection efforts. The Ocean Conservancy's International Coastal Clean Up (ICC) is an example of a multi-country citizen-science initiative that has led to the generation of long-term data about marine debris, within which Grenada could participate.

Increasing knowledge-sharing and promoting collaboration between Grenadian and regional institutions are mechanisms to improve opportunities to scale up existing projects and help increase capacity to access funding. Examples of recent regional projects on which to build, include the FAO project *Climate Change Adaptation in the Eastern Caribbean Fisheries Sector Project (CC4FISH)* that increased baseline knowledge of fisheries data and CANARI's Caribbean Sea Innovation Fund (CarSIF) that increased public awareness, promoted coastal restoration and sustainable livelihoods.

The role of government is central to creating the enabling environment for the formation of multi-sectoral committees/task forces to tackle specific emerging issues as they arise, such as Sargassum, coral diseases, ghost gear, microplastics, deep sea mining and coastal adaptation. Here, enabling policies and plans, such as the *National Adaptation Plan and Nationally Determined Contributions (NDCs)*, can be modified to provide the mechanism to link these actions with funding. Active participation in regional and international negotiation of MEAs, such as MARPOL, could lead to strengthening of Grenada's technical capacity and accessing multilateral finance mechanisms and instruments.

An opportunity exists for the new technologies and instruments needed to support and enhance ecosystem service delivery to be catalysed by private sector investment. Governments can further facilitate this by offering relevant incentives to the private sector. For example, government incentives to boost private sector led initiatives to turn problems like Sargassum into a resource. Innovative solutions include developing carbon credit systems for Sargassum, such as currently being developed in Puerto Rico. It is estimated that over the next 50 years the value of Grenada's Blue Carbon ecosystems could be worth up to US$10.7 million (McHarg *et al.*, 2022).

Blue carbon ecosystems are currently receiving high levels of attention globally due to their high rates of carbon sequestration and countries are being urged to include blue carbon in their NDCs. Grenada's MPAs will be pivotal for developing blue bond and carbon credit mechanisms to conserve these important systems. Here, leveraging financial institutions to play a role in the implementation of projects such as nature-based solutions for coastal infrastructure, blue bonds for wetland restoration and re-structuring fisheries insurance policies, will be an important priority.

Grenada has already taken steps towards strengthening the blue economy with a strong focus on developing the financial potential of the blue economy in the *Medium-Term Action Plan (MTAP)*. Recent examples of blue economy initiatives include the *Grenada Second Fiscal Resilience and Blue Growth Development Policy Credit* project, which included financial support and fiscal reforms to diversify the blue economy and the Caribbean Oceans and Aquaculture Sustainability Facility (COAST) to pilot a new insurance scheme for Grenadian fisheries. Grenada is currently participating in the *Unleashing of the Blue Economy of the Caribbean Project (UBEC)*, a regional project to scale up the blue economy. These projects provide important foundations for the growth in acceptance of these novel financial tools as means to support ES in Grenada.

Table 5.4. Solutions mapping to the existing financial environment for the delivery of ecosystem services across all ecosystems

Approach	Policy area	Ecosystem	Agreement	Evidence
Develop budgetary allocations specific to mainstreaming ecosystem services	Finance, cross-sectoral	All ecosystems	High	High
Enable Green Fund mechanism	Finance, environment, forestry, fisheries	All ecosystems	High	High
Incentives and disincentives for grazing behaviour change	Finance, agriculture, environment	Terrestrial, agriculture and freshwater	High	Medium
Incentives and disincentives for pollution behaviour change	Finance, environment, agriculture, fisheries, industry	All ecosystems	High	Medium

Widen and strengthen environmental levy to include commercial and industry	Finance, industry, environment	All ecosystems	High	High
Enable National Parks Development Fund	Finance, environment, forestry, fisheries	Terrestrial, marine and freshwater	High	High
Remove perverse subsidies	Finance, agriculture, fisheries, industry, forestry, environment	All ecosystems	High	High
Strengthen national and regional participation in negotiation of finance mechanisms and instruments through capacity investment	Finance, foreign affairs, environment, agriculture, fisheries, forestry	All ecosystems	Medium	Medium
Access to financial resources e.g. loans, microfinancing	Finance, environment, forestry, fisheries, agriculture, water	All ecosystems	High	High
Green/blue bonds	Finance, environment, forestry, fisheries, agriculture	All ecosystems	Low	Medium
Disaster insurance schemes	Finance, environment, forestry, agriculture, disaster preparedness	All ecosystems	Medium	Medium
Business operating permits	Finance, Environment	All ecosystems	Low	High

5.5. From silos to integrated response

This section discusses options for encouraging development of cross-sectoral policy, legislation and economic responses to improve ecosystem services. Central to this section is the development of a whole ecosystem approach (Box 5.23) that leverages all the lessons highlighted across the ecosystem types in the review. Specifically, we prioritise responses which have implications for multiple economic sectors.

Our underlying assumptions in our recommendations include the view that the response options should provide for joined-up thinking across the sectors of the economy. Here:

- high degrees of specialisation have traditionally meant silo-based thinking, planning, budgeting and management of ecosystem services;
- building relationships across the sectors and across actors in the national community can improve buy-in, decision making and implementation effectiveness and lead to improvement in the quantity and quality of ecosystem services obtained by Grenadians; and
- emphasising a shift from solely economic sectoral lenses to one that prioritises relationships and networks of stakeholders can provide new ways to improve management of ecosystem services that are relevant the small island community of the tri-island state of Grenada.

While the objective trees in this chapter identify multiple potentials activities which can achieve such trans-sectoral dividends, we highlight how a few key interventions in each of the ecosystems covered in the chapter, can serve as catalysts for broader ecosystem benefits.

How terrestrial interventions can impact other sectors:

- intact forests positively impact downstream ecosystem services (e.g. reduced siltation, water quality, fisheries, agricultural productivity/food security);

- resilient forests improve climate resilience (e.g. flood protection, disaster risk reduction, gender equality);
- link between access to green spaces and biodiversity with improved wellbeing and healthy populations (e.g. lower healthcare costs, improved air quality, reduction in lost productivity and education days). This aligns with the OneHealth approach advocated in Chapter 4; and
- intact forests provide more opportunity for ecotourism and recreation (e.g. livelihoods, wellbeing).

How agricultural interventions can impact other sectors:

- sustainable land management of agroecosystems can contribute to safe food production, sustainable farming livelihoods and springboard a niche market in agrotourism;
- sustainable land management also helps mitigate freshwater and coastal degradation;
- agroforestry in particular can mitigate against habitat degradation as farmers are encouraged to farm within terrestrial systems; and
- agroforestry can provide landscape corridors that support wildlife migration.

Box 5.23. Cross-sectoral ecosystem-based approaches – Ridge-to-Reef

Stakeholders in Grenada have strongly advocated for Ecosystem-based Approaches (EbAs) such as *Ridge to Reef project*s. EbAs are strategies that adopt integrated land, water and living resources management (CBD, 2023). EbAs are by nature cross-sectoral, and investments in EbAs provide a platform to diversify economies, reduce tourism dependency and build resiliency to externalities (Batra and Norheim, 2022).

The 2017-2019 UNDP *Ridge-to-Reef project* in Grenada successfully promoted connectivity between land and marine management, with land-based restoration activities having a positive impact on coral reef health (International Resource Panel [IRP], 2019). Simple interventions, such as the agroforest restoration in this project, have been demonstrated more widely to amplify socioecological benefits and empower communities (Mercer *et al.*, 2012). The interconnectedness of these approaches also enhances system-wide climate resilience (IRP, 2019). EbAs also promote education and awareness about the interrelatedness of ecosystems (Glasgow *et al.*, 2018).

To date, EbAs throughout the region have typically been supported by project-based funding and run as short-term projects, with little focus on sustainability or long-term monitoring and evaluation. For many islands, the focus is now on scaling-up of existing projects rather than starting new (pilot) projects. As well as the financial challenge of scaling up, limited inter-island knowledge-sharing reduces the opportunities for learning and optimising management. Lessons to improve implementation of EbAs from across the Caribbean (Mercer *et al.*, 2012; Batra and Norheim, 2022) include:

- mainstreaming biodiversity and climate change;
- stronger focus on integrating local knowledge and learning from existing programmes;
- increasing the emphasis on terrestrial inland systems;
- encouraging buy-in by demonstrating immediate gains versus long-term benefits;
- increasing the effectiveness of monitoring and evaluation; and
- strengthening private sector financing for implementation and capacity building.

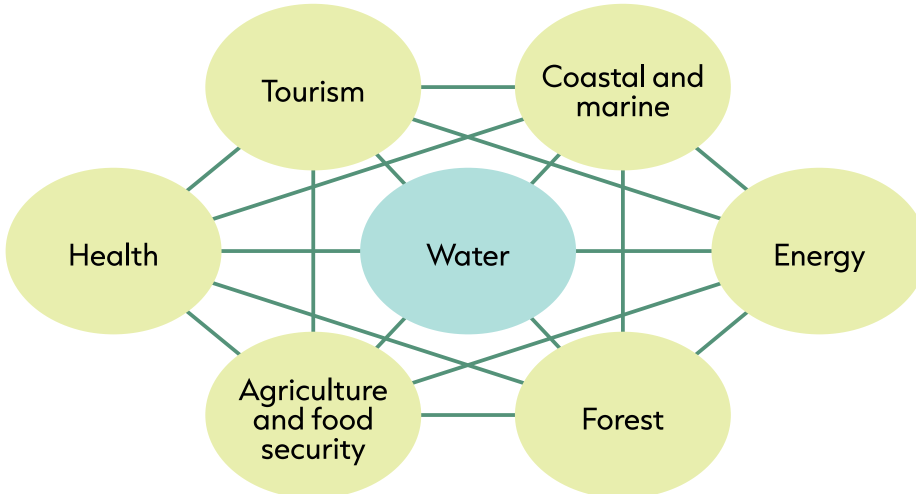


Figure 5.36. *Sectors identified in the CARICOM Regional framework* (Peters and Smith, 2020)

Box 5.24. Grenada Water Stakeholder Platform (G-WaSP)

G-WaSP, a branch of the International Water Stewardship Program, functions through collaborative efforts of Grenadian public, private and community stakeholders. With the support of the German Agency for International Cooperation (GIZ), the platform's focus is water resources management, water risk and water pollution. Its objective is to improve Grenada's water security by targeting the following:

- Flood risks
- Pollution risks
- Risks posed by drinking water supply systems
- User conflict risks

How freshwater interventions can impact other sectors:

As shown in Figure 5.36, water quality impacts many sectors. Some examples of how interventions can impact other sectors are as follows:

- healthy freshwater ecosystems increase the value of ecosystem services that both tourists and residents can enjoy. This also increases the availability of potable water for household and agriculture uses (Box 5.24);
- polluted freshwater creates a 'web' reaction impacting freshwater flora and fauna and depending on the pollutant, can travel up the food chain; and
- polluted waters also ultimately pollute marine and coastal ecosystems. Preventing water pollution is therefore important.

How coastal and marine interventions can impact other sectors:

The effective management of Sargassum influx in specific coastal areas can have positive impacts such as:

- protects sensitive coastal/marine ecosystems and species;
- promotes the delivery of ecosystem services;
- protects human health; and
- protects fishing and tourism activities which are of economic importance to Grenadians

A coordinated, multi-sectoral approach to policies, laws and regulations with a focus on integrating ecosystem services into governance and multisectoral planning, policies and frameworks, would provide a means to improve ecosystem services management. Such a multi-sectoral approach would also address some of the challenges with institutional capacity by promoting interagency coordination, knowledge sharing, and sharing of personnel, technical capacity and equipment, to enable evidence-based and informed decision making.

Problem tree analyses and the subsequent identification of potential solutions for all ecosystems in this chapter clearly demonstrate the potential value of trans-sectoral links, where one activity can result in co-benefits across multiple problems (e.g. agrobiodiversity, on-farm management, habitat degradation, downstream pollution, etc) and multiple sectors (e.g. agriculture, health, energy, finance, tourism) (Boxes 5.23, 5.24, 5.25). Thus, the mainstreaming of ecosystem services across all national policies and plans offers an effective solution to amplify the delivery of these services for the Grenadian population by providing the enabling environment for the development of new ecosystem service-based services, markets and education systems. Operationally, while writing new policies is one option for achieving mainstreaming and may be relevant especially for outdated policies, an alternative cost-effective option may be to amend national policies by adding ecosystem services to relevant objectives.

Box 5.25. Debushing as a socioecological cross-sectoral example

Throughout the Caribbean there is a paradoxical relationship with 'bush'. It is perceived both as having little value, and so in need of cleaning up, whilst also perceived as places of natural beauty (Jaffe 2006); stakeholder opinion suggests this paradox holds true in Grenada. The development of government debushing programmes as a part of road maintenance and as a safety net for providing employment, are widespread throughout the region (Jaffe, 2006; Jeffrey *et al.*, 2013). However, clearing vegetation has many unintended environmental consequences. For example, local communities in Grenada have reported increased flooding due to the loss of vegetation and a related reduction in fish abundance due to increased sedimentation, following debushing (Glasgow *et al.*, 2018).

Roadside vegetation performs important ecosystem functions including:

- contributing to soil stabilisation, air and water pollution control and providing habitat for biodiversity (Fernandes *et al.*, 2018; Deshmukh *et al.*, 2019); and
- contributing to carbon sequestration and thus MEA goals (Fernandes *et al.*, 2018).

Potential solutions to manage roadside vegetation need to take a nature-based solutions (NbS) approach, by using scientifically informed restoration and maintenance of intact vegetation, that then leads to wider ecosystem service benefits. Creating cross-sectoral links e.g. between the debushing and Disaster Risk Reduction and Climate Adaptation programmes, can promote joined-up thinking and achieve holistic solutions, as will increased education of those directing debushing programmes.

While current debushing programmes provide a reliable alternative livelihood for some in Grenada, given that they operate only for short periods and the contribution to overall employment is small (e.g. 6%) (Jeffrey *et al.*, 2013), they do not contribute to sustainable long-term income generation. An alternative approach that may empower individuals to develop sustainable livelihoods that also benefit ecosystem services, could include the redirection of such debushing financial tools towards micro-financing, infrastructure for small business enterprises, training and associated development of transferable life skills. For example, facilitation of activities in the circular economy that address litter management (Box 5.5 on page 349), creating urban greenspaces to improve human health and wellbeing and developing horticultural and agricultural skills. Given that this issue is relevant across the Caribbean, regional knowledge sharing is key to finding solutions to this coupled socio-ecological problem.

5.6. Conclusions

This assessment found that despite a national policy framework for the environment that illustrates good intentions, there remain many opportunities for the people of Grenada to improve and optimise nature's contributions to society. Thus, while some existing policies appear to explicitly affect/regulate ecosystem service use or management, the harmonisation of policy objectives relative to these specific ecosystem services is often lacking (high agreement, high evidence). Grenada currently has many draft national policies and plans that are directly relevant to ecosystem services and biodiversity. The development of such policies represents a significant technical investment in the court's governance and management frameworks. However, the lack of rapid adoption and implementation of such policies greatly undermines and erodes the value of such investments.

Many of the existing and draft national policies and plans will require revisions to include ecosystem services and biodiversity. Such revisions can lead to important improvements in ecosystem service management and increased economic and social well-being of Grenadians. A key step to ensuring mainstreaming of ecosystem services for Grenada is to commission a multisectoral review of all currently approved and draft national policies to ensure that ecosystem services used and affected by those policies are explicitly addressed in those policies. Such a review process should propose specific text for the amended national policies and adopt a programme of work for their drafting and for consideration by the State (high agreement, high evidence).

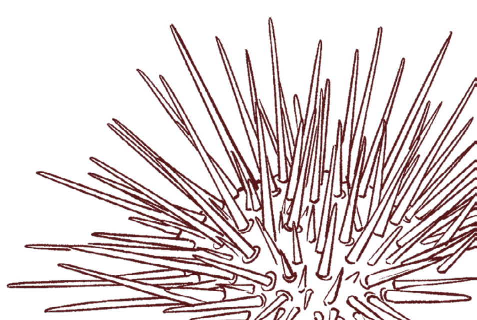
Traditional sectoral planning, budgeting and management of the economy is an accepted norm in national-level governance. However, the recurrent message arising from this chapter's analysis of the policies, plans and programmes relevant to the ecosystem services was that the maximisation of ES can only be achieved by explicitly mainstreaming such services into all national plans, policies and programmes. Current weaknesses in management of ES reported in previous chapters, suggest a lack of meaningful cross-sectoral engagement at the national level. Here key steps are required. The chapter recommends high-level national oversight in implementation and monitoring and evaluation of the activities identified in the NEA. This may involve an explicit Cabinet-level responsibility and/or cross-party parliamentary committee for such coordination. Building a cross-party and Cabinet-level consensus on insulation of institutional frameworks for management of ES, from frequent political disturbance, while at the same time, ensuring accountability and transparency, has been highlighted by stakeholders (Chapter 1) as an important criterion for ensuring a sustainable long-term approach to ES management (high agreement, high evidence).

During NEA stakeholder consultation, a key concern identified was the concern for the focus on high-level decision making vs. grass-roots stakeholder engagement. It is critical here to indicate that these processes should be thought of as parallel and complementary tools for effecting ecosystem services management. Ultimately, the lack of implementation identified throughout the NEA speaks to the failure of silo-based decision making. Given the Westminster-based governance system, the ultimate power for decision making lies in the State. As a result, the implementation of national policy and enactment of legislation, budgeting and personnel allocation are actions only the State can take.

A related issue is the urgent need to redraft and enact national legislation for fisheries, forests, wildlife and waste management to ensure that international obligations (e.g. CITES), co-management tools (e.g. stakeholder led resource management), responsiveness to climate change and the relevant policy-specific decisions, are supported in national law (high agreement, high evidence). Recurrent across all sectors is the need to (re-)invest in human capacity, knowledge generation and monitoring of the state and management of ecosystem services, and monitoring and enforcement of national regulations (high agreement, high evidence).

Priority actions identified cover fundamental issues associated with improvements in land tenure, waste management, misuse of agrochemicals, transparency of decision making at all levels, and stakeholder participation in knowledge-generation, governance and management of ecosystem services (high agreement, high evidence).

A central task is the development and adoption of funding mechanisms to pay for such investments in maximisation of these ecosystem services. The chapter suggests, exploration of PES, implementation of the Environmental Levy, development of green bonds, debt for nature swaps and blue carbon are all worth exploring as means to finance the investments proposed in ecosystem services identified in the chapter (medium agreement, high evidence). Finally, the re-examination of existing taxing and subsidy structures that support business, manufacture, tourism, agriculture, fishing and private forestry, to ensure that these do not lead to perverse incentives (with undesirable results) that encourage waste or externalisation of degradation of ecosystem services are key steps to mainstream ES (high agreement, high evidence). Instead, there should be a transition to NbS and climate-smart practices that support a more circular economy and lead to nature positive benefits for all Grenadians.



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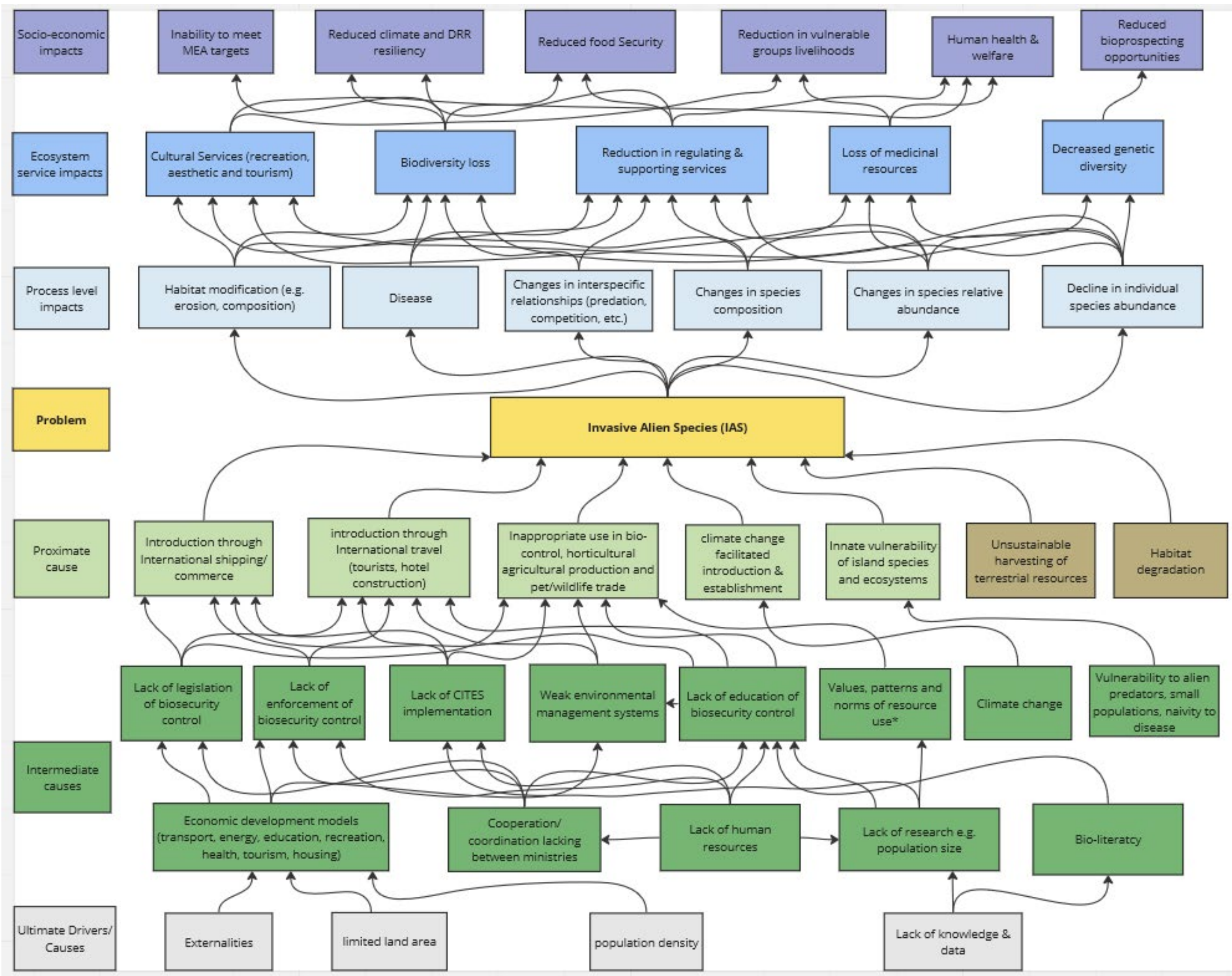
Appendices

Appendix 1. Causal factors and objective tree pertaining to IAS

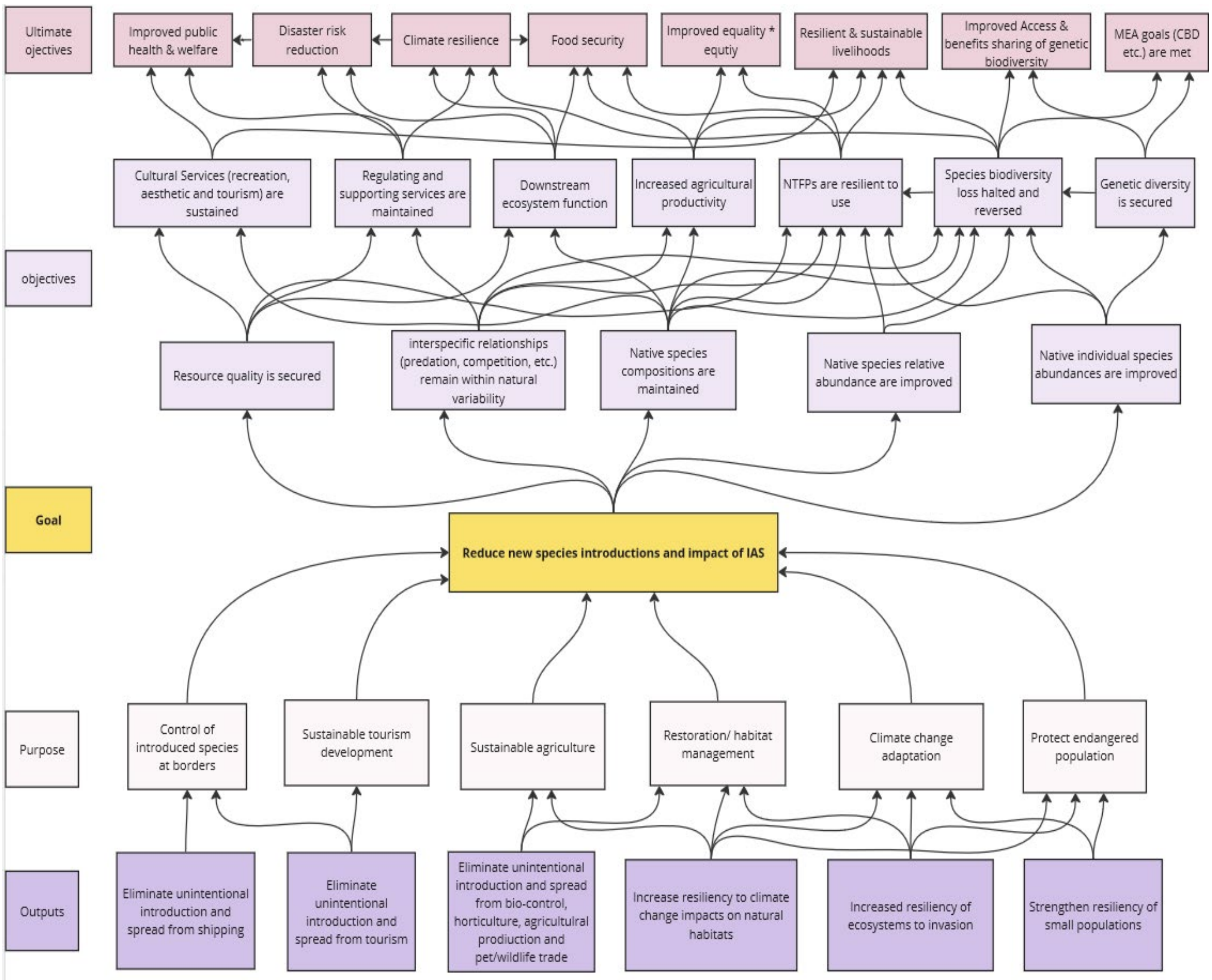


Appendix 1. Figure 1. ***Causal factors leading to IAS and the effects for terrestrial systems.***

Unsustainable harvesting and habitat degradation refer to problem trees in Figures 5.4 and 5.7.

**Externalities include global markets, national debt, trade balances, global financing, global information trends, global tourism trends, conservation finance mechanisms.

*Patterns and norms of resource use refers to public perceptions at the individual level, including of the value of natural spaces, waste elimination function of nature, externalisation of cost to public commons.



Appendix 1. Figure 2. Objectives tree showing outputs, purposes, goals and objectives for responding to terrestrial IAS and improving the delivery of ecosystem services.

Activities (Foundational, Enabling and Instrumental) that map to the outputs are presented in Appendices 2 and 4.

Appendix 2. Analysis of legislation relevant to terrestrial protected areas

Key legislation	Last amendment date	Key points related to Protected Area management	Gaps and potential overlaps
Forest Land Act	1984	• Governor General can proclaim private land as protected forest, including for preservation of health; landowners can be compensated • Private landowners can voluntarily request land be managed by forestry and that provisions of act can be applied to such land (e.g. protection)	• Overlap with Physical Planning Act over declaration of Crown Lands as forest reserves and private lands subject to special protection • No mention in aims of ecosystem services or climate change resilience
National Parks and Protected Areas Act	1991	• Governor General responsible for national parks system; can add to national park any private land leased or purchased by private treaty or donated (but compensation unclear). • National Parks Development Fund provision to fund management. • Regulations provide for a National Parks Advisory Council	• Reasons for declaring protected areas do not include climate change or ecosystem services • National Parks Advisory Council given responsibility for maintenance of national parks; potential for conflict between National Parks Authority and Advisory Council • Not explicit about how existing protected management institutions are to be treated • Not explicit about ecosystem services or climate change
Physical Planning and Development Control Act		• Provides for declaration of environmental protection areas, defined as places of natural beauty or natural interest that are not forest reserves, wildlife sanctuaries, national parks, protected areas, or marine protected areas under any enactment	• Focus mostly on permitting, building standards, EIAs for coastal zone, wetlands, PAs, sensitive environmental areas
National Water and Sewerage Authority Act	1990	• Has authority to declare protected areas, but not those falling under responsibility of Chief Forestry Officer	• Makes no reference to national parks systems and unclear reporting structures for managing watersheds
Draft Environmental Management Act	2005	• Provision for identifying and designating Protected Areas, formulating/implementing management plans and policies/protection for threatened species • Establishment of Environmental Management Agency, Sustainable Development Council. • Overseeing EIA, pollution, knowledge (including establishing database) • Responsible for monitoring environmental changes	• Overlap with protected area designation and management with Forestry and National Parks • No ecosystem services or climate change although focus on integrated environmental management • MEA Committee – overlap in reporting structure with other agencies

Appendix 3. Analysis of gaps in policies, plans and strategies related to terrestrial ecosystem services

Key policies/ plans/strategies	Priority areas relevant for terrestrial ecosystems	Key terrestrial ecosystem service relevant objectives/actions	Gaps
Draft Protected Area, Forestry and Wildlife Legislation 2003	Promote conservation of forestry, wildlife and biodiversity and contribute to social and economic development	Set out national protected area and forest reserve system Provision for joint management of private land as protected areas Establish a Forestry and National Parks Advisory Council	Climate change and ecosystem services not mentioned Limited detail on interconnectedness with agriculture and other sectors Some detail lacking on resolving inter-agency management responsibilities
Draft Grenada Protected Area System Plan 2009	Identification of sites to be considered for designation as protected areas to implement site management	Designate proposed protected areas critical for endangered species and habitats Development strategy for system of protected areas, their assessment and management	Climate change and ecosystem services not mentioned Limited detail on interconnectedness with agriculture and other sectors
National Energy Policy 2011	Pursue environmental sustainability through 'green energy'	Promote sustainability in tourism industry Waste for energy • renewables • environmental levy	Importance of environmental impacts and link with forestry recognised but no mention of ecosystem services Impacts of infrastructure on forested, higher elevation areas or on ecosystem services not recognised in light of hurricanes and vulnerability to climate change impacts
The Food and Nutrition Policy and Plan of Action for Grenada 2013-2018	Promote sustainability of use and management of land and marine resources, sustainable traditional cultural practices and use of natural products	Implement sustainable forest management practices and Forest Policy Promote soil and water conservation Implement environmentally friendly pest and disease control programme Mainstream climate change and disaster risk reduction issues in planning processes	Importance of environment and link with forestry recognised but ecosystem services and biodiversity not explicitly mentioned
Gender Equality Policy and Action Plan (GEPAP) 2014–2024	Integrate gender equality into disaster management, climate change policies and programmes for natural resource development to build a green economy'	Undertake gender impact assessments Gender responsive approaches in utilising, managing and preserving natural resources of Grenada	Importance of environment recognised but ecosystem services and biodiversity not explicit and objectives vague with respect to terrestrial systems

National Agriculture Plan (2015-2030)	Reduce adverse impact on climate change and the environment, ensure development is socially, economically, and environmentally sustainable	Strengthen sector's resilience to climate change and natural disasters and promote development that is socially, economically, and environmentally sustainable	No mention of ecosystem services, but recognition of importance of reducing impact on environment and link with forestry
National Land Policy draft 2016	Sustainable, productive and equitable development, management and use of Grenada's land and natural resources	Establish management agency to coordinate integrated approach to conserve biodiversity, reduce pollution, and support sustainable and environmentally sound social and economic opportunities Support ecosystem-based livelihood and tourism Management of vulnerable land and natural resources to conserve ability to support social and economic benefits for present and future generations	Importance of environment and link with forestry recognised but ecosystem services not explicitly mentioned. Gaps in management of impacts from climate change on ecosystem resilience
National Biodiversity Strategy and Action Plan (2016-2020)	Importance of biodiversity conservation and ecosystem services for enhanced livelihood, national development and poverty reduction.	Mainstream biodiversity in all national development processes to achieve national targets consistent with obligations under the Convention on Biological Diversity	Little specific detail on how objectives restore, amplify and increase resilience of ecosystem services
National Climate Change Policy (2017-2021)	Build climate resilience including for biodiversity and ecosystems	Incentivise renewable energy and energy efficiency Sequester carbon through afforestation/ reforestation activities Restructure Ministry responsible for land, environment and natural resources to oversee and coordinate implementation Establish formal climate change focal points in priority ministries with clear roles and responsibilities to cover themes including forestry, land use planning, physical planning, tourism, water	Importance of environment and link with forestry recognised but ecosystem services not explicitly mentioned States 20% of marine and coastal, but not terrestrial, be protected and sustainably managed by 2021. However, Climate Change Adaptation Plan (2017-2021) includes 20% of terrestrial ecosystems by 2021
National Climate Change Adaptation Plan for Grenada, Carriacou and Petite Martinique (2017-2021)	Improve policy, legal, regulatory and institutional framework to increase resilience of important ecosystems whilst providing livelihood options	Improve availability of ecosystem data and strengthen monitoring of critical ecosystems, with focus on Protected Areas Implement tree planting for improving soil erosion, soil fertility and environment, maintaining biodiversity Participatory mapping to understand and identify key ecosystem services. Increase awareness about ecosystem-based adaptation for sustainable development	Ecosystem services mentioned but little focus. Ecosystem valuation studies proposed for key coastal areas to promote benefits of ecosystem conservation and restoration as a means to reduce vulnerability to climatic hazards, but not proposed for terrestrial systems Very coastal focused.

Revised Forest Policy for Grenada, Carriacou and Petite Martinique 2018	Focus on sustainable forest management to promote ecological resilience	Promote sustainable agriculture practices Strengthen promotion of and support for more efficient water management and conservation (water and soil) measures. Reverse trends of environmental degradation Prevent flooding and soil erosion Ensure environmental management integrated into national development policy framework Empowerment of local communities. Develop and implement climate change adaptation and mitigation approaches	Ecosystem services not explicitly mentioned. Recognition of links with coastal systems but no specific objectives Lacking alignment of institutional arrangements for protected areas to match forest legislation Little specific details for cross-sectoral integration e.g. agriculture and energy sectors Targets and timelines not clearly outlined No strategy for addressing issues associated with climate change Roles and responsibilities are unclear Forest products and services are not thoroughly explored Resources access plan not clearly outlined
National Water Policy 2019	Secure water to maintain, restore and enhance ecosystem services through conservation and protection of ecosystems	Publish annual report on state of ecosystems Scrutinise developments that impact maintenance of healthy ecosystems Minimise water-related climate change risks by adopting ecosystem-based adaptation solutions.	Importance of environment and ecosystems and link with forestry recognised but no mention of biodiversity
(Draft) Grenada Drought Management Plan (2019)	Management of water resource including maintaining health of ecosystems	Forest rehabilitation for degraded forest areas but little detail	Drought (Disaster) Risk refers to ecosystem services but little specific detail
Grenada's Nationally Determined Contribution (NDC) 2020	Manage ecosystems and forest resources to enhance climate change resilience and conserve species and genetic diversity through reducing greenhouse gas emissions	Update and review Protected Area legislation to incorporate climate change along with expanded and effective management of Protected Areas Implement Vegetation Management Plan to reduce soil erosion, increasing climate resilience Develop national long-term data collection framework	Importance of forestry recognised but little detail and ecosystem services and biodiversity not explicit
National Sustainable Development Plan 2020-2035 Grenada	Protect and restore water-related ecosystems, including mountains, forests	Ecosystem restoration and water-system reinforcement targeting the watersheds associated with urban areas Encourage and incentivise private sector to continue and develop approaches to upscale ecosystem-based services	Emphasis on value-added agricultural production, climate-smart agriculture Forestry/environment responsibility not recognised and no recognition of NTFP livelihoods No recognition of ecosystem services.

Medium-Term Action Plan (MTAP) Programme of Action for Economic Recovery, Transformation and Resilience 2022 – 2024	Boost economic, social and environmental contribution of the agriculture and fisheries sector; tourism	Increase health and wellness of citizens; foster culture of evidence-based decision making Improve climate resilience, mainstream adaptation and invest in climate resilience and environmental protection Mainstream climate-smart agriculture; rehabilitate wetlands and forests (no details)	Little focus and detail about environment and ecosystem services and biodiversity not explicitly mentioned. Objective to unleash potential of blue and orange economies but not green economy Environmental protection very focused on Marine Protected Areas, little emphasis on terrestrial systems

Appendix 4. Potential activities

Table 1. Potential activities related to the enabling environment as a response to managing habitat degradation, overexploitation and invasive alien species in terrestrial ecosystems in order to improve ecosystem service delivery (outputs in columns map to outputs in objective trees).

	Habitat degradation											Overexploitation									IAS					
Activity	Livelihoods	Restoration	PA management	Resiliency externality	Systems management	Wildfires enforcement	Pollution enforcement	Land conversion	SLM	Sector integration	Values/norms	Restoration	Bioliteracy	Livelihoods	Sector integration	Systems management	Values/norms	NTFP enforcement	Land conversion	SLM	Shipping IAS	Tourism IAS	Agri hort pet IAS	IAS climate resiliency	IAS species resiliency	IAS ecosystem resiliency
Behaviour change projects in SLM		X	X		X	X	X	X	X	X	X	X	X		X		X	X	X	X			X	X	X	X
Training enforcement			X		X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X			
Expansion of EbA		X	X		X			X	X	X	X	X			X	X	X		X	X				X	X	X
Detection, data sharing and enforcement			X		X	X	X	X	X	X	X				X	X		X	X	X	X	X	X			
NTFP cooperative	X			X	X				X	X	X		X	X	X	X	X		X	X			X			
Fire detection and notification			X		X	X		X	X	X		X			X	X			X	X				X	X	X
Human resources (HR) for NTFP enforcement			X		X			X	X				X		X	X		X	X	X				X		X
Integrated pest management					X			X	X		X					X			X	X			X	X	X	X
Stakeholder mobilised for habitat restoration		X	X								X	X				X	X			X				X	X	X
HR needs for NTFP management	X				X						X	X				X		X								
Diversification of NTPFs	X				X				X	X				X	X					X						
HR needs for PA management			X																							
Green economy enabling policy	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Implement Environmental Management Act	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Implement Land Use Policy	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Integrate ecosystem services in policy and planning	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cross-sectoral cabinet integration	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X			
Strengthen public participation	X	X	X		X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X			
New NBSAP	X	X	X		X	X	X	X	X	X	X	X			X	X			X	X	X	X	X	X	X	X
Harmonise PA policy and legislation		X	X		X	X	X	X	X	X	X	X	X		X	X	X	X	X	X				X	X	X
Enable PES policy	X	X	X	X	X			X	X	X	X	X		X	X	X	X		X	X				X	X	X
Strengthening EIA process			X		X	X	X	X	X	X					X	X			X	X	X	X	X	X	X	X
Improved solid waste management		X	X			X	X		X	X	X	X			X		X				X					
Resolve insecure land tenure	X				X			X	X	X					X		X		X	X						
PPP opportunities for PA management	X	X	X						X			X		X						X						
Implement CITES	X		X							X								X			X	X	X			

Activity	Habitat degradation											Overexploitation									IAS					
	Livelihoods	Restoration	PA management	Resiliency externality	Systems management	Wildfires enforcement	Pollution enforcement	Land conversion	SLM	Sector integration	Values/norms	Restoration	Bioliteracy	Livelihoods	Sector integration	Systems management	Values/norms	NTFP enforcement	Land conversion	SLM	Shipping IAS	Tourism IAS	Agri hort pet IAS	IAS climate resiliency	IAS species resiliency	IAS ecosystem resiliency
Ratify Nagoya Protocol	X								X		X			X		X	X	X	X	X						
Ratify Escazu Agreement					X				X		X				X	X	X		X	X						
Ratify Convention on Migratory Species			X								X	X				X	X	X	X	X				X	X	X
Agriculture/horticulture/pets IAS																										

Table 2. Potential activities related to the instrumental environment (financial, technical and practice) as a response to managing habitat degradation, overexploitation and invasive alien species in terrestrial ecosystems in order to improve ecosystem service delivery (outputs in columns map to outputs in objective trees).

Activity	Habitat degradation											Overexploitation									IAS					
	Livelihoods	Restoration	PA management	Resiliency externality	Systems management	Wildfires enforcement	Pollution enforcement	Land conversion	SLM	Sector integration	Values/norms	Restoration	Bioliteracy	Livelihoods	Sector integration	Systems management	Values/norms	NTFP enforcement	Land conversion	SLM	Shipping IAS	Tourism IAS	Agri hort pet IAS	IAS climate resiliency	IAS species resiliency	IAS ecosystem resiliency
Climate-smart agriculture	X	X	X		X	X		X	X		X	X	X				X		X	X				X	X	X
Best practices for habitat restoration		X	X		X			X	X	X	X	X			X	X	X		X	X				X	X	X
Monitoring and warning for IAS		X	X						X	X		X			X	X				X	X	X	X	X	X	X
Predator-proof fencing for IAS for PAs		X	X		X			X	X			X							X	X		X	X	X	X	X
Best practices for sustainability in construction sector			X				X		X	X	X				X		X	X		X		X				
Habitat assessment and prioritisation for restoration		X	X						X			X							X	X				X	X	X
Replanting invasives with native species		X	X						X			X								X				X	X	X
Invasive species action plan																						X	X	X	X	X
Establish ex situ populations of endangered species			X																					X	X	
Budgetary allocations to mainstream ecosystem services	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Strengthen Green Fund	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Green bonds		X	X	X	X			X	X	X		X		X	X	X			X	X				X	X	X
Insurance schemes disaster		X	X	X	X			X	X	X		X		X	X	X			X	X				X	X	X

Activity	Habitat degradation											Overexploitation									IAS					
	Livelihoods	Restoration	PA management	Resiliency externality	Systems management	Wildfires enforcement	Pollution enforcement	Land conversion	SLM	Sector integration	Values/norms	Restoration	Bioliteracy	Livelihoods	Sector integration	Systems management	Values/norms	NTFP enforcement	Land conversion	SLM	Shipping IAS	Tourism IAS	Agri hort pet IAS	IAS climate resiliency	IAS species resiliency	IAS ecosystem resiliency
Incentive and disincentives for grazing behaviour	X	X	X		X			X	X		X	X	X				X		X	X				X	X	X
Incentives and disincentives for pollution behaviour		X	X		X		X	X	X		X	X	X				X		X	X				X	X	X
Strengthen Environmental Levy		X	X	X	X		X	X	X	X		X			X	X				X	X	X	X			
Enable National Parks Development Fund		X	X	X	X				X	X		X			X	X				X				X	X	X
Remove perverse subsidies			X		X			X	X	X	X				X		X		X	X				X	X	X
National regional finance mechanism instrument				X	X				X	X					X	X				X	X	X	X			
Financial resources, loans, microfinancing	X				X			X	X		X			X			X		X	X						
Agriculture/horticulture/pets IAS																										

Table 3. Potential activities related to knowledge access, generation and sharing as a response to managing habitat degradation, overexploitation and invasive alien species in terrestrial ecosystems in order to improve ecosystem service delivery (outputs in columns map to outputs in objective trees).

Activity	Habitat degradation											Overexploitation									IAS					
	Livelihoods	Restoration	PA management	Resiliency externality	Systems management	Wildfires enforcement	Pollution enforcement	Land conversion	SLM	Sector integration	Values/norms	Restoration	Bioliteracy	Livelihoods	Sector integration	Systems management	Values/norms	NTFP enforcement	Land conversion	SLM	Shipping IAS	Tourism IAS	Agri hort pet IAS	IAS climate resiliency	IAS species resiliency	IAS ecosystem resiliency
Long-term ecological, climate, socioecological monitoring	X	X	X		X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Local/national/regional action learning group	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Open data sharing programme		X	X		X	X	X		X	X		X	X		X	X		X		X	X	X	X	X	X	X
Education programme for farmers	X	X	X		X	X	X	X	X		X	X	X	X		X	X	X	X	X			X			
Fire education awareness		X	X		X	X		X	X	X	X	X	X		X		X	X	X	X				X	X	X
KAP natural resources enforcement BES		X	X		X	X	X	X	X	X	X	X	X		X	X	X	X	X	X						
Data synergies on IAS, climate change and disease threats	X	X	X		X			X	X			X				X			X	X	X	X	X	X	X	X
KAP valuation NTFP livelihoods	X	X	X		X			X	X		X	X	X	X	X	X	X	X	X	X						

Activity	Habitat degradation											Overexploitation									IAS					
	Livelihoods	Restoration	PA management	Resiliency externality	Systems management	Wildfires enforcement	Pollution enforcement	Land conversion	SLM	Sector integration	Values/norms	Restoration	Bioliteracy	Livelihoods	Sector integration	Systems management	Values/norms	NTFP enforcement	Land conversion	SLM	Shipping IAS	Tourism IAS	Agri hort pet IAS	IAS climate resiliency	IAS species resiliency	IAS ecosystem resiliency
KAP values fire use impact		X	X		X	X		X	X		X	X					X	X	X	X				X	X	X
Education pollution terrestrial		X	X				X	X	X		X	X	X				X		X	X				X	X	X
Data on impacts of IAS on native species		X	X		X			X	X			X					X		X	X			X	X	X	X
KAP survey on public awareness on IAS spread impact			X						X		X		X				X			X	X	X	X	X	X	X
KAP survey on PES	X	X	X		X			X	X		X	X		X			X		X	X						
Baseline surveys on PAs ecology and ecosystem services	X	X	X		X				X			X				X				X				X	X	X
Baseline surveys on NTFP ecology and ecosystem services	X		X		X							X			X	X				X				X	X	X
Data on IAS and plant carbon storage	X	X	X		X			X	X			X								X				X		X
KAP survey on value of IAS	X	X	X						X		X					X	X			X			X			
NTFP management capacity survey of agencies			X		X				X	X					X	X		X	X	X						
NTFP education awareness	X				X				X		X		X	X			X	X		X						
Value chain assessment of NTFPs	X	X	X		X						X		X	X			X	X								
Impact of IAS on genetic resources	X		X		X																			X	X	X
Education for border agency and customs													X		X						X	X	X			
Education awareness for tourists													X				X	X			X	X				
Assess risk of introduced species becoming IAS																					X	X	X			
Agriculture/horticulture/pets IAS																										

Appendix 5. List of agencies/ministries, responsibilities, related laws/regulations, relevant to water management

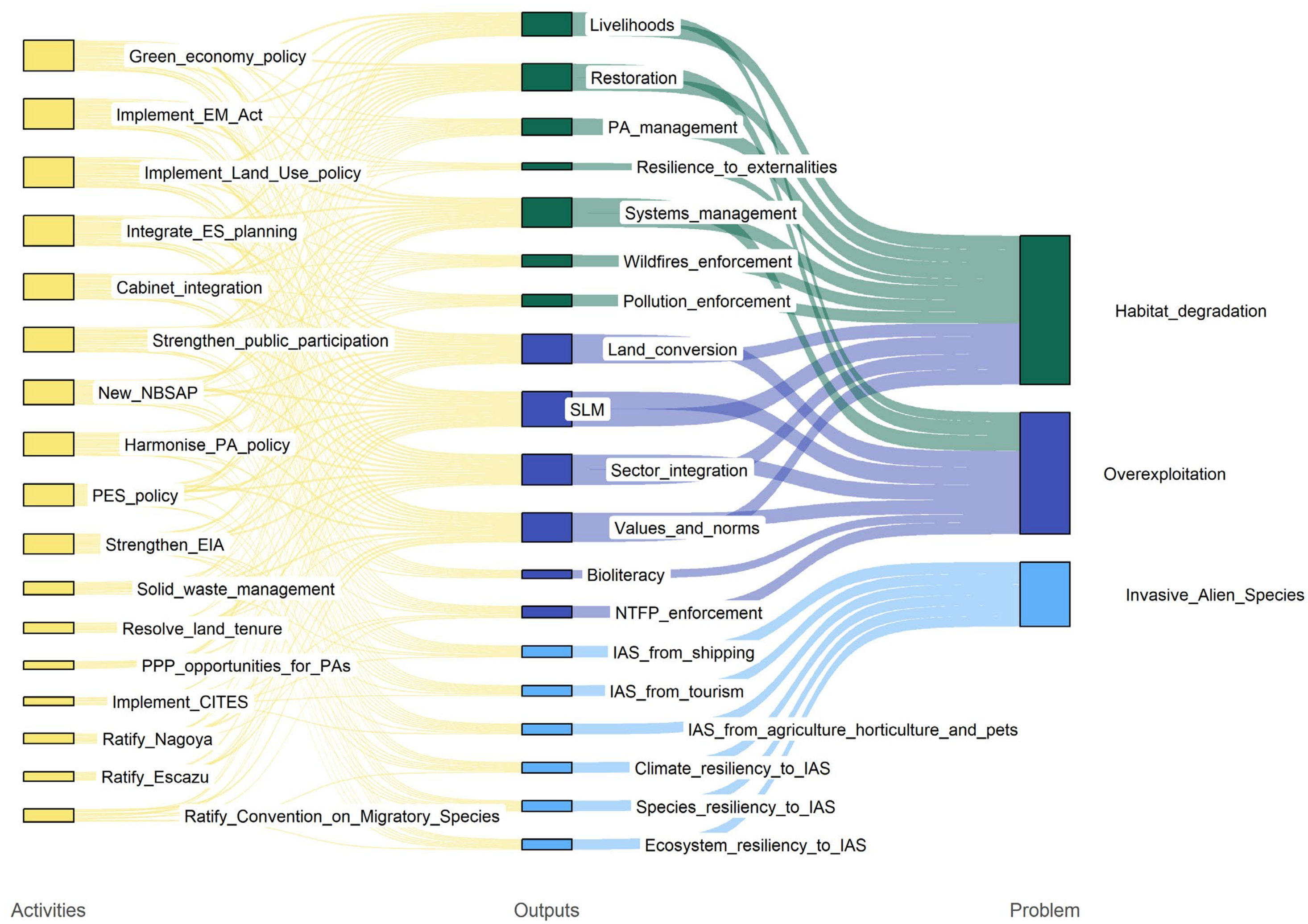
Agencies/Divisions	Water-related responsibilities	Legislation/Law
National Water and Sewage Authority (NAWASA) Statutory body	• Full authority over all surface and underground water • Monitor water quality and make recommendations for improvement, conservation, preservation and utilisation • Monitor consumption and demand rates, project future supply and demand • Determines rates and charges for water and sewage and other services or facilities provided by the Authority • Determine sewage disposal needs and make recommendations for the maintenance, improvement and provision of additional facilities • Provide a satisfactory supply of potable water for domestic, agricultural, industrial and commercial uses • Provides for the management and protection of catchment areas	*NAWASA Act (1990) and Amendments (1991 and 1993), NAWASA, Cap. 208* *Grenada National Water Policy 2020*
Ministry of Health, Wellness and Religious Affairs	• Oversight and audit functions of NAWASA to ensure compliance with water quality regulation and the control of pollution to the freshwater and marine environment • Develop and implement water quality standards and regulations covering drinking water quality and effluent standards • Develop rules and standards governing wastewater reuse and augmentation • Enforce quality and effluent standards, the requirement for the submission of remedial action and implementation plans, and the imposition of penalties in the event of on-going breaches (GoG, 2019)	Envisioned *Water Resources, Supply and Sewerage Act*
Planning and Development Authority Statutory body	• Regulate land use • Require developers to submit EIA for various types of development projects • Require the preparation of a physical plan for the whole of Grenada, with land allocations for prescribed purposes including protection of coastal zones, special resources and use areas, controlling the disposal of sewage and the pollution of water bodies	*Physical Planning and Development Control Act 23 (2016)*
Land Use Division Ministry of Economic Development, Planning, Tourism, ICT, Creative Economy, Agriculture and Lands, Fisheries and Cooperatives	• Regulate the development, management and use of state-owned land • Management of forest resources • Planning and zoning of agricultural lands • Conduct hydrological studies • Mapping and soil surveys (Krishnarayan, 2002; Zhongming *et al.*, 2012)	*LDC Act (1968 and Amendments (1983);* *Land Development Regulations SRO No.13 (1988)*

Agencies/Divisions	Water-related responsibilities	Legislation/Law
Pest Management Unit Ministry of Economic Development, Planning, Tourism, ICT, Creative Economy, Agriculture and Lands, Fisheries and Cooperatives within the Agriculture Division	• Governs the manufacture, packaging, importation, sale and use of particular pesticides or classes of pesticides. • Control the use of pesticides • Set the conditions under which pesticides are to be stored, labelled, and disposed of • Require the keeping and inspection of records, with respect to pesticides • Prescribe standards for the composition and the manner of application of pesticides • Power controls advising farmers on approaches and methods for pest management (with an emphasis on integrated pest management) • Establishes the Pesticides Control Board mandated to advise the Minister on matters relevant use, importation, manufacturing, storage of pesticides. However there is no management unit to support the activities of the board (review of very toxic pesticides currently registered)	*Pesticides Control Act, Cap. 238 (1972) amendment 1979*
Forests and National Parks Department Ministry of Economic Development, Planning, Tourism, ICT, Creative Economy, Agriculture and Lands, Fisheries and Cooperatives within the Agriculture Division	• Manage forest reserves, national parks and government-owned lands • Manage forest resources above abstraction points • Manage plantations (Krishnarayan, 2002; Zhongming *et al.*, 2012),	*Forest, Soil and Water Conservation Ordinance Cap. 129 (1949) Amendments (1984);* *Crown Lands Forest Produce Rules (1956);* *Protected Forest Rules (SRO No. 87, 1952;* *Forest, Soil and Water Conservation Act, Cap. 116*
	• Designate and maintain national parks and protected areas • Protect and preserve environmentally sensitive area	*National Parks and Protected Areas Act Cap. 206(1990)*
	• Governs the use of lands at the Grand Etang Forest Reserve for public purposes and forest conservation and promotion of rainfall and water supply of Grenada	*Grand Etang Forest Reserve Act, Cap. 124 (1906)*
Environmental Health Department Division of the Ministry of Health, Wellness and Religious Affairs	• Regulate the management and disposal of solid and liquid waste • Monitor the quality of water • Protection of water resources (Krishnarayan 2002; Zhongming *et al.*, 2012)	*Public Health Ordinance Cap. 237 (1925), amendments, SRO 218 (1957)* *Public Health Act, Cap. 263 SRO 44 (2006)*
Grenada Bureau of Standards Statutory Body	• Make recommendations for science and technology on national policy and plan • Plans and evaluate scientific and technological projects, programmes and aspects of programmes • Directs standardisation and quality control policies at the national level	*Standards Act No. 6 (1989)*

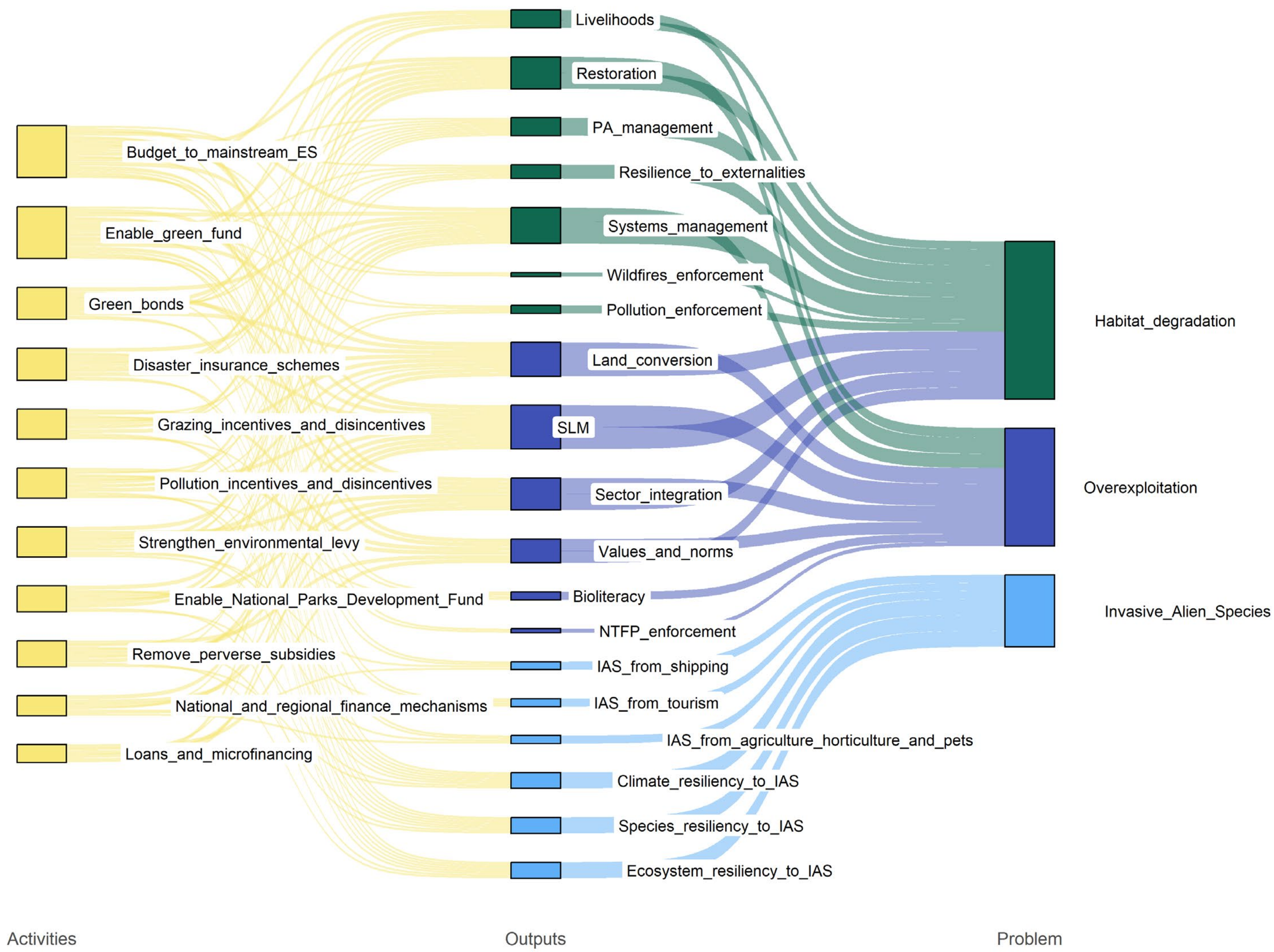
Agencies/Divisions	Water-related responsibilities	Legislation/Law
National Science and Technology Council	• Practices, and with due regard to ecological and environmental factors. make recommendations to the Government on a national policy and plan for science and technology • Establish the process of science and technology planning and to guide activity throughout all its stages paying special attention to the compatible transfer of technology from all parts of the world and the further development and stimulation of indigenous technology; • Coordinate and monitor scientific and technological projects; • Initiate and evaluate scientific and technological projects, programmes and aspects of programmes;	*Science and Technology Council Act Cap 298(1982)*
Grenada Solid Waste Management Authority (GSWMA) Statutory Body	• Develop the solid waste management facilities, services and other resources with due regard to ecological and environmental factors	*Grenada Solid Waste Management Authority Act, Cap. 131A*
	• Provide for the management of waste in conformity with the best environmental practices • Governs unauthorised disposal of waste in national parks or protected areas; prohibition on the importation of waste; waste storage requirements; industrial and commercial waste generation; and management and storage of used oil	*Waste Management Act, Cap. 334A*
Sanitary Authority	• Governs all matters related to the quality of water intended for human consumption	*Water Quality Act, Cap. 334B*
Public Utilities Regulatory Commission Statutory Body	• Coordinates, multi-sectoral, policy level planning for water sector • Provide policy-level support for water related emergencies such as natural hazards and disasters, water security, compliance with national, regional and international agreements and conventions • Provides policy-level oversight of the proposed WRMU • Set, monitor and report annually, the standards of service provided to customers • Delegate functions and duties to other regulatory agencies • Ensures justifiable levels of tariffs for water and wastewater are set (GoG 2019)	*Public Utilities Regulatory Commission Act, 2016 ('PURC Act')*
Ministry of Finance	• Conserve and prevent petroleum and other natural resources • Allows for prevention and control of, and compensation for, pollution by controlling the flow, and preventing the escape, of petroleum, water, gases (other than petroleum) and other noxious or deleterious matters (including drilling fluid or a mixture of drilling fluid and water or any other matter)	*Petroleum and Natural Gas Deposit Act (1989) Amended 2007* *Act No. 22 of 1989 amended by Act No. 31 of 2007.]*
Upland Watershed Management Unit	• Facilitate and coordinate the management of watersheds through the involvement and participation of stakeholders (Krishnarayan, 2002)	
Minor Spices Cooperative Marketing Society	• Encourage and support good soil and water conservation practices (Krishnarayan, 2002)	
Agency for Rural Transformation (ART)	• Drives sustainable development using rural community advocacy initiative (Krishnarayan, 2002)	

Agencies/Divisions	Water-related responsibilities	Legislation/Law
Grenada Community Development Agency (GRENCODA)	• Encourages sustainable development practices among small farmers, women and youth through rural development initiatives (Krishnarayan 2002)	
Water Resources Management Unit (WRMU)	• Overall management of Grenada's water resources (surface water, ground water, stored municipal supplies, estuarine waters) • Establish, analyse, assess and monitor the status of national water resources on a routine basis, and identify the available resources and their potential sustainable yields • Work to ensure the protection, efficient and sustainable use of water resources by coordinating with communities, water resource providers and other stakeholders. • Develop a permit system for the allocation of access rights to the use of water resources, • Develop standards, regulations and guidelines governing the management of water resources • Design and deliver public education and awareness programmes on water resources management (GoG, 2019)	

Appendix 6. Synergies to address terrestrial objectives

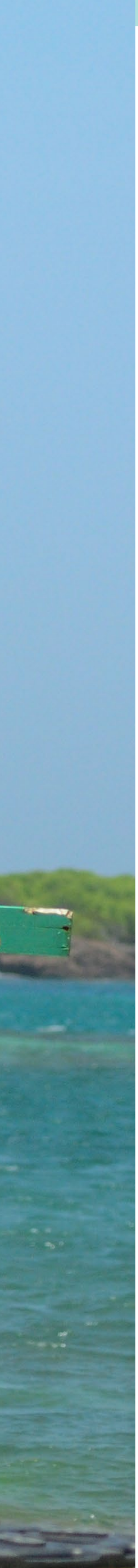


*Appendix 6. Figure 1. **Synergies between enabling policy response activities and outputs to address terrestrial objectives.***
Lines between activities (left column), objective tree outputs (middle column) and objective tree problem (right column) illustrate how individual enabling policy activities map to multiple objective tree outputs. These outputs overlap between the objective trees habitat degradation (Figure 5.8), overexploitation (Figure 5.9) and IAS (Appendix 1). Activities with a greater number of lines are indicative of impacting a greater number of outputs. For the full list of activities see Appendix 4.

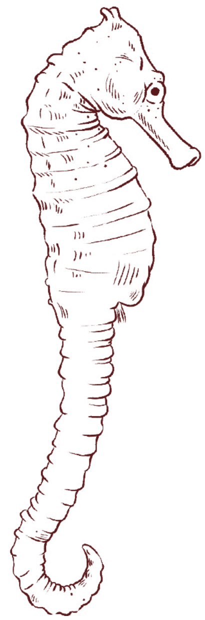


Appendix 6. Figure 2. Synergies between finance instrument response activities and outputs to address terrestrial objectives.
Lines between activities (left column), objective tree outputs (middle column) and objective tree problem (right column) illustrate how individual finance instrument activities map to multiple objective tree outputs. These outputs overlap between the objective trees habitat degradation (Figure 5.8), overexploitation (Figure 5.9) and IAS (Appendix 1). Activities with a greater number of lines are indicative of impacting a greater number of outputs. For the full list of activities see Appendix 4.

Hog Island, Grenada
Photo credit: Quincy Augustine



6. Scenarios and pathways to a sustainable future



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Summary

"Scenarios are stories. They are works of art, rather than scientific analyses. The reliability of their content is less important than the types of conversations and decisions they spark."
(de Geus, 2002, p.30)

This chapter on scenarios is a bridge between the previous chapters' detailed analyses of the current state of Grenada's ecosystems and their future challenges. Here, we explore the question: what future does Grenada want for its biodiversity and ecosystems? The future scenarios developed in this chapter demonstrate that choices made today have long-term implications. They aim to provide food for thought for all Grenadians whether leaders, policy makers, business people or ordinary citizens to help them make informed decisions about the future they want.

We present three scenarios of what Grenada could look like in 2050 to illustrate how different pathways could lead to very different outcomes for ecosystems. These scenarios are not predictions about the future. Rather, they provide the means to explore the uncertainties around the trends and developments identified in earlier chapters and how they might affect future outcomes. They are primarily intended to provide information to help develop policies that would support biodiversity and ecosystems.

Chapter Structure

The chapter's scenarios tell stories about how trends, policies and actions might affect ecosystems and biodiversity. Section 6.1 sets out the value of using scenarios, followed by an explanation of how the scenarios were developed (Section 6.2). The three scenarios are described in Section 6.3. In the central part of the chapter, we evaluate the drivers of biodiversity and ecosystem changes (Section 6.4) and provide a rationale for the drivers and changes. We also discuss how the future might play out under each scenario in terms of biodiversity and ecosystems (Section 6.5) and the resulting changes in ecological goods and services (Section 6.6). Section 6.7 provides an overview of wild card events, and Section 6.8 summarises the most important knowledge gaps and avenues for future research.

Section 6.9 aims to help readers think about the necessary requirements to build a sustainable pathway to a future that supports ecosystems and biodiversity. The section embraces the notion that proactive action and innovation are necessary; developing a vibrant and equitable economy underpins actions needed to protect biodiversity and ecosystems. The section also presents options that could be utilised to build a pathway to a preferred future. Finally, in Section 6.10, we provide a concluding discussion that suggests a way forward to an ecologically-rich 2050.

6.1. Introduction to scenarios

6.1.1. Why use scenarios

The use of scenarios to inform decision making dates back to the 1950s, when the RAND Corporation (a US global policy thinktank and research institute) wanted to build on the advances in military planning developed during the second world war. Interest in the use of scenarios continued with notable developments in the 1970s. Examples include The Limits to Growth modelling study by the Club of Rome (Meadows, 1972) and Royal Dutch Shell's work on the future of oil, which prefigured the oil crisis of 1973 to 1974 (Schoemaker, 2022). Between 1991 and 1992, the Republic of South Africa used scenarios to 'reverse engineer' the decisions that needed to be taken to achieve a peaceful transition to democracy in the country (Schoemaker, 2022). Other examples of the use of scenarios include the following: the Millennium Ecosystems Assessment (MA) global scenarios (MA, 2005); the Representative Concentration Pathways (RCP) (van Vuuren *et al.*, 2011) adopted by the Intergovernmental Panel on Climate Change (IPCC); the Shared Socioeconomic Pathways (Riahi *et al.*, 2017); and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) Natures Futures Framework (Pereira *et al.*, 2020).

Scenarios provide a systematic approach to informing present-day decisions that affect future outcomes. They are a structured and orderly way of generating ideas about the future to anticipate and better prepare for change (Godet, 2006). Scenarios are explorations of different plausible futures, and the opportunities and challenges they could present. The objective, as stated earlier, is not to accurately predict the future but to expand and reframe the range of plausible developments and potential outcomes. In proposing alternative pathways, inherent uncertainty can be accommodated.

Scenarios can be used when the future is uncertain and unpredictable, when there are multiple possible futures and when a longer-term perspective is needed. Time horizons can be up to 50 years or longer, depending on the focus. Both qualitative and quantitative methods can be used to inform the development of the scenarios. Good scenarios are based on the analysis of change factors and allow critical uncertainties to be identified. They represent alternative possible outcomes and, as indicated in Figure 6.1, they can take on different forms.

6.1.2. Scenario types

It is generally accepted that there are four scenario types, whose characteristics are summarised in Figure 6.2:

- Target-seeking (backcasting) scenarios
- Exploratory scenarios
- Ex-ante scenarios (policy screening scenarios)
- Ex-post scenarios (retrospective policy assessment)

In the development of this chapter, only the first two approaches were deemed appropriate. The target-seeking approach, illustrated in Figure 6.3, imagines an idealised future state and the challenge is to develop alternative pathways to reach that end

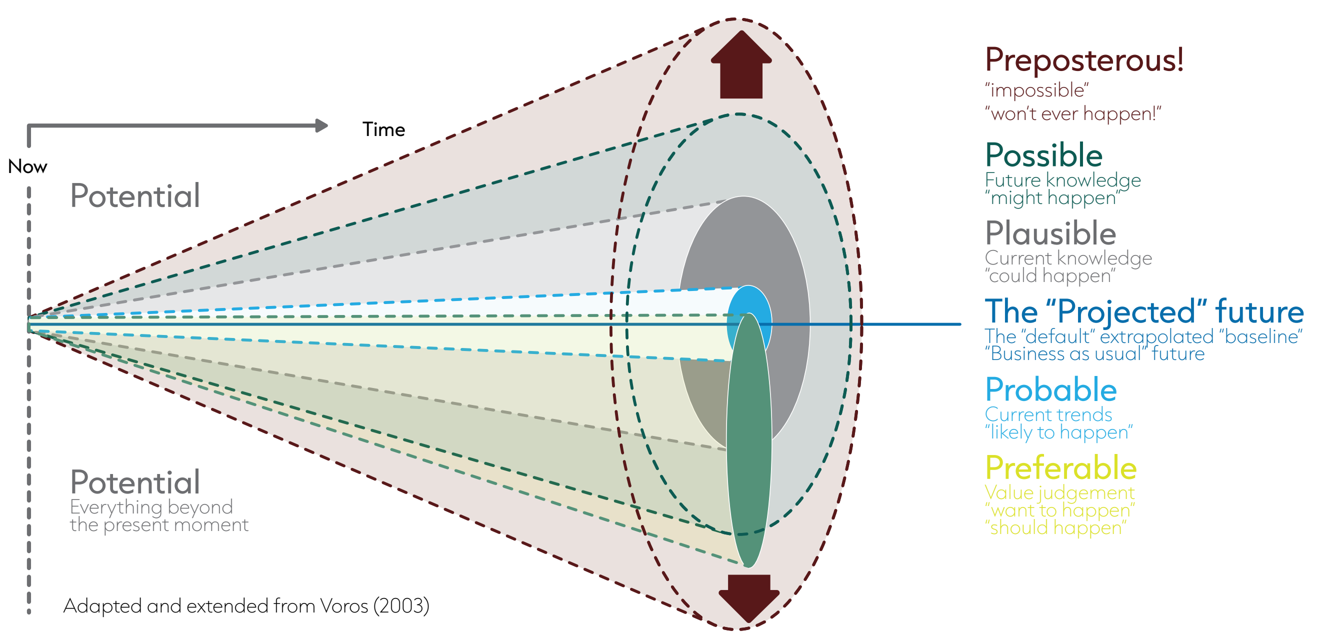


Figure 6.1. Potential alternative futures (Voros, 2003)

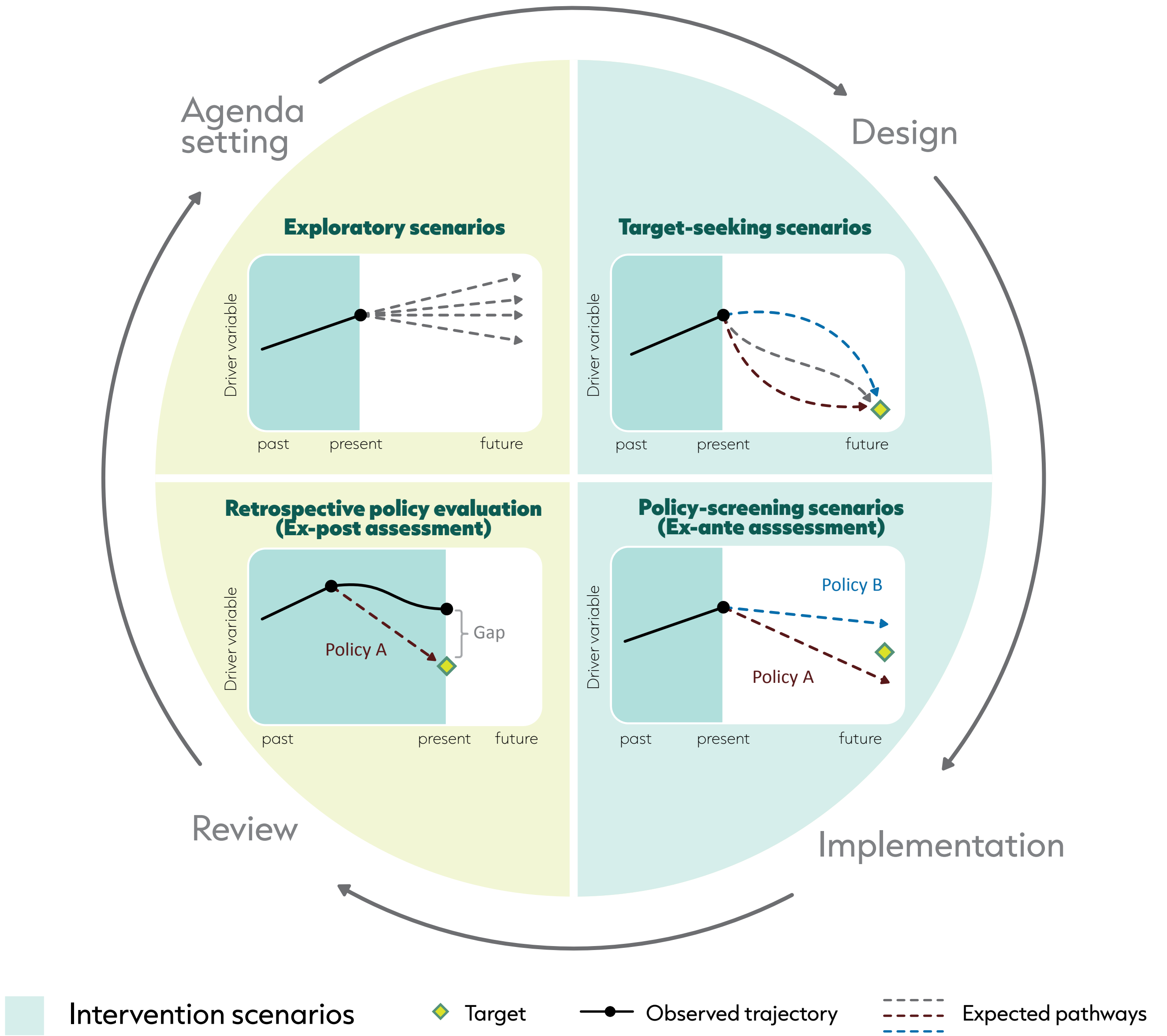


Figure 6.2. Scenario types (Ferrier et al., 2016)

state. The question then becomes: what actions and interventions would be necessary to transition from a current state to achieve a desired future state? The exploratory approach of Figure 6.4 assumes that there are several future states, and each is equally possible, depending on how change factors (drivers and trends) and uncertainties play out over time.

We eventually decided to adopt the exploratory approach to scenario building (IPBES, 2023) as it offers several advantages. It raises awareness of future policy challenges and is applicable where there are alternative policy responses. It incorporates qualitative and quantitative components, often combined with participatory approaches involving stakeholders. It provides a flexible approach to the construction of storylines covering a wide range of possible outcomes.

An important consideration was deciding on an appropriate time horizon for the scenarios. Ideally, the horizon should be sufficiently far into the future

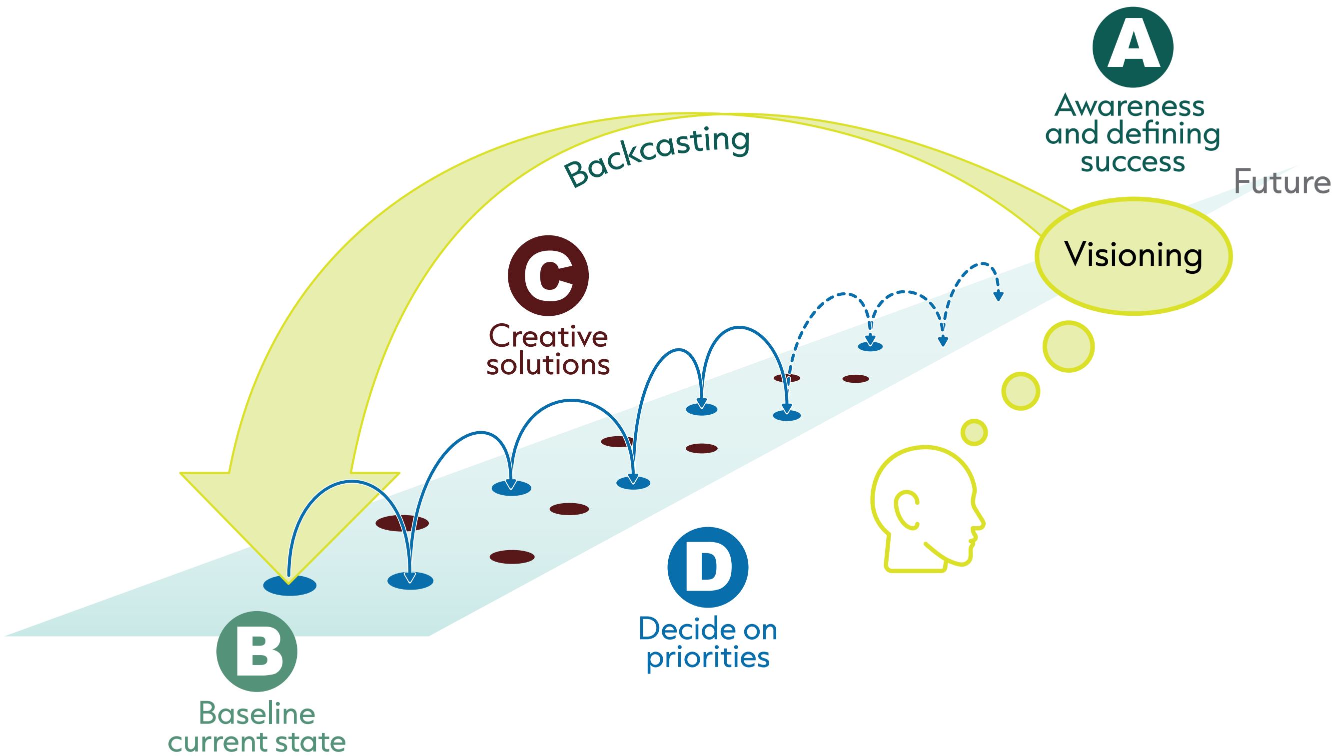


Figure 6.3. *Backcasting scenarios* *(Source: The Natural Step)*

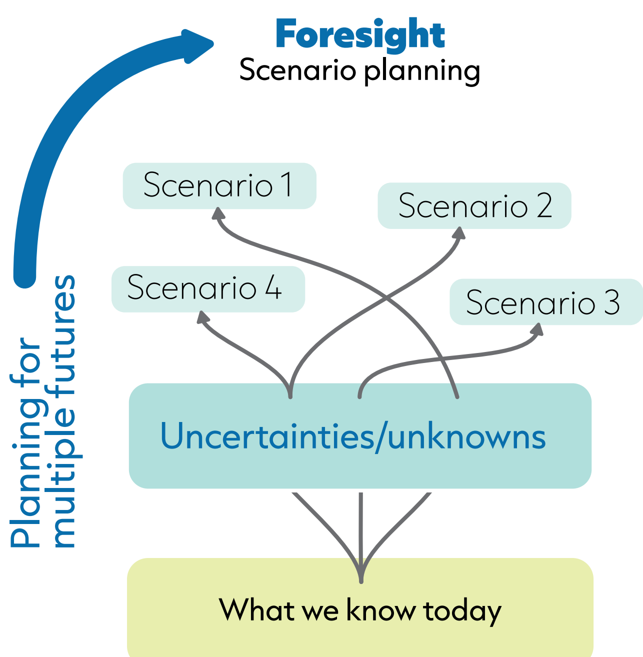


Figure 6.4. *Exploratory scenarios* *(Future Station, 2023)*

to allow the effects of the driving forces to be realised but not so far as to introduce an unacceptable level of uncertainty with respect to outcomes. Two horizons were proposed: a 30- and 50-year horizon. After deliberation among stakeholders, a decision was made to adopt a 30-year horizon, with 2050 as the end time period.

6.1.3. Need for national scenarios

There are many examples of scenarios that have been developed that take a global or regional perspective on a particular subject. While some of the existing scenario work does address the future of ecosystem services, this has not been done systematically for the Caribbean region. The development of scenarios and pathways for Grenada has been informed by previous global and regional work. However, it is important that the scenarios reflect the status, drivers and trends that specifically relate to Grenada's ecosystems and the services they provide.

6.1.4. Framing the future – the chapter's key theme

Following deliberations among the chapter team members and discussions with stakeholders, the following framing question for the chapter was agreed upon:

What could be the status and contribution of biodiversity and ecosystem services to the economy and social well-being of Grenada by 2050, in this scenario?

This question was used to focus the purpose of developing the scenarios and to guide the deliberations. It incorporates the time horizon and links ecosystem services to the economy and social well-being. The focus of the scenarios is firmly on ecosystem services and their functionality under contrasting scenarios.

6.2. Scenarios development process

This section discusses the use of scenario archetypes and matrix methods in developing future scenarios. It highlights the importance of these tools in understanding the potential impacts of different driving forces on various systems. The section also describes the development of the Grenada-specific scenarios through a process of stakeholder engagement and expert elicitation.

6.2.1. Introduction to scenario archetypes

The use of archetypes was developed by Dator at the University of Hawai'i at Mānoa (Bezold, 2009). The methodology uses four generic futures, and the development goes through four main steps: first, identifying the driving forces of change affecting the future; second, determining the direction of the driving forces; third, interpreting the behaviour of the driving forces in four predetermined archetypal futures–Continued Growth, Collapse, Discipline and Transformation; finally, writing scenario narratives based on the interpretation for the archetype. The scenario archetypes are generic and therefore must be customised to the topic of interest.

A widely adapted set of global scenarios was developed by the Global Scenario Group of the Stockholm Environment Institute in 2002 (Kemp-Benedict, Heaps and Raskin, 2002). Similarly, four scenarios were developed: Market Forces, Policy Reform, Fortress World and Great Transitions, which draw, to a certain extent, on Dator's earlier work.

Based on the work of Kemp-Benedict, Heaps and Raskin (2002) these scenarios can be paraphrased as follows:

- Market Forces is a story of an orderly progression, a market-driven world in which trends unfold without major surprises. Here, economic integration continues, but despite economic growth, disparities between rich and poor remain a critical social trend, and environmental degradation becomes an increasing global concern;
- by contrast, Policy Reform posits a world where public concern and consensus drives the political will to take action to ensure a transition to a sustainable future;
- Fortress World–a variation on Dator's Collapse–envisages an authoritarian response to deteriorating social, and economic order, where elites are privileged. Here repression, environmental destruction and social inequality are the order of the day; and
- lastly, Great Transitions envisages solutions to the challenges of sustainability and the emergence of new socio-economic arrangements. Here, society transitions to one which preserves natural systems and provides a high level of welfare.

While the Global Scenarios Group's work has been applied across a wide spectrum of scenarios, there are more ecosystem-specific scenario archetypes. The IPBES, for example, has developed its own set of global archetypes, which has been used as a starting point for regional assessments (Shin *et al.*, 2019). These include: Global Sustainable Development, Business as Usual, Regional Competition, Economic Optimism, Reformed Markets, Regional Sustainability and, Inequality. Each of these archetypes has its own set of attributes used to guide the development of narratives around each scenario such as economic development, population growth, technological development, main objectives, environmental protection, trade, policies and institutions, and vulnerability to climate change.

Of relevance to this work is the Millennium Ecosystems Assessment (MA) and the scenarios developed for the MA (United Nations, 2005). The Scenarios Working Group of the Millennium Ecosystems Assessment developed four global scenarios, which considered changes to biodiversity and ecosystem services from 2000 to 2100. Apart from creating the four scenarios, the work also addressed significant questions arising from it, such as the plausibility of changes in development paths, the reliability of the findings across scenarios, critical uncertainties, gaps in understanding, opportunities for managing ecosystem services, and human well-being. In brief, the four scenarios were as follows: Global Orchestration, Order from Strength, Adapting Mosaic, and TechnoGarden (Cork, Paterson and Petschel-Held, 2005). The scenarios are described here in greater detail:

- the Global Orchestration scenario depicts a worldwide connected society in which global markets are well developed. Supra-national institutions are well placed to deal with global environmental problems, such as climate change and fisheries. However, their reactive approach to ecosystem management makes them vulnerable to surprises arising from delayed action or unexpected regional changes;
- the Order from Strength scenario represents a regionalised and fragmented world concerned with security and protection, emphasising primarily regional markets and paying little attention to the common goods and with an individualistic attitude toward ecosystem management;
- the Adapting Mosaic scenario depicts a fragmented world resulting from discredited global institutions. It sees the rise of local ecosystem management strategies and the strengthening of local institutions. Investments in human and social capital are geared towards improving knowledge about ecosystem functioning and management, resulting in a better understanding of the importance of resilience, fragility, and local flexibility of ecosystems; and
- the TechnoGarden scenario depicts a globally-connected world relying strongly on technology and on highly-managed and often-engineered ecosystems to deliver needed goods and services. Overall, eco-efficiency improves, but it is shadowed by the risks inherent in large-scale human-made solutions (Cork, Paterson and Petschel-Held, 2005, pp. 230, 237, 244 and 254).

An alternative, complementary method to the use of archetypes is the matrix method (Rhydderch, 2017; UNDP, 2018), which consists of six steps. The first step is to identify the driving forces affecting the futures, usually entailing research and stakeholder engagement to identify as many driving forces as possible. Second, the driving forces are clustered in groups that have a high mutual impact on each other. Third, the extreme behaviours of clusters need to be determined along a continuous axis; the extreme behaviours are referred to as factors. Fourth, these factors are ranked on two measures, impact and uncertainty, with the goal to identify the two or three most impactful and uncertain factors. Fifth, these two or three factors have to be located on a matrix. Last, scenario narratives are created based on the constraints of the produced matrix. It is possible to map archetypes onto a matrix if the appropriate factors are identified.

An example of the use of a 2x2 matrix is shown in Figure 6.5, from a paper that considered urban sustainability in China in 2050 (Bina and Ricci, 2017). It shows the two-factor axes and four alternative scenarios along with the major features of each scenario.

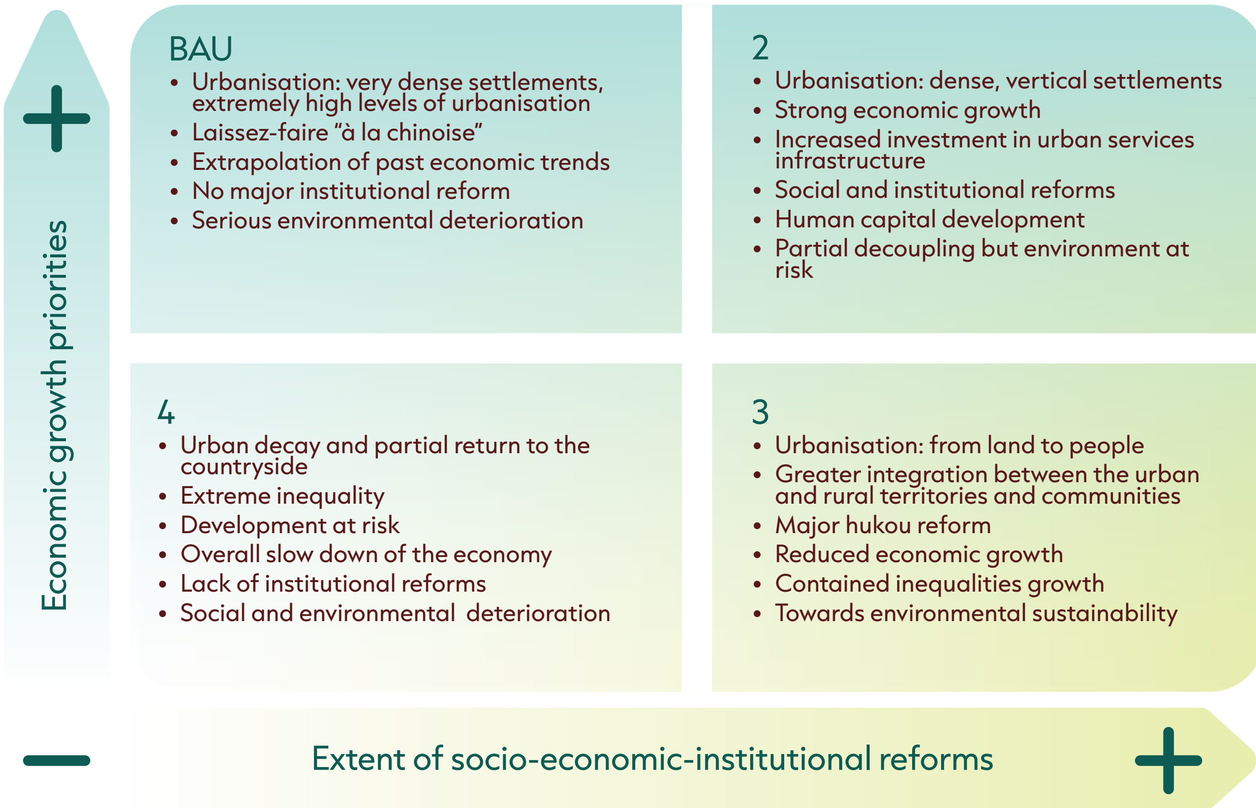


Figure 6.5. Example of a two-factor scenario matrix (Bina and Ricci, 2017)

The archetypes and matrix methods are the most common approaches used in developing scenarios. The archetype method is well documented, is relatively easy to apply and can be creative.

The matrix method is comprehensive, and the participatory way in which it is developed often leads to acceptance by stakeholders, especially when they have been part of the process. The two methods are not mutually exclusive and can be combined by using archetypes as a starting point.

In developing scenarios, the choices range from translating global scenarios in a direct and linear way into congruent regional/national scenarios without regional deviations, through consistent and coherent scenarios to complementary scenarios. In the latter, national scenarios are developed largely independently from global archetypes but "up-linking" (Drakes *et al.* 2020) with information from global foresight studies e.g. IPCC reports (van Vuuren *et al.*, 2011; Riahi *et al.*, 2017) and studies by the US National Intelligence Council (USNIC, 2021).

For the Grenada NEA, a decision was taken to develop coherent scenarios, starting with the matrix approach to scenario development. This approach of using a complementary scenario approach, combined specific national drivers with insights from academic literature, global and regional scenario studies and reports, drawing on relevant archetypes.

6.2.2. Overview of Caribbean scenarios

While a large body of work exists on the development and use of scenarios globally, there are no scenario studies that relate directly to Grenada. There are a few regional Caribbean scenario studies and several scenario studies for Latin America (GECAFS, 2006; Barlagne *et al.*, 2016; Marczak and Engelke, 2016; Drakes *et al.*, 2020). These were reviewed to extract information that would be relevant to the development of the Grenada scenarios.

6.2.3. Development of scenarios

The Grenada scenarios were developed through a combination of predominantly qualitative methods, as is common in scenario building. Qualitative research and analysis involve collecting and analysing non-numerical data to understand concepts, capture themes and patterns, and provide in-depth insights into causal relationships, experiences and perspectives. The qualitative data-gathering included the trends and issues identified by stakeholders, and expert elicitation, which drew on expert knowledge and expertise.

Capacity building

The development of the Grenada ecosystem scenarios began in August 2021 with a series of training workshops for stakeholders and the chapter development team. The workshop consisted of five sessions covering:

- an introduction to scenarios and why they might be used;
- the different types of scenarios and their relationships with policy;
- the importance of understanding direct and indirect drivers and trends, and three alternative approaches to go about developing scenarios;
- the various methods and techniques that can be used within the approaches that facilitate the development of scenarios; and
- examples of scenarios.

During the sessions, the workshop participants made a start on understanding and identifying some of the inputs for the development of scenarios.

Scenario-building workshop

A broad cross-section of national and regional stakeholders was invited to participate in a scenario-building workshop. These stakeholders were selected on the basis of experience, knowledge areas and disciplines. Prior to the workshop, participants were provided with briefing material to orientate them and apprise them of the expected outcomes.

For the workshop, 95 persons or organisations were invited, of which 70 were present for the two days: 42 online and 28 in person. A hybrid approach was adopted to ensure that as many people as possible could join in and contribute. The design of the workshop and its agenda was based on a template taken from The Futures Toolkit (Waverley Consultants, 2017) and adapted to suit local needs. The Futures Toolkit is a collection of tools and techniques designed to help policy makers and organisations better understand and navigate the complexities of future developments, trends, and uncertainties. It includes various methods for strategic foresight, scenario planning, and horizon scanning to enable more informed decision making (Waverley Consultants, 2017).

The agenda for the first day focused on identifying critical drivers of change and developing axes of uncertainty on which to map them. The second day aimed to cluster the drivers of uncertainty into related groups and to describe the uncertainties. By the end of the second day, the workshop break-out groups had identified several critical uncertainties. However, in the closing plenary session, although the possible critical uncertainties were agreed upon, no decision was taken regarding which ones might form the basis for developing the scenario narratives.

The critical uncertainties were synthesised and circulated to all participants after the workshop. Participants were then asked to rank the areas of uncertainty. The top two from the polling formed the basis of the axes of uncertainty. The four options emerging from the workshop were: climate change, economic activity, regional integration, and governance. In the case of governance, four sub-options were given:

- Top-down–bottom-up
- Government-led–community-led
- Strong institutions–weak institutions
- Reactive–proactive governance

Ultimately, climate change and economic activity emerged as the top two choices, with climate change ranging from low emissions to high emissions and economic activity broadly described as a sustainable blue/green or circular economy versus a brown or a business-as-usual economy.

Based on the two critical uncertainties selected, draft scenario narratives were developed.

Development of draft scenarios

In developing the draft scenarios, we adopted a coherent scenarios approach as indicated in Section 6.2.1. The starting point for this approach was to synthesise the broad rationale, assumptions and outcomes of various global scenarios. Although the national scenarios incorporated elements from various global scenarios, the descriptions of developments and conditions were firmly based on national characteristics and circumstances.

In developing the scenarios, we drew on trends, previous experiences, and emerging changes identified from the literature but particularly by Grenadian stakeholders in the workshops and follow-up surveys.

In addition to the literature mentioned in Section 6.2.1, other literature on global and regional scenarios was drawn upon to provide information for the development of the scenarios. This included: reports by USNIC (USNIC, 2021); the IPCC's Shared Socioeconomic Pathways (Riahi *et al.*, 2017); the MA (MA, 2005); the Inter-American Development Bank's *Latin America and the Caribbean 2030: Future Scenarios* (Marczak & Engelke, 2016); Arup's *2050 Scenarios: Four Plausible Futures* (Arup, 2019) and *Caribbean Scenarios 2050: GoLoCarSce Report* (Drakes *et al.*, 2017). The narratives also drew on existing policy documents as well as a broad range of existing literature such as reports from the British

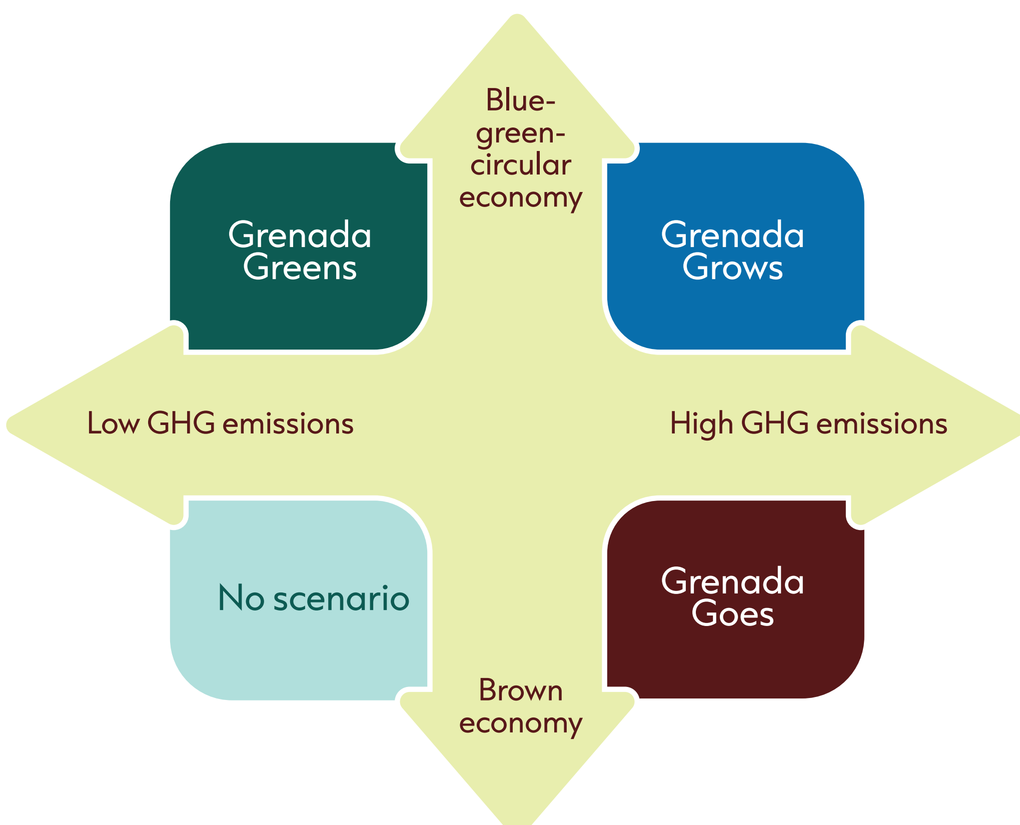


Figure 6.6. Factor axes and Grenada scenarios

Broadcasting Corporation (BBC) Future's thinkpieces (BBC, 2023) and the UNEP's Foresight Briefs (UNEP, 2023). We also carried out what is termed 'horizon scanning', looking for material and trends that may be of relevance.

Using the axes of uncertainty, we developed three separate scenario narratives, drawing on the outputs from the stakeholder workshops and surveys of Grenadian stakeholders, expert elicitation, as well as the literature sources indicated above. The narratives were subject to peer review and comments and adjusted accordingly.

Several iterations of naming the scenarios were made. A dual approach to naming was adopted, which involved pairing a descriptive element with a book title that reflected the essence of the narrative. The axes of uncertainty and respective scenario names are shown in Figure 6.6.

6.3. Scenario narratives

In this section, we provide a synopsis of the three scenario narratives: the Grenada Greens scenario, which envisions a sustainable future with low material growth, reduced energy intensity and greater focus on human well-being; the Grenada Goes scenario, which highlights demographic and developmental changes globally that have implications for Caribbean Small Island Developing States (SIDS), including Grenada, in 2050; and Grenada Grows, which is appropriately named because it highlights the country's growth and resilience in the face of environmental, political and economic challenges. Figure 6.7 provides a visual representation of the main features of each scenario. More detailed descriptions of the scenarios can be found in Appendix 1. The narratives and their subsequent implications for biodiversity and ecosystems services align with the Nature Futures Framework (Pereira *et al.*, 2020) scenarios proposed by IPBES, and shown in Box 6.1.

6.3.1. Grenada Greens scenario

In this scenario, at a global level, efforts to reduce greenhouse gas (GHG) emissions have been successful along with reductions in extractive resource use in favour of resource recovery and inclusive

Figure 6.7. Graphic encapsulating the three scenarios

Box 6.26. Nature Futures Framework (Peirera *et al.*, 2020)

Arcology

Nature for nature

People respect and value all life on Earth intrinsically. This world is characterised by extreme land sparing as vast areas of land and sea are strictly protected from human interventions. People live in dense self-sustaining urban areas designed to minimise the role of humans in the biosphere. Human population cannot be very high in this future.

Optimising Nature

Nature for society

A highly-connected world that shares knowledge and technology to maximise efficient and sustainable utilisation of nature's contributions to people while ensuring maintenance of the key ecosystem functions that underpin them.

Reciprocal Stewardship

Nature as culture/one with nature

In this world, values of reciprocity and harmony drive the relationships of humans with nature at all levels of human organisation. Biological and cultural diversity are co-conserved and co-anaged across a wide range of interconnected bio-cultural systems.

development. There is a greater focus on human well-being, which has garnered greater investment. There is low material growth, reducing the amount of resources used to generate economic growth while decreasing environmental deterioration and ecological scarcity.

By 2050, Grenada's gross domestic product (GDP) is estimated to be US$2,220 million. Debt forgiveness and a debt-for-nature swap in the 2030s allowed the country to reduce its debt-to-GDP ratio to 58%. By 2050 the percentage of the population in the poor and low-income categories has been substantially reduced to 10% and 25%, respectively. Tourism contributes 30% to GDP, agriculture and fisheries 20%, education 20%, industry 10%, and services and the rest contribute 20% to GDP. Circular economy approaches play a large role in key sectors. The overall unemployment rate stands at 7%, with youth unemployment at 15%.

Outward migration has reduced and is balanced by older nationals returning to Grenada. There is an increase in the number of female-headed households and a decrease in family/household sizes. Urbanisation is occurring at a slower rate, with a larger concentration seen in the south-eastern parts of Grenada. Many of the trends are replicated in Carriacou and Petite Martinique but at a much slower rate.

There is greater regional cooperation supporting the economic transformation of Caribbean nations in the areas of agriculture, food security and energy. Greater integration with the Spanish-speaking Caribbean nations has been achieved by revising the Caribbean Community (CARICOM) and Organisation of Eastern Caribbean States (OECS). This has led to greater intra-regional trade through lowered transportation costs, aided by regional marine spatial planning efforts. Regional development is guided by the first Caribbean Sustainable Development Plan, increase in foreign direct investments and growth in intra- and extra-regional trade. The expansion of the Caribbean Development Bank and the successful implementation of the Loss and Damage Mechanism have led to increased adaptation of Caribbean countries to climate change and provided innovative financial frameworks.

Tourism source markets have expanded and a more consistent demand has been created. Ecotourism and nature-based subsectors have been further enabled by the debt-for-nature swap programme and an increased number of land and marine Protected Areas (PAs). Growth in health and wellness, 'orange' tourism[1] (arts, events, culture), and blended tourism

[1] Also referred to as the purple economy

Box 6.27. Grenada's tourism

The development of Grenada's tourism product differs across the scenarios.

In Grenada Greens, tourism has diversified, moving away from a reliance on 'sun-sand-sea', as well as its traditional tourist markets of Europe and North America. Its offerings now include a strong ecotourism and nature-based subsector with an emphasis on supporting and promoting biodiversity, health and wellness, medical tourism and orange tourism. Tourism accommodation stock has been gradually replaced or upgraded with low-impact developments. Cruise ship tourism has experienced slow growth outstripped by the growth in yacht tourism, with Carriacou having emerged as a yachting hub. The growth in tourist numbers and product diversification has increased the numbers of people and businesses offering services. It has also increased local ownership and participation in the sector. Improved skills and training together with developments in technology have led to a decrease in the number of low-skilled jobs and increases in incomes.

Grenada Goes' tourism has continued with the 'sun-sand-sea' model. In an effort to spur economic development, the country has encouraged more tourist accommodation to be built. There is, however, increased competition in a relatively stagnant market both nationally and regionally. New operators have developed mini themed parks which have become a feature of Grenada's tourism as a way of offsetting the loss of beaches. The rise in crime has made tourist security an issue and now many coastal areas are given over almost exclusively to tourists. In spite of these efforts, tourism demand remains largely flat and tied to seasonal cycles. One result of the developments has been an increase in employment and supporting services in this sector, albeit in low skilled and paying jobs.

Grenada Grows' tourism relies on the 'sun-sand-sea' model though adapting to the effects of climate change. There is now a wider range of tourism accommodation, increased competition and growth in niche tourism products, which compensate for the decline in beach tourism. Tourism demand remains largely tied to seasonal cycles in the traditional markets. Employment conditions and pay in tourism have improved to recruit and retain the workforce. The effects of climate change have all but wiped-out the ecotourism subsector. Cruise ship tourism has continued to grow and yacht-based tourism has continued to be popular. Yacht tourism has benefited Carriacou through the development of marina facilities. The increasing threat from climate-induced hazards and associated insurance costs has made the tourism plant more resilient and able to resist the effects of hurricanes.

(combining work with leisure) has also expanded the sector, now focused on sustainability, lower impact and accreditation. While cruise tourism has declined, yacht tourism has grown with Carriacou emerging as a hub for the southern Caribbean. The growth in yacht tourism has been driven by factors such as increased environmental awareness, changing demographics and preferences, and infrastructure development (e.g. marinas and supporting facilities) in yachting destinations. See Box 6.2 for the development of Grenada's tourism product across the scenarios.

The growth in tourism has led to continued increase in air travel, resulting in multiple upgrades to the Maurice Bishop International Airport (MBIA) to cope with the new traffic. The growth of Grenville as an economic hub led to the redevelopment of Pearls Airport–upgraded to Pearls International Airport–primarily to handle the growing volume of freight associated with the burgeoning agroindustry.

Traditional food production systems have been transformed due to climate change, the regional drive for food security and the impact of changes in global food production. There has also been a cultural shift in people's approach to nutrition as new crops and foods have been introduced and the number of small holding agrogardeners has increased. Facilitated by significant sector investment, the town of Grenville has emerged as the food processing capital of

Grenada. Advances in marine-based food production have allowed the seaweed-farming industry to become profitable. The introduction and increased use of information and communications technology (ICT) and certification systems have revolutionised traceability and ethical sourcing, allowing access to high value markets. Pests, invasive alien species (IAS) and diseases continue to afflict terrestrial and marine ecosystems. However, due to advances in technology, early warning systems and better institutional infrastructure, their impacts are more easily managed.

The expansion of the tertiary education sector and an emphasis on skills development have positioned Grenada to develop as a regional leader in health and wellness and veterinary medicine. Health outcomes for the population have improved and the prevalence of non-communicable diseases such as diabetes has decreased, although mental health issues remain a problem. Nationwide health insurance is now available to the wider population and life expectancy has increased from 72 to 80. Increased occurrences of new, emerging and re-emerging diseases continue to challenge the healthcare services. Some of these diseases have been attributed to climate change, greater international mobility and habitat loss, all of which bring humans into closer proximity to disease reservoirs.

Climate change has also led to decreased water availability, not only during the dry season but also the rainy season, blurring the traditional seasonal boundaries. Projected water deficits were largely averted following the adoption of a raft of measures after the mid-2030s drought emergency. These measures targeted a combination of interventions focusing on greater use efficiency, circular water reuse, increased water capture and use, and a move to hybrid centralised/decentralised water systems. Decentralised and individually-tailored wastewater systems have been introduced to key localities, including St. George's, Gouyave and Grenville, as well as locations in Carriacou and Petite Martinique, leading to improvements in marine water quality. Additional legislation and enforcement, as well as the use of advanced technology, have assisted with the prevention of illegal dumping.

In tandem with these water management advances, the energy sector has also undergone significant transformation. Energy is now generated by a mix of solar photovoltaic (PV) technology, wind turbines, waste-to-energy, geothermal energy and biogas. Energy generation is decentralised, comprising a network of mini-grids with both Carriacou and Petite Martinique being self-reliant. In 2050, all vehicles are now either electric or use other forms of renewable energy. Although Grenada's Exclusive Economic Zone (EEZ) contains exploitable reserves of hydrocarbons, the country has a policy of not developing these reserves.

The global spread and development of interconnectivity, data mining, blockchain technology, machine learning and artificial intelligence (AI) together with 3D printing have increased the number of people in the ICT sector, allowing it to grow significantly. Advances in this area have enabled the development of a range of tools, including enhanced digital twins and real-time monitoring, the Internet of things (IoT), immersive reality (avatars), and remote research and manufacturing facilities.

The Grenada government's continued restricted recruitment in the public sector during the mid-2020s led to a significantly smaller civil service, which consequently diminished its overall effectiveness. In response to this, a polycentric governance system was established, funded by the government and facilitated by re-forming the Public Service Commission. This new system enabled the devolution of roles to local communities, community-based organisations, members of the diaspora, and civil society.

This shift towards a more collaborative governance model served as a catalyst for the development of various regional initiatives that focused on corporate social and environmental responsibility. These initiatives included passing the *Freedom of Information Act* and the ratification of the *Escazú Agreement* [2]. The introduction of these

[2] A regional accord across Latin America and the Caribbean regarding access to information, participation and justice in environmental matters

measures contributed to an increased awareness and consciousness of environmental issues among the population, resulting in heightened social and environmental activism. Consequently, environmental concerns have become more prominent on the political agenda, driving further action and policy changes.

6.3.2. Grenada Goes scenario

In 2050, marked demographic and development changes have occurred across the globe, with immense implications for Caribbean SIDS and nations in transition. The global population has increased to 10 billion people, with increased inequalities in access to food, water and other essential resources. Global poverty levels have risen and are disproportionately experienced in developing regions. Geopolitical challenges related to migration, war, and conflicts over water resources continue to threaten attainment of key development targets, pushing more people into extreme poverty. Climate change is of grave concern. Global temperatures have increased; the goal of limiting temperatures to less than 2°C has not been achieved. The increases in sea surface temperatures (SST) and sea level rise have had serious negative impacts on low-lying SIDS. Further, adaptation efforts have not kept up with the scale of vulnerability of SIDS. There is an increased emphasis on the adoption of scientific and technological solutions to mitigate the effects of climate change.

The population of Grenada has fallen to around 122,000 from 124,000 in 2020 due to a combination of a deteriorating economy, increase in infant mortality rates and stagnated life expectancy. Migration rates have increased significantly to about 25 people in every 1000 of the population, equivalent to the exodus of the 1960s to the 1990s. Many educated young people, especially females, have left Grenada due to limited employment opportunities, increasing the dependency ratio to 70%. Population decline is even more pronounced in Carriacou and Petite Martinique, catalysed by the gradual withdrawal of government services, resulting in major tension with mainland Grenada. Household size has decreased, particularly in urban areas. However, poorer households are generally comparatively larger, with higher dependency ratios. Female-headed households have increased from 47% in 2020 to 55% by 2050, and the urban population has increased to makes up about 50% of the total, spread across all major towns. This imposes immense pressure on ill-prepared and obsolete water, waste, and wastewater infrastructure.

In the meantime, the agriculture sector has undergone significant changes. Commercial farming has increased (i.e. 35% of all farms are now commercial) and there have been efforts to transform the agriculture sector since the adoption of the *National Sustainable Development Plan 2020-2035*. However, despite these efforts, climate change has adversely affected food and agriculture production systems, diminished water resources, and worsened human health and well-being. In addition, the traditional fishing sector has collapsed due to the adverse effects of climate change on marine and coastal habitats. This has resulted in serious livelihood implications for small-scale fisherfolks in coastal communities such as Soubise, Sauteurs, Duquesne, Harvey Vale, L'Esterre, and Petite Martinique. However, amidst these challenges, an innovative Sargassum-based sector has emerged, producing a variety of products such as bioplastics, fertiliser and food products. This industry is based around Grenville, an area that has become a mini-industrial hub in recent times.

Despite these developments, Grenada has faced economic struggles over the last 30 years. GDP has risen by less than 0.5% per year, standing at US$1.455 billion in 2050, compared to US$1.287 billion in 2020. Along with other Caribbean countries, there has been little change in the overall income profile in the country due to rising sovereign debts, fragmented trading environments and the impact of the mid-2020s recession brought on by the COVID-19 pandemic and international conflicts. Growth of the middle classes has slowed, hindered by increases in the cost of healthcare, education and other living costs. Advancements in the education system have stalled, limiting the capacity of the workforce to capitalise on available skilled positions. Grenada has also lagged behind in effectively tapping into the global technological revolution.

Grenada's tourism product has continued to rely on the sun-sand-sea model. To spur economic development, the country has allowed more tourist accommodation to be built, though there is increased competition in a relatively stagnant tourism market. The rise in crime has made tourist security an issue. Despite this, some of the coastal areas are given over almost exclusively to tourists. Not all tourist development has taken place along the coast, with inland destinations also proving to be popular. However, tourism demand remains flat and tied to seasonal cycles dominated by influxes from North America rather than Europe. One of the benefits of these tourism developments has been an increase in employment and supporting services, albeit in low-skilled and low-paying jobs. Cruise ship tourism has continued, though repeated health issues have supressed demand from time to time. Yacht-based tourism has continued to be popular within its own niche market.

With regard to energy security, high and unstable energy prices have prompted Grenada to redouble efforts to harness renewable energy. Advancement in the uptake of solar energy systems has been driven by both the private sector and households. Development of geothermal energy initially struggled because of a lack of external support and investment. Yet, it is now an integral part of the country's sources of energy generation. Grenada's EEZ contains exploitable reserves of hydrocarbon. Driven by the country's precarious financial position, Grenada has allowed these resources to be exploited. However, although the country derives royalties from oil and natural gas, the revenue generated has not filtered down to, or benefited, the local economy, such as by providing societal services. Rather, it has fuelled the diversion of revenues away from government, and unsustainable developments.

6.3.3. Grenada Grows scenario

Identifying global and regional changes is important as they provide the context within which to understand the challenges and vulnerabilities faced by Grenada in this scenario. Global factors include the ongoing political and environmental challenges of keeping the global temperature increase under 1.5°C while trying to mitigate climate change and pursuing development. In addition, the context of Grenada Grows is framed by the need to address the economic fallout from the COVID-19 pandemic and subsequent pandemics, as well as from the ongoing Russia-Ukraine war.

As a result, the 2030s and 2040s for Grenada are marked by cycles of social, economic and environmental vulnerability. Visible effects of climate change include sea level rise, increases in the frequency and amount of Sargassum, and more intense periods of droughts as Grenada and the wider Caribbean region tend towards a drying climate. Hurricanes also increase in frequency and intensity. These effects negatively impact water resources, subsistence food production systems, animal health, traditional fisheries and tourism. These events lead to worsening food poverty and unemployment among certain sections of the population.

By 2050, because of socio-political changes to the world order governing relations between states and other international actors, Grenada has entered a period of growth. The country's economy and society have become more resilient due to adaptation measures such as technology adoption, renewable energy integration, the installation of desalination plants, more robust integration of wastewater usage, and the shift from traditional fisheries to other marine-based food systems. Access to the COP27 Loss and Damage Fund has supported adaptation measures and provided the country with an economic buffer. Additionally, stronger political ties with the United States and western nations have ushered in new economic opportunities in the form of a thriving technology sector. Cloud services and other IT manufacturing services are a significant part of this sector, which has created new forms of employment. These services have also spurred new activities in the manufacturing sector via start-ups, research, bio-pharmaceutical companies, food production, transport, and utility services. As a result of the changes to the make-up of the economy, tourism is no longer its main driver, with the sector contracting due to climate change. Niche tourism products remain in the form of eco-tourism and yachting. Economic growth has reduced both poverty and unemployment levels to 15%.

Although the late 2040s has been a period of economic growth, the population has plateaued at 136,000 and is expected to decline due to lower fertility rates, improving levels of education and the growth of a middle class. Approximately 60% of the population is of working age (20-65 years). At the national level, the overall household size has decreased, although rural household sizes are still twice as large as urban household sizes. Around 50% of the population is living in urban centres across the tri-island state. Urban growth is driven mainly by decreases in urban household sizes, resulting in increased demand for housing, and, to a lesser extent, rural–urban migration. Outward migration has decreased due to two main factors: increased economic activities at home and tightened immigration policies outside of Grenada.

By 2050, ecosystems have transitioned into new phases, primarily due to climate change and human degradation of the environment. Within coastal ecosystems, small-scale fisheries have experienced stock collapses due to coral reef bleaching, ocean acidification, increasing Sargassum, and overfishing, thereby undermining small-scale fishing livelihoods. This, in turn, has caused small-scale fisherfolk to abandon this form of livelihood in search of other opportunities. A consequence of climate change is a new shift towards aquaponics and hydroponics, such as the raising of sea urchins and conchs. Mariculture has grown in importance as an economic sector.

The drying climate has negatively impacted watershed ecosystems, reducing streamflow and available freshwater supply. Adaptation responses to the reduction in water supply include the installation of desalination plants across major towns and the integration of treated wastewater into the water supply mix, in order to support water access to urban and rural households as well as to agricultural livelihoods. Access to climate change funding made these adaptive responses possible and ushered in changes in water governance arrangements via public-private partnerships (PPP), new planning regulations and incentivisation for private services.

Targeted interventions within the agriculture sector before 2050 have supported the resiliency of agriculture systems. By 2050, technological innovations in smart agriculture and the use of sensor data to support agriculture management are evident. Small-scale farmers are tenure secured, providing them with the means to access capital and services. A noticeable shift has occurred in small-scale farming, which has moved towards drought-resistant crop production and integrated rainwater harvesting practices. Farmers are also engaged in providing ecosystem services on their farms under the Ecological Land Management Scheme. There is a resurgence in commercial agriculture, with 35% of farmers being involved in this activity and an increase in terrestrial food production. A positive shift in female-led farming, mainly in insect farming for animal feed production, has led to cost reductions in livestock and poultry feed and meat products.

Grenada has achieved energy security through a mix of dispersed generating sources such as solar PV, wind turbines, waste-to-energy, geothermal energy and biogas. Energy generation is decentralised, comprising a network of mini-grids, which entails both Carriacou and Petite Martinique being self-reliant. Grenada's EEZ contains exploitable reserves of hydrocarbons. After much debate as to whether to allow the development of an oil and gas sector, Grenada has decided to allow limited exploitation of natural gas but not oil. This has led to the development of onshore facilities. The government benefits from the royalties, with 50% of the royalties being hypothecated to support environmental initiatives, ecosystems, and the natural parks system. However, the development of a hydrocarbon sector has resulted in tensions with the fisheries and mariculture sectors.

An integrated focus on sustainable ecosystem management characterises the 2050s growth period. Although climate change effects persist, improved data monitoring, education and training, and increased access to climate/sustainability finance have led to better ecosystems oversight. Changes in land tenure arrangements have facilitated payment for ecosystem services (PES), playing a vital role in facilitating their provision. A new governance arrangement in ecosystem service provision has been established via the emergence of community corporations. These corporations manage ecosystem services, arrange carbon markets between local communities and actors in the Global North and mediate payments to local land users.

6.4. Trends in drivers of change in biodiversity and ecosystem services

6.4.1. Direct and indirect drivers

The trends in the drivers of change in biodiversity and ecosystem services (BES) are discussed under five categories of drivers: social, economic, technological, political, and environmental. The most significant drivers within each of the five categories were determined through a process of literature review and expert elicitation. As a result, the following drivers under each category were selected, as shown in Table 6.1.

Table 6.1. Direct and indirect drivers of change in biodiversity and ecosystems

Social drivers • Demographic changes • Urbanisation • Poverty and inequality • Education	**Technological drivers** • Renewable energy • Water use and treatment technology • ICT, computing and AI • Agroindustrial technology	**Environmental drivers** • Climate change • Pests, diseases and IAS • Land use and land use change, including PAs and coastal squeeze • Natural resource use • Pollution
Economic drivers • Economic growth and improved performance, including changes in GDP, tourism, employment, trade, employment and inequality • Blue and green economy, including food production	**Political drivers** • Internal institutions and governance • Environmental policies and regulations • Regionalisation and geopolitics • Transparency, accountability, rule of law and corruption	

The drivers of change for each of the three scenarios considered are summarised in Table 6.2. A fuller description and discussion of the changes is provided in Appendix 2.

Table 6.2. Trends in drivers of change of biodiversity and ecosystem services

Legend	Strong increase	Increase	Stable	Decrease	Strong decrease
Positive	↑	↗	→	↘	↓
Neutral	↑	↗	→	↘	↓
Negative	↑	↗	→	↘	↓

Drivers of change in BES	Grenada Greens	Grenada Goes	Grenada Grows
Social drivers			
Population and demographic change	Population increases very slightly to 128,000. Contributing factors to slow growth include declines in fertility and a focus on economic well-being. Dependency ratio increases to 60%. Lower population numbers have a positive impact on BES.	Population decreases to 122,000, driven by outward migration in search of employment opportunities, leading to a loss of working-age people. Dependency ratio increases to 70%. Increase in pressures on BES.	Population increases to 136,000. More people are in the workforce, with dependency ratio at 55%. Increases in population exert pressures on BES but in this scenario they are neutral in driving change.
Urbanisation	Increased rate of urbanisation, 70% of the population urbanised, concentrated in Greater St. George's, Grenville and Gouyave. Quality of the urban environment is high with emphasis on sustainability. Positive impact on the environment and especially urban ecosystems.	Slow growth of urban areas, increasing to 50% of the population. Urban sprawl is an issue with poor access to services. Increase in tourism developments. Overall, despite some increase in negative impacts on the environment, it is offset by decrease in population.	Slow growth of urban areas, increasing to 50% of the population. Improvements in access to services. Urban development is better planned but increases in population mean an expansion of urban areas, affecting the environment. Absolute increase in urbanisation has a negative impact on the environment overall.

Drivers of change in BES	Grenada Greens	Grenada Goes	Grenada Grows
Poverty	Reduction in poverty levels and overall the population is economically better off, with an expanded middle class. Reduced poverty and greater affluence positively reduce pressures on the environment. Social inequalities are less and there is a greater degree of equity. ↘	Decrease in extreme poverty but continued pockets of poverty. However, 50% of the population is classed as lower income. Increased pressures on the environment. Social inequalities sharpen with implications for crime. ↗	Decrease in extreme poverty with 40% of the population in the lower income group. Impact on the environment is neutral as there are fewer in extreme poverty having transitioned into the low-income groups and a small increase in higher-income groups. Social inequalities have lessened to a certain extent and there are some gains in equity across society. ↘
Education	High investment in education and an expansion of the tertiary education sector has led to a skilled and educated workforce. High numbers going on to tertiary education. Positive impact on the state of the environment. ↗	Fall in school-aged population. Little improvement in learning outcomes and low numbers advancing to tertiary education, resulting in a predominantly low-skilled workforce. Impact on the environment is neutral at best. ↘	Increased expenditure driven through PPP, with a focus on technical and vocational training to support the needs of the private sector. Positive impact on the state of the environment. ↗

Drivers of change in BES	Grenada Greens	Grenada Goes	Grenada Grows
Technology drivers			
Energy and renewable energy generation and use	Grenada has transitioned to 100% renewables through a mix of energy-generating technologies, including geothermal. Decoupling of generation from transmission and distribution. Decentralised network of mini-grids. Transport uses renewable energy sources. Energy prices have dropped dramatically, which has attracted energy-intensive industries as these are now economically viable. Grenada has not exploited its offshore hydrocarbon potential. ↗	Grenada has not transitioned fully to 100% renewables though it does use a mix of renewable energy. It has allowed the exploitation of its offshore hydrocarbons and fossil fuels are a part of its energy mix. Energy generation has been separated from transmission and distribution but the development of mini-grids has been patchy. Transport uses a mix of fossil fuels – due to be phased out at some later stage, and renewable energy sources. Energy prices have come down but not sufficiently to attract new industries. ↘	Grenada has transitioned to 100% renewables through a mix of technologies. Decoupling of generation from transmission and distribution. Decentralised network of mini-grids. Transport uses renewable energy sources. Energy prices have dropped dramatically, which has attracted energy-intensive industries as these are now economically viable. Grenada has exploited its offshore hydrocarbon potential, producing natural gas for export. →
ICT Computing and AI	Uptake of AI, Computing, Information and Communication Technology (AICICT) across many sectors of the economy and government is supported by a skilled workforce. This enables 'cloud' manufacturing and research. Powers the circular economy. Has an overall positive, indirect impact on BES. ↗	Due to low-skilled economy, uptake and use of AICICT across economic sectors and government is low. Has minimal impact on the state of the environment. →	Similar to Grenada Greens but because AICICT is mostly deployed in the interests of economic activity, the impact on the state of the environment is stable. →

Drivers of change in BES	Grenada Greens	Grenada Goes	Grenada Grows
Water use and treatment technology	Water use increases but water distribution losses have been cut and wastewater treatment and recycling technology have reduced the level of resource abstraction. Increase in water storage balances variability. Climate change has led to decrease in stream flows and recharge, which have also affected aquatic biodiversity. Better land management has decreased sources of water pollution. Overall, the situation has been stabilised. →	The low population numbers and lower income levels restrict increases in domestic water use. Increases in consumption linked to tourism are offset by requirements for water efficiency and reuse. Water losses have been reduced. Overall water demand has decreased. Uptake of technology to improve water services is hampered by economic conditions. Climate change has impacted the state of aquatic ecosystems. Flooding and pollution are concerns. →	Water use increases, but as with Grenada Greens, water losses have decreased and wastewater treatment and recycling have increased. However, the combination of population growth and climate change have put greater abstraction pressures on water resources, resulting in an increase in use of desalination technology. Some streams run dry and lake levels are depleted. Aquatic ecosystems affected. Overall negative cumulative impact. ↘
Agroindustry technology	Widespread uptake and use of agrotechnology, expansion of hi-tech terrestrial and marine farming systems. Development of new and novel food sources with an emphasis on sustainability. Overall, has a positive effect on maintaining biodiversity by minimising pressures to convert forested areas to farming. ↗	Continuation of small-holder subsistence agriculture with a small emerging commercial subsector. Limited improvements in agricultural practices. Substitution has decreased use of polluting chemicals. Traditional fisheries have collapsed but there has been some substitution with fish farming. Clearing land for conversion to agricultural use, the continuation of poor agricultural cultivation practices and use of chemicals continue to have a negative on the environment. ↘	Growth of the food production sector, with both terrestrial and marine food production supported using technology and private sector investment. Application of gene editing. Decrease in subsistence agriculture. Better phytosanitary conditions and surveillance systems. Impact on BES uncertain. →

Drivers of change in BES	Grenada Greens	Grenada Goes	Grenada Grows
Environmental drivers			
Climate change	Low emissions scenario Average temperature rise: 0.9°C. The number of days with temperatures greater than 35°C increases, mostly during the months of July to October. Frequency of Categories 4 and 5 hurricanes increases by up to 30%, with storms becoming up to 11% stronger. SST increase by 0.26°C per decade. Annual rainfall decreases by approximately 10%, with an average drop of 3% for each month of September, October and November. Changes are manageable through adaptation. →		High emissions scenario Average temperature rise: 1.5°C. The number of days with temperatures greater than 35°C increases, extending from June to November. Frequency of Categories 4 and 5 hurricanes increases by up to 30%, with storms becoming up to 11% stronger. SST increase by 0.26°C per decade. Increase in ocean acidification affecting marine organisms. Annual rainfall decreases by 18% while rainfall in September, October and November decreases by 13% for each month. Higher threats from climate change make it harder to adapt. ↘
Land use and land use change, including PAs, coastal squeeze	No expansion of cultivated areas and no expansion of development in coastal areas. Good regulation and control over land use. ↗	Land under cultivation increases in the lowland areas into previously cultivated areas. Coastal areas developed for tourism. Weak land use controls and land open to exploitation. ↘	Some expansion of agricultural development in previously cultivated areas. Coastal areas have been developed. Better control and management of land use change →
Pests, diseases and IAS	Higher degree of surveillance and control, with enhanced capacity to control pests, diseases and IAS. →	Poor capacity to control the introduction and exposure to pests, diseases and IAS increases vulnerability. ↘	Improved capacity for surveillance and ability to control and combat pests, diseases and IAS, particularly for commercially important crops and animals. →

Drivers of change in BES	Grenada Greens	Grenada Goes	Grenada Grows
Natural resource use	Adoption of circular economy and increase in recovery of resources largely removes pressure on the use and exploitation of natural resources. ↘	Continued exploitation of natural resources results in negative impacts on BES. However, smaller population size mitigates the level of exploitation. ↘	Similar to Grenada Greens but late adoption circular economic measures means that there are legacy issues from previous pollution related activities. →
Pollution	Effective management of the sources of pollution and better provision of services that address sources of pollution: provision of wastewater treatment, solid waste and landfill management, adoption of sustainable agriculture and change to organic fertilisers and pest control. ↘	Public services such as solid waste management and, to a lesser extent, wastewater management face challenges in addressing and managing pollution. Farming practices contribute to pollution from agricultural sources. ↘	Similar to Grenada Greens but there are legacy issues from previous polluting activities, which mean that BES have been affected. The situation is now stabilised. →

Drivers of change in BES	Grenada Greens	Grenada Goes	Grenada Grows
Economic drivers			
Economy and economic performance	Rise in GDP to US$2.2 billion or US$17,200 per person. Youth and female employment rates have increased substantially, contributing to relatively high employment rates. Regionalisation of trade has expanded employment opportunities in a broadly mixed economy. Land-based food production has adopted many principles of organic agriculture and is closely integrated with mariculture. Grenville has emerged as a major economic and development hub, supporting offshore manufacturing facilities. Marine economy is a strong performer. Environmental safeguards, certification and traceability are strictly enforced. Tourism has diversified to take in health and the orange economy. ↑	The economy has stagnated: GDP is US$1.45 billion or US$11,900 per person. Economy is dominated by low-skilled, low-paid jobs in tourism and service sectors. Tourism is the main economic driver giving rise to continuing coastal squeeze. However, there is an emerging commercial agricultural sector. Youth unemployment is high. There has been limited growth in green jobs. Given the poor economic performance, emphasis is shifting to allow the exploration and development of offshore hydrocarbon resources. ↘	Rise in GDP to US$2.3 billion or US$16,900 per person. Unemployment rates have dropped. Economy has diversified with the relative importance of tourism declining as other sectors grow: education, manufacturing, food products, agroprocessing and mariculture. There is growth in exports. Carriacou is a major yacht and cruising hub. Growth of repurposing of resources, including solid and liquid waste, which has led to a decline in extractive industrial activity. Strict environmental compliance and regulations are attached to the performance of economic sectors. ↗

Drivers of change in BES	Grenada Greens	Grenada Goes	Grenada Grows
		Political drivers	
Internal institutions and governance	The effectiveness of a small Civil Service is enhanced through the emergence of collaborative governance arrangements, with communities and the democratisation of decision making enabled by technological advances. Greater use of dynamic economic instruments and national accounts now reflect the costs and benefits of environmental improvements. The role of government ministries has shifted to setting policy goals with operational matters devolved. ↗	Weak government finances and lack of experienced personnel have reduced the effectiveness of government. The ability to develop environmental legislation is challenging. The monitoring and management of natural resources is underfunded and under resourced, and there is little ability and political will to enforce regulations. There has been a degree of 'state capture' [3] by the tourism industry and others. ↘	Closer collaboration and integration within the OECS have broadened environmental governance, which is made more effective through shared responsibilities, greater financing and expertise. Expansion of co-management arrangements and the role of the third sector in environmental governance. ↗
Environmental policies and regulation	Strong environmental policies in place, complemented by the ability to implement and enforce them. Policy reform to incorporate sustainability tests and adoption of international best practice. Increased protection afforded to the environment. Grenada is a 'policy setter', due to its progressive approach to environmental regulation and programmes. ↗	Environmental policies are developed but there is weak implementation due to fiscal and resource restrictions. ↘	Environmental policies try to strike a balance between encouraging economic activity and mitigating adverse impacts on the environment. Wide use of offsets and cap-and-trade mechanisms. Voluntary self-regulation is a feature of this scenario. ↗

[3] State capture is a type of systemic political corruption in which private interests significantly influence a state's decision making processes to their own advantage

Drivers of change in BES	Grenada Greens	Grenada Goes	Grenada Grows
Geopolitics and regionalisation	Greater degree of regional integration. Stronger support and coordination for maintaining biodiversity and nature's services.	Weak regional institutions and fragmented international order. Relative isolation from international community and therefore less able to benefit or capitalise on limited available support to BES.	Greater global integration and mobilisation to combat the negative effects of climate change. Grenada benefits from this renewed resolve.
Transparency, accountability, Rule of Law, and corruption	High degree of transparency, accountability and access to information. Increased opportunities for citizen participation in national development and decision making.	Characterised by weak ability to operationalise agreements, conventions and national legislation on transparency and accountability. Limited opportunities for citizen participation. Corruption and state capture by elites are threats to society	Some positive developments in the ability of citizens to influence policies but the private sector is able to exert significant influence on decision making.

6.5. Changes in biodiversity and ecosystem services under three scenarios

6.5.1. Grenada Greens

Under this scenario, biodiversity conservation is given a high priority at the political and economic level. With the drive to mitigate climate change impacts, sustainability and circular economy practices have been prioritised and encouraged by government through a mixture of regulations and incentives to maintain biodiversity and ecosystem services. As a result, Grenada's biodiversity and the services provided by ecosystems could be expected to improve as far less pressure would be placed on them. This would mitigate the otherwise negative impacts of climate change.

The pressure to convert and exploit forest and woodland ecosystems would be minimal and subject to sustainability controls. This would promote the retention of intact forest and reforestation efforts, particularly for the elfin and rainforests ecosystems. The lower elevation forests and woodland could also be expected to rebound, especially if brought under beneficial co-management where the value of ecosystem services is realised. That said, these ecosystems would still be subject to a degree of climate stress, but this would be better managed due to more competent human resources and financing. The pressure for land conversion associated with the expansion of urban areas, agriculture and tourism would be minimised with a policy emphasis on repurposing existing land, set asides, and 'planning offsets and gains'. Furthermore, biodiversity loss and its stressors would be reduced by transitioning to environmentally-friendly agricultural practices, switching away from harmful agrochemicals and using biological controls as well as soil conservation and restoration practices. These changes, along with improved surveillance and approaches to pests, diseases and IAS, would work in favour of biodiversity.

Similarly, maintaining forest and woodland cover and integrity and minimising the use of harmful chemicals would have beneficial effects on aquatic ecosystems associated with rivers, streams and lakes. Co-management of forested areas and improved surveillance systems should also reduce pressures on forested areas and reduce the harvesting of freshwater aquatic fauna. The improved wastewater and sewage management system surrounding greater St. George's and other urban areas would result in a drastic reduction in land-based point source pollution. Although reduced population and improved water management practices would reduce pressure on water resources, this would have to be balanced against the negative impacts of climate change on the water cycle. Overall, the effects of reduced population and improved water management practices on rivers, streams and lakes would be beneficial.

Intensive land use (agrosystems) would not have expanded the total area under cultivation, and most would have transitioned to food production systems that minimise environmental impacts through a combination of approaches, including organic and enclosed agriculture. The absence of monocropping, payments under ecological land management schemes and traceability would collectively promote biodiversity and improve environmental services. Hence, intensive land-use systems would, under this scenario, have a beneficial effect.

Coastal and marine ecosystems would not benefit to the same extent, more because of the legacy effects of climate change than changes in use of marine resources. Biodiversity pressures would be reduced by establishing PAs, making interventions to address declines in coral reef species, and transitioning to alternative marine-based livelihoods. Addressing and minimising land-based sources of pollution would also reduce a potent source of stress on marine ecosystems.

Urban and artificial areas would benefit from the dual effects of a small population and improvements in the built environment, including the provision of green spaces, climate resilient homes and infrastructure, and reductions in air and other sources of pollution. A proactive approach to these areas, which would include smart cities technologies, would include promoting a healthy environment. Table 6.3 illustrates the changes in BES under the Grenada Greens and other scenarios.

Table 6.3. Changes in biodiversity and ecosystem services under each scenario

Legend			
Increase	Decrease	Stable	Variable
↗	↘	→	↑↓

Ecosystem	Scenario					
	Grenada Greens		Grenada Goes		Grenada Grows	
	Biodiversity	Ecosystem Services	Biodiversity	Ecosystem Services	Biodiversity	Ecosystem Services
Forests and woodlands	↗	↗	↘	↘	↑↓	↗

Wetlands, lakes and rivers	↗	↗	↘	↘	↘	→
Intensive land use – agrosystems	→	→	↘	↘	↑↓	↑↓
Coastal and marine ecosystems	→	→	↘	↘	↘	→
Urban and artificial areas	↗	↗	↘	↘	↑↓	↑↓

6.5.2. Grenada Goes

The combination of higher emissions and poor economic performance would have a generally adverse impact on all ecosystems, negatively affecting biodiversity as well as related services. Higher temperatures, drier conditions and more variable rainfall would stress forests and woodlands and have a negative effect on stream flows and lake levels. While it is unlikely that there would be significant habitat fragmentation of forest and woodland ecosystems, the expansion of subsistence agriculture and weak controls over land conversion, particularly for tourism-related developments would serve to reinforce the negative effects of climate on biodiversity and on the health of forest, woodland, rivers and lake ecosystems. Of concern, would be the combined effects on pollinating species and the implications for ecosystem composition and diversity. These effects would be exacerbated by pests, diseases and alien IAS along with the potential adverse effects of increased bushfires. The effects of climate change-reducing water availability would more than offset reductions in water demand associated with domestic and commercial/industrial use, and likely improvements in water efficiency.

Intensive land use (agrosystems) are expected to feature a continuation and growth of subsistence agriculture. A lack of capital investment and upscaling of food production systems would be expected to have an adverse effect on the environment as they would imply a continuation of poor practices and bringing more land into cultivation. However, although the availability of harmful agrochemicals would have been subject to control, some use would probably persist.

The impact of increased SST and ocean acidification is expected to result in an almost complete loss of coral reefs with concomitant effects on these ecosystems. The added stress arising from over exploitation of fisheries and the continuing impacts of Sargassum would severely impact marine biodiversity and ecosystems. It is unlikely that regional efforts to mitigate these effects would have any noticeable impact.

Poor planning and development controls on urban and artificial areas, together with poor economic conditions, would be expected to give rise to urban sprawl and inadequate service provision in less affluent areas, as well as encroachment into forests and woodland and intensive land-use areas.

6.5.3. Grenada Grows

While there is a focus on integrated sustainable ecosystem management under Grenada Grows, the interaction of local and global drivers will lead to mixed impacts on biodiversity and ecosystem services. There are trade-offs when we consider the social, economic, environmental, and technological cross-scalar interactions within Grenada's social-ecological system.

Global temperatures would continue to increase even if we were to cut global gas emissions to the agreed level. These would exacerbate social-ecological vulnerabilities and the climatic effects experienced by SIDS (Mycoo *et al.*, 2022). Climate change persists as a threat under Grenada Grows, which will result in a shift within the local climate to drier conditions, with marked reductions in rainfall. While these conditions will have negative effects on biodiversity and ecosystem services, the level of impact is dependent on the adaptive response measures that are put in place.

The ecosystem types that will be most affected, resulting in a marked decrease in biodiversity, are coastal/marine and freshwater ecosystems. Increased ocean temperatures, ocean acidification, frequent Sargassum tides and microplastic pollution would lead to coral reef bleaching and destruction, loss of fish habitat, changes in fish composition and size as well as declining fish stocks. The increased population by 2050 and the potential increase in demand for fish due to dietary needs could tip declining fish stocks into collapse. This would result in loss of livelihoods for traditional fisherfolk and the loss of locally sourced, commonly-eaten fish in local diets. However, the development and expansion of mariculture has enabled the substitution of traditional fish sources and, to an extent relieved the pressure on them. This could allow coastal and marine ecosystems to stabilise.

As Grenada experiences more droughts, it is expected that biodiversity degradation will occur within freshwater ecosystems. As expected, a 25% reduction in rainfall, coupled with increasing bushfire events, will lead to the loss of organic matter, increased soil erosion, and a reduction in the water retention capacity of watersheds. This, in turn, will disrupt local water cycles as streamflow and groundwater recharge reduce. An overall decrease in freshwater resources available for various uses is expected as the three major freshwater bodies - Grand Etang, Lake Antoine and Levera Pond- will experience reduced capacity.

Adaptation responses to climate change are visible within agricultural ecosystems. These include investments in climate-smart agriculture and the transition of small-scale farmers to drought-resistant crops. There would also be an expansion of payment for ecosystem services schemes to support nature-positive farming that supports the maintenance of biodiversity across farming lands such as soil organic matter, pollinators, and seed dispersers.

Under the Grenada Grows scenario, population growth and urban expansion are anticipated, which will have both negative and positive impacts on biodiversity. Population growth places a higher demand on local food systems, which can result in agricultural intensification. In addition, it places a higher demand on freshwater access for households. However, under this scenario, it is anticipated that adaptation investment in desalination plants and the integration of treated wastewater will address increased water needs amidst a drying climate.

Increase in housing demand and urban expansion underpinned by population growth will drive land cover change. This will result in habitat fragmentation and loss within coastal and terrestrial ecosystems and, in turn, can create the loss of endemic species. The conversion of natural surfaces into impermeable surfaces can contribute to increased surface runoff and flooding. Concrete structures and surfaces used for urban expansion, coupled with ongoing climate change, can contribute to urban heat island effects, which then indirectly contribute to climate change. However, adaptation responses to support biodiversity in urban areas are noted. For example, the integration of green spaces supports not only healthy living but also local biodiversity via the planting of local flora. Furthermore, green spaces can act as areas of carbon sinks within urban areas (Portner *et al.*, 2021).

6.6. Changes in ecosystem goods and services under the three scenarios

Ecosystems provide a range of goods and services that sustain life and the sources of food and fibre, energy, timber, freshwater and medicinal resources, as well as aesthetics and spirituality, contributing to social and individual wellbeing. The state and integrity of these services differ across the three scenarios and are organised and discussed based on different types of ecosystem services, namely provisioning, regulating, supporting, and cultural services. Moreover, Tables 6.4 to 6.7 present an overview of the predicted changes in these services under the three scenarios when compared to their current state.

6.6.1. Provisioning services

The provisioning services under each of the scenarios are summarised in Table 6.4 and discussed in this section.

Table 6.4. Changes in provisioning services in the three scenarios

Legend			
Increase	Decrease	Stable	Variable
↗	↘	→	↑↓

Nature's Services	Component	Grenada Greens	Grenada Goes	Grenada Grows
Provisioning services	Freshwater flows	→	↘	↑↓
	Food and fibre–terrestrial	↗	↘	→
	Food and fibre–marine	↗	↘	↑↓
	Genetic resources–terrestrial	→	↘	→
	Genetic resources–marine	↑↓	↘	↑↓
	Natural resources–terrestrial	↗	↘	→
	Natural resources-marine	↘	↘	↘
	Energy (wind, solar, geothermal, natural gas & oil)	↗	↗	↗

Grenada Greens

This scenario is characterised by low population growth and an ageing population. It is also characterised by a higher proportion of the population now living in urban areas, though the overall number has not increased significantly. With overall population hardly increasing, the demand for additional housing and development would be low. Low demand coupled with urban planning policies have limited urban sprawl and encroachment into non-urban areas. The number of persons in poverty has decreased as a result of the rise in employment and better wages as the economy has diversified. Food security has improved through changes in diet, increased local food production, and, through regional integration, allowing imports from regional sources.

Limited expansion of cultivated areas has brought back into use previously abandoned farmlands as the diversified food production sector has grown. Much of this growth has been achieved through changes in food production practices and technology, which have brought about more productive use of existing areas. Growth has also been underpinned by policies to promote sustainable land use. Thus, there has been very limited pressure to expand the total area under cultivation. The reduced pressures on land for development, for food production and on forested areas have had a beneficial effect on terrestrial ecosystems, reducing pressures on medicinal and genetic resources. However, these resources are still vulnerable to the effects of climate change, which are more likely to become evident after 2050. Pressure on water resources is mixed as, on the one hand, there is more efficient use of available water, reducing consumption by at least 30%, but on the other hand, climate change is expected to reduce water resource availability by up to 25%. Inter-seasonal and inter-annual variability, however, is of greater concern.

Despite the negative effects of climate change and human activities on coastal and marine resources, there are opportunities to address food security challenges. Specifically, the development of new marine-based food production opportunities could provide a sustainable solution. However, the situation with respect to marine medicinal and genetic resources is less clear, and marine natural resources such as coral reefs are unlikely to recover. Fortunately, energy production through the use of renewable sources, such as solar and wind power, is expected to have a positive impact.

Grenada Goes

This scenario is characterised by a slight population decrease and an ageing population. The root cause of the decrease is attributed to high levels of outward migration spurred by unfavourable economic conditions and limited opportunities. As a result, the household dependency ratio has increased and there are growing numbers in low-income groups, leading to rural poverty and food insecurity. The quality of the urban environment has declined due to urbanisation, which has led to land conversion in low elevation dry forest areas. Although informal and subsistence agriculture has expanded, they have taken place in previously cultivated areas and have not significantly impacted rain and elfin forest areas. While the negative effects on medicinal and genetic resources are attributed to the impacts of climate change and IAS, and diseases on native flora and fauna, poor agricultural practices and the use of agrochemicals also have a negative effect on water resources, which are a key concern in the context of water scarcity and climate change.

The negative effects of climate change on water yields for ecosystems are more pronounced, which would noticeably reduce water availability. The population is smaller, so demand has not increased, especially given the low level of economic activity. However, during the dry season, water consumption will likely be constrained due to reductions in surface water and groundwater, which will impact dependent ecosystems. These constraints have important implications for agriculture, which is the primary user of water resources.

The negative effects of climate change on coastal and marine ecosystems are another concern. Higher SST and acidification, combined with the impact of Sargassum, are expected to have negative consequences across the board for their provisioning services. Despite these challenges, there is a silver lining: the region's energy sector is a net beneficiary, providing an opportunity for economic diversification and sustainable development.

Grenada Grows

Grenada's population continues to grow, which suggests an increasingly ageing population. While urbanisation has increased numerically, the percentage of the population living in urban areas has remained relatively stable. However, densification and expansion of urban areas have led to settlement of slope areas in the greater St. George's area and encroachment into previously cultivated and forested areas outside of this area. The expanding economy has led to fewer people in poverty and lower income categories. Increased employment opportunities, primarily located within the expanded urban areas, has resulted in continued daily commuting practices and congestion. Pressures on natural resources such as stone and aggregate have been minimised through the adoption of circular economy approaches and reuse and repurposing of materials.

In this context, food security remains a significant challenge due to the more variable climate coupled with the impact of pests, diseases and IAS on agricultural productivity across the commercial and subsistence sectors. This has resulted in volatility in local food production, which is only partly offset through regional imports. Commercial food production has grown and accounts for 35% of all farms, though its area footprint per productive output is smaller than the subsistence/small holder farming. Overall, there has been an expansion of the land area under food production though all of the conversion has taken place on previously-cultivated land. There are still large areas of previously-cultivated land, which have not been brought back into production.

In terms of water resources, the effects of climate change are the same as for Grenada Goes. However, this scenario has an increased population, including an increased urban population that tends to consume more water than rural populations. To manage potential negative effects, more extensive water harvesting, conservation, and recycling measures are employed, resulting in a variable impact.

With respect to the coastal and marine environment, again, the effects of climate change on marine natural resources are negative while on the provision of food and fibre, medicinal and genetic resources, the effects are variable.

6.6.2. Regulating services

The changes in regulating services provided by ecosystems are summarised in Table 6.5 and described in this section. The services include regulating climate, air quality, water flows, soil erosion, natural hazards, pollination and carbon sequestration.

Table 6.5. Changes in regulating services in the three scenarios

Legend			
Increase	Decrease	Stable	Variable
↗	↘	→	↑↓

Nature's Services	Component	Grenada Greens	Grenada Goes	Grenada Grows
Regulating Services	Air quality	↗	→	→
	Climate regulation	→	↘	↘
	Erosion control and soil sediment retention	→	↘	→
	Water flows, quality and purification	→	↘	→
	Natural hazard controls	→	↘	↘
	Pollination and seed dispersal	→	↘	↘
	Biological control: pests, disease and IAS regulation	↗	↘	↘
	Carbon sequestration	↗	↘	→
	Soil formation and fertility	→	↘	↘
	Nutrient cycling	↗	↘	→
	Coastal protection	↗	↘	→

Grenada Greens

Air quality is affected by the use of fossil fuels, transport emissions, smoke, road dust, industrial emissions, pollen, plant and equipment emissions, and use of chemicals. In addition, there are external sources such as Sahara dust which impact air quality. Sunshine, rain, higher temperatures, wind speed, air turbulence and mixing all affect pollutant concentrations. The switch to renewable energy caused many of the sources of emissions to be reduced and the higher regulatory standards on emissions from commercial and industrial processes would also have had an effect. The maintenance of forest cover and the greening of urban areas would make a positive contribution to climate regulation. The lower GHG emissions would be expected to mitigate the potential impact of Sahara dust.

Climate change-induced changes to the marine environment include acidification, as CO_2 is absorbed by oceans. Increased acidification reduces the oceans' ability to further sequester carbon, and oxygen levels correspondingly decrease. The changes threaten coral reefs, disrupt ocean currents and affect the recruitment of fish stocks. As sea temperatures rise, the ability of the oceans' to act as a heat sink reduces. Coastal ecosystems such as mangroves and seagrass beds all sequester and store more carbon than forests. Thus, these changes to the marine environment, which lie largely outside Grenada's control, limit climate regulation. The lower GHG emissions in this scenario, along with the minimal impact on forests, suggest that climate regulation is relatively stable.

Water flows are a function of the nature of rainfall and the state of land cover. More intense rainfall events are anticipated, which would increase surface runoff, reduce soil moisture and groundwater infiltration, and contribute to increased soil erosion. Increased surface runoff would result in flashier stream and river flows while reduced groundwater recharge would reduce baseflows in rivers and streams particularly during the dry season and into the early wet season. Changes in river flow regimes would have an impact on aquatic fauna. However, the negative effects on rainfall patterns in this scenario are likely to become evident in the second half of the millennium. Furthermore, the negative effects are mitigated in this scenario by the land management practices that would be promoted under a circular (blue-green) economy, which prioritises sustainability. Such practices would also have a positive effect on maintaining overall water quality and the assimilation and purification functions of terrestrial ecosystems, taking into account the minimisation of the use and application of hazardous biochemicals in the environment.

While changes in terrestrial ecosystems could impact pollination and seed dispersal services, it is expected that GHG mitigation would result in little change. Management and control of pests, diseases and IAS across ecosystems rely on monitoring and surveillance, resistance development, and mitigating conditions that enable their spread.

It is worth noting that globalisation of trade and travel has facilitated the transfer of pests, diseases and IAS across ecosystems. Managing them effectively requires a combination of monitoring and surveillance, developing resistance, and mitigating conditions that enable their spread and proliferation. In this scenario, it is anticipated that all three conditions would be met and therefore the adverse impact on ecosystems would be minimised.

Carbon sequestration, soil formation and nutrient cycling services improve in this scenario due to the maintenance of forested areas, urban greening, the adoption of sustainable agricultural/land management practices and the reduction in use of artificial fertilisers. Such measures mitigate emissions.

The maintenance of forest cover, resilient urban areas and infrastructure, nature-based solutions, early warning systems and climate smart farming practices in this scenario serve to moderate the effects of extreme events. The protection of coastal areas depends on the functionality and vitality of natural systems such as coral reefs, seagrass beds and mangroves, and on how coastal areas have been developed. In this scenario, the impact of extreme events and a higher level of coastal protection would be achieved through the expansion of protected nature areas, the reduction of land-based sources of marine pollution, coastal restoration efforts and development controls.

Grenada Goes

The increase in GHG emissions and their impacts, along with the limited availability of fiscal resources, poses a significant challenge to Grenada's efforts to successfully implement climate change mitigation and adaptation programmes and policies that aim to preserve biodiversity and ecosystem services.

For instance, fiscal resources, such as funding for research and development of sustainable practices are necessary to reduce the negative effects of climate change on agricultural productivity, water resources, and marine ecosystems. However, limited fiscal resources hinder the implementation of such programmes and result in the decline of regulating services, such as carbon sequestration, nutrient cycling, and pollination. Air quality, however, would remain stable.

In this scenario, there is loss of forest cover, an increase in smallholder/subsistence agriculture, the continued exploitation of coastal and marine resources, and the likely development of hydrocarbons as a way to address financial constraints. Overall, these developments reduce climate regulation, and the ability to maintain water flows and control soil erosion. Soil erosion contributes to land degradation and has negative impacts on land cover and forested areas, as well as on soil formation and nutrient cycling. Furthermore, in this scenario, there are few improvements in the ecological functioning of urbanised areas, which in the other scenarios make a positive contribution to both provisioning and regulating services. The ability to control pests, diseases and IAS is also compromised. Vulnerability to extreme events increases, compounding adverse impacts across regulating ecosystem services.

Grenada Grows

The two features that distinguish this scenario from Grenada Greens are the population size and intensity of climate change. Whereas the anticipated climate changes under low emissions are anticipated to be moderate, they would have become manifest and more intense under higher emissions. Higher population numbers, with an accompanying increase in urban populations, increase stress on biodiversity and regulating ecosystem services. While the ability to cope is similar under both these scenarios, the effectiveness would not be the same.

As industrial activity continues to increase and the prevalence of Sahara dust is anticipated to rise, the stability of air quality may be at risk due to higher levels of GHG emissions. This, in turn, could negatively impact on the oceans' ability to sequester carbon. While the maintenance of forest cover can support climate regulation, changes in forest ecosystem diversity and species loss may lead to a reduction in their regulating services. However, even with these potential challenges, forest cover and sustainable land management are crucial to mitigating negative effects, such as the variability in precipitation patterns and increases in extreme events that could negatively impact water flows, lakes, wetlands and soil erosion.

Moreover, pollination and seed dispersal services may be impacted by changes in forest composition and diversity, and the effects of higher temperatures and increased CO_2 content. The changes would increase stress and reduce the effectiveness of these services. At the same time, the climate conditions would create more favourable conditions for pests, diseases and IAS, which the surveillance systems would be challenged to address. Changes in soil formation and nutrient cycling would be affected by the higher temperatures and changes in rainfall patterns and ecosystem species composition. The adverse changes would be mitigated, to a certain extent, by the adoption of climate-smart agricultural practices in the commercial and subsistence agriculture sectors.

While in this scenario, Grenada would, ordinarily, be similarly able to moderate the impact of extreme events, the anticipated increase in the number and severity of such events, under increased GHG emissions, would challenge this moderating ability. Coastal protection would similarly deteriorate.

6.6.3. Supporting services

Changes in the provision of supporting services by ecosystems under the three scenarios are summarised in Table 6.6 and discussed in this section. Supporting services enable the provision of the other three sets of ecosystem services. Thus, the state of supporting services has a direct influence on the state of the other services.

Table 6.6. Changes in supporting services in the three scenarios

Legend			
Increase	Decrease	Stable	Variable
↗	↘	→	↑↓

Nature's Services	Component	Grenada Greens	Grenada Goes	Grenada Grows
Supporting services	Terrestrial habitat	↗	↑↓	→
	Coastal and marine habitat	→	↘	→
	Material cycling	↗	↘	→
	Soil formation and retention	↗	↘	→
	Biomass production – terrestrial	↗	↑↓	→
	Biomass production – marine	→	↘	→
	Water cycling	↗	↑↓	→
	Genetic diversity	→	↑↓	→
	Biodiversity – terrestrial	→	↑↓	→
	Biodiversity – marine	→	↘	→
	Photosynthesis	↗	↘	→
	Oxygen production – terrestrial	↗	↑↓	→
	Oxygen production – marine	→	↘	↘

Grenada Greens

In general, this scenario has improvements in supporting services due to a number of factors. These include: the avoidance of the more extreme impacts of climate change in a lower emissions pathway; the adoption of sustainable practices backed up by investments in a blue-green-circular economy; better regulation; the achievement of many of the Sustainable Development Goals (SDGs)–albeit somewhat later than 2030; limited population growth; and a better performing economy.

The maintenance of vegetation cover and the protection and management afforded to forested areas, along with improvements in land management and to the urban environment, have positive effects on terrestrial habitats for fauna and flora, materials cycling, soil formation and retention, biomass production, water cycling, photosynthesis and oxygen production. While it is possible to exert a degree of management and control of land-based processes, this is more difficult to achieve for the marine environment as it has more characteristics of a global commons. The establishment of PAs and accompanying adaptation measures counter the negative effects of global heating on the marine environment. Thus, coastal and marine habitats, marine biomass, biodiversity and oxygen production services are stable.

Grenada Goes

In contrast to Grenada Greens, the state of supporting services is more varied. Climate heating is greater, and although population numbers have not put additional pressure on resources, poor economic performance means that Grenada is less able to address many of the challenges. The provisioning services associated with the coastal and marine ecosystems are the most adversely affected in this scenario, for similar reasons, but compounded by the greater level of GHG emissions and global heating. Thus, it is anticipated that coastal habitats will deteriorate along with marine biomass production and oxygen production. For the other components, the situation is variable with some stability and some declines. Terrestrial habitats associated with rain and elfin forest are likely to be stable though experiencing some decline in their extent, while the expected expansion of low elevation dry forest along with conversion of previously abandoned land back to agriculture production would be adversely affected. Consequently, associated functions such as biomass production, water cycling, genetic and biodiversity similarly experience variable effects.

Grenada Grows

In this scenario, all of the supporting services remain stable and provide services at a level comparable to the current state. The major difference between this and the Grenada Goes scenario is the better economic performance and the adoption of sustainability precepts guiding the use of natural resources and the recognition that a healthy environment is key to a healthy economy and society. These investments have been made to adapt to climate change in order to maintain and support and provisioning services.

6.6.4. Cultural services

The changes in the provision of cultural services in the three scenarios are described in this section and summarised in Table 6.7. These are the non-material benefits that individuals and society enjoy and that can have a positive impact on well-being.

Table 6.7. Changes in cultural services in the three scenarios

Legend			
Increase	Decrease	Stable	Variable
↗	↘	→	↑↓

Natures Services	Component	Grenada Greens	Grenada Goes	Grenada Grows
Cultural services	Recreation–terrestrial	↗	↘	→
	Recreation–marine	↗	↘	→
	Aesthetic	↗	↘	→
	Education/Indigenous and local knowledge (ILK)	↗	↗	↗
	Heritage	↗	↘	↗
	Spiritual	↗	→	→
	Intrinsic and existence	↗	↘	→
	Cultural diversity	↗	→	↗
	Social relations	↗	↘	↗

Grenada Greens

The ability of Grenada to maintain biodiversity and ecosystem services and a growing appreciation of the cultural services that the environment can provide suggest that, in this scenario, there has been a positive change across all the components. Recreational opportunities are enhanced and the greater appreciation of heritage and cultural diversity has supported their incorporation into the diversification of tourism. The support, through reparations, has made a positive contribution.

Grenada Goes

There is some modification of the terrestrial landscape though it is the marine environment that is most affected by climate change and, to a lesser extent, by increased anthropogenic stressors. As a result, the quality of recreational opportunities has deteriorated, which in turn affects any aesthetical appreciation of the environment and its intrinsic value to society. Heritage is adversely affected mostly by a lack of investment. On the other hand, the spiritual value of the environment and cultural diversity remain stable. Social relations are anticipated to become strained, affected by the poorer economic conditions and employment opportunities and increases in crime.

Grenada Grows

Although not as optimistic as the Grenada Greens scenario, this particular scenario witnesses either stable or enhanced modifications in cultural services. The improvement in economic performance has a favourable influence on education, heritage, cultural diversity and social cohesion. However, in other areas such as recreation, aesthetics, spiritual and intrinsic values, there is relative stability because the potential severe impacts of climate change on these services are better managed. For instance, adequate measures have been taken to ensure that recreational facilities are protected from extreme weather conditions; cultural heritage sites are safeguarded from natural disasters; and spiritual sites are managed in a sustainable way to maintain their intrinsic value. Moreover, efforts have been made to promote sustainable tourism, which not only enhances the visitor's experience but also ensures the long-term preservation of cultural services.

6.7. Wild card events

Examples of wild card events include hurricanes, the COVID-19 pandemic and the Fukushima nuclear disaster. These are events which can have profound impacts on communities, infrastructure, and ecosystems. They can lead to widespread disruption, relocation of populations, and long-term ecological and socio-economic changes. Generally, wild card events can be foreseen, and preparations can be made in advance to manage the consequences, though not in all cases. An asteroid striking Earth would have such vast global implications that there would be little you could do to mitigate the effects.

Wild cards have the following characteristics:

- they are events, not trends or drivers;
- they are not reversible; once they have happened, they cannot unhappen;
- although unlikely, wild cards can be anticipated; and
- they can be both negative and positive.

The range of hazards which could be covered by wild card events includes, but is not limited to: geological hazards; hydrological hazards; meteorological hazards; biological and health hazards; chemical hazards; social unrest; and terrorism. Many of these events can have serious impacts on biodiversity and national well-being. Two questions arise:

- To what extent could they impact biodiversity and ecosystems?
- How well would Grenada manage the effects?

Often, there are prior examples of the respective impacts on biodiversity and ecosystems. The impact of Hurricane Ivan on Grenada's forests and woodland ecosystems and their subsequent recovery have been documented. The impact of volcanic eruptions in Martinique, Montserrat and St. Vincent have been similarly documented. Some of the effects have been discussed elsewhere in this chapter. Intact ecosystems often mitigate the impact of natural hazards. Under normal conditions, ecosystems regenerate and recover over time, though the extent of recovery can be facilitated through supportive interventions. However, where natural hazards impact degraded ecosystems, the chances of recovery are reduced.

It is beyond the scope of this chapter to discuss the range of impacts that different wild card events could have on Grenada's ecosystems, in part because it is too broad a topic to be adequately covered. However, as a general rule, it has been suggested that the greater the level of GHG emissions and continuation of a resource-extractive economy, the greater the adverse impact of wild cards on biodiversity and ecosystems.

The second question addresses the extent to which Grenada would manage the effects of wild card events. Under Grenada Greens, biodiversity and ecosystems are in a better condition than at present, with exploitive pressures on them having been reduced. At the same time, the country's institutions are stronger and there is greater social cohesion. Under these conditions it would be expected that the country would be better able to cope and recover. There would be a greater use of nature-based solutions, green infrastructure and, for example, the re-establishment of coastal mangroves. Not so under Grenada Goes; climate change impacts are more severe, which together with the continuation of an extractive brown economy, weak institutions and a poor financial position would exacerbate the negative impacts. The country would therefore be poorly placed to manage and recover. In contrast, under Grenada Grows, the country would be better able to cope because of the improved financial conditions. However, the negative effects of climate change suggest that total recovery would be unlikely.

6.8. Knowledge gaps and research needs

It is important to remember that scenarios are potential future scenarios that aid decision making by exploring what the future might look like under different conditions. They are not predictions but rely on current conditions and identifying key drivers of future changes. These drivers can be direct or indirect and are determined using expert judgement and literature reviews. Forecasts of drivers and their impacts on local settings are essential, as is understanding the uncertainties associated with them. This applies to physical, ecological and social conditions. The scenarios are qualitative and descriptive in nature but may include quantitative projections based on known trends. While climate projections are available and can provide some quantitative information, other areas could benefit from further quantitative modelling. Climate projections draw on cutting-edge research, which has reduced uncertainty in recent years. However, our understanding of how future climatic conditions will affect the local environment is limited. Similarly, our understanding of social processes and drivers related to future economic, political, and demographic conditions creates significant uncertainty in the scenarios presented here. Further modelling work in such areas, for which the basic tools exist, would add value to the scenario narratives.

Modelling of demographic changes: according to the current population models developed by the United Nations Department of Economic and Social Affairs (UNDESA), certain assumptions are made about future population trends, focusing primarily on birth and death rates (United Nations, 2022). However, these models do not account for the impact of migration resulting from economic shocks or natural disasters. As has been suggested, changes influenced by economic conditions can significantly affect future population numbers and age structures, which in turn can have implications for factors such as dependency ratios (Bloom, Canning and Sevilla, 2010). Research is needed to develop more nuanced projections of Grenada's future demographics under a range of conditions.

Macroeconomic modelling: Understanding how future macroeconomic conditions may affect Grenada remains an important knowledge gap. As illustrated in the scenario narratives, how well the economy performs has a major influence on the country's ability to finance projects and programmes, the effect of natural disasters on expenditures, and levels of employment and income distribution. Being able to explore how the economic landscape changes in response to different assumptions would yield better insights into how ecosystems and society might fare under the different scenarios. Additionally, creating a sub-model on energy usage could provide a more detailed understanding of how energy demand and supply may evolve under different scenarios, and how this could impact the economy and the environment. Such modelling can aid in identifying the most effective policies and investment decisions to achieve the SDGs while maintaining economic growth.

Modelling changes in land use and cover composition: Changes in land use respond to changes in economic activity and development pressures, while changes in species composition respond to changes in climate and development pressures. In fact, aspects such as economic activity and land use change can have a greater ecological impact than climate change, though when taken together the pressures become self-reinforcing. Understanding these would provide a starting point for understanding how ecosystems might respond to pressures and the effects on biodiversity. Modelling historical land cover change could provide valuable insights into potential future changes of landscape, health risks and the impact of natural disasters.

Changes in water yields: While it is possible to use existing downscaled climate models to make projections regarding future climates, they provide limited insights into how these changes will affect flows in rivers and streams, changes in lake levels and water yields from catchments. Current understanding of the physical hydrology of Grenada represents a significant knowledge gap which needs to be addressed to understand future water availability. Furthermore, we need to know how changes in water quality could affect aquatic fauna and flora. The timing and amount of nutrient and pollutant loads to streams and the nearshore remain unknown. Understanding how these all might change would provide insights into how ecosystems might be affected and the extent to which future water demands could be met.

6.9. Building blocks of a sustainable future

Biodiversity and ecosystems are, and will continue to be, subject to anthropogenic pressures, with mostly adverse effects, through resource extraction, conversion, pollution, harvesting and other such activities. The pressures are driven directly and indirectly by the drive to satisfy human needs and wants. If the state of biodiversity and ecosystems and the services they provide are to be maintained and enhanced, then decision making must be based on the realisation that natural capital cannot be substituted by physical and financial capital. Natural capital is complementary to human and social capital. Maintaining and growing natural capital goes beyond establishing PAs and regulating uses. These are necessary but not sufficient conditions by themselves. This chapter section takes a broader perspective and focuses on the building blocks that should be in place to provide the ability to mobilise the resources and expertise needed to achieve a sustainable future for all. It argues that we need to invest in people as well as nature and the environment we live in. Thus, this section considers the foundational building blocks needed for a sustainable Grenadian future.

The three future scenarios present distinct development pathways for Grenada. Human activity, encompassing past, present, and future actions, will determine the state of Grenada's biodiversity and ecosystem services. In this chapter, climate change and economic activity are identified as the key uncertainties driving the potential future state of the country. While there is consensus that the climate has warmed and changed because of GHG emissions, whether or not this warming trend and its effects can be mitigated depends on current policies and future actions–which are inherently uncertain. Current policies and pledges are insufficient to limit global temperature rises to 1.5°C. According to the International Energy Agency, "renewable electricity needs to expand faster to reach the milestones in the Net Zero Emissions by 2050 Scenario, where the renewable share of generation increases from almost 29% in 2021 to more than 60% by 2030. Annual generation has to increase at an average rate of over 12% during 2022 to 2030, which is twice the average of 2019 to 2021" (IEA, 2022). Greenhouse gas emissions is an area over which countries like Grenada have little agency or control. Some of the effects of GHG emissions, such as increasing SST, are already evident, and even if emissions ceased, their impacts would persist for some time (IPCC, 2021). Consistent with the *Paris Agreement*, Grenada has iterated its 5th Nationally Determined Contribution aimed at managing GHG emissions through strategic interventions in priority sectors.

As well as recognising the challenges and uncertainties presented by climate change, it is important to explore building blocks–policies and pathways that can lead Grenada towards a sustainable future. By focusing on four key areas–economic activity, renewable energy, development planning and governance–this section aims to identify strategies that can effectively address environmental issues, reduce dependence on non-renewable resources and ensure the well-being of Grenada's people and ecosystems. Additionally, the section considers pollution and other related concerns. This exploration is crucial because addressing pollution, whether in the form of air, water or soil contamination, can have profound effects on both human well-being and ecological integrity.

6.9.1. Economic activity

Economic activity is an area over which the government can exercise a degree of control through policies that can influence the types of activities encouraged and the nature of resource use. A notable development, pioneered by the Welsh Government (National Assembly of Wales, 2015) is to evaluate proposed developments for their sustainability and impact on future generations, ensuring that policies incentivise/prioritise sustainable development. The exploitation of Grenada's natural resource endowment during the colonial period has impacted the ecosystems of the tri-islands and continues as one form of economic activity succeeds another. The possible mix of economic activities depends on how factors such as natural resource endowment, global conditions and national policies come together. Here, we examined the potential outcomes ranging from one end of the spectrum, where economic growth is decoupled from resource utilisation, to the other end, where there is a continued dependency on the exploitation of resources, including abiotic, biotic and human resources.

What is evident from Sections 6.4, 6.5 and 6.6 is that the way uncertainties unfold has a profound impact on the state of biodiversity and ecosystems. The state of biodiversity and ecosystems is determined not only by the ways in which they are protected but more by the conditions that enable their protection and use. Looking across the scenarios, the type and state of the economy have an overarching influence and impact on biodiversity and ecosystem services. Therefore, the state of the economy and factors that facilitate its vibrancy and success are of overarching importance. A sound economy creates fiscal space for government to invest in environmental policies, programmes and projects, and leverage and direct investments.

The Grenada Goes scenario illustrates the consequences for the environment when government does not have the resources to invest in the environment. Both the Grenada Greens and Grows scenarios also illustrate the importance of education, not only in creating opportunities but also in providing key building blocks of a successful economy and investment environment: knowledge, skills and expertise. In this respect, the existing approach to Technical and Vocational Education and Training (TVET) set out in the 2020 TVET Policy Review (UNESCO, 2020) needs to go much further in supporting transitions to a digitally reliant economy. Policies supporting the opportunities to grow tertiary-level education, particularly into specialised areas of health and agriculture where there are existing advantages, would support and expand economic opportunities.

6.9.2. Renewable energy

All three scenarios assume that renewable energy has become prevalent, a development that can be reasonably anticipated with a high degree of certainty. They vary in terms of the extent of the energy transition, and the degree to which its potential can be harnessed. Regardless of the scenario, this transition holds significant implications for enabling both the economy and the environment. As highlighted, access to affordable, dependable energy creates opportunities that are currently unavailable. Moreover, accelerated adoption should yield economic benefits and support the greening of the economy (IPCC, 2021). Energy policy is, therefore, a crucial component of preserving biodiversity and ecosystem services. However, policies should also acknowledge the potential for new forms of pollution arising from electrical and electronic facilities and equipment, battery and electronic component disposal, and the establishment of renewable energy facilities such as wind farms and geothermal plants. While goods like batteries for electric vehicles and electronic parts would be subject to extraterritorial regulation (e.g. in manufacturing regions like the European Union or the USA), other forms of regulation could be implemented through the planning and operating licensing system (European Commission, 2021).

6.9.3. Development planning

Urbanisation, planning and development of the physical environment, and land use change strongly influence the state of biodiversity and ecosystem services. The extent to which these three inter-related drivers can be directed depends on the strength and robustness of their governance: the existence of policies, legislation and regulations; fairness, impartiality and accountability; and the ability to enforce the regulations. Physical development plans, planning regulations, and building standards' requirements have a positive role to play in shaping what can be done, where and how. They can also provide the impetus for the provision of new services. For example, planning requirements for how wastewater is managed create opportunities for their management and operation. In doing so, the pollution of surface water, aquifers and the marine environment can be progressively addressed. National standards can support the utilisation of water savings devices, reducing consumption. Planning requirements and regulations that require built-in resilience to climate change and extreme events, together with urban development plans, can have positive impacts on the environment. These, in turn, can reduce the impact of extreme events. In rethinking planning, it would be logical to include requirements to incorporate operation and end-of-life (decommissioning) considerations along with periodic assessments of the planning and regulation regime's effectiveness. Limiting global temperature rises to 1.5°C is unlikely, so planning for a warmer world becomes a necessity. The Grenada Greens scenario, which has sustainability as a core focus, indicates the potential environmental gains that can be realised as it creates a framework within which development can be directed.

Implied within this approach to physical development planning are the establishment of PAs as a means of addressing environmental issues and concerns. The PAs would encompass both terrestrial and marine areas. Also implied is the idea of Enterprise Development Area Hubs. Their operation would need to be underpinned by their legal status and governance arrangements, embracing ideas of co-management. Both would have to set out acceptable and sustainable practices within a framework for their operation, management and financing. Under both Grenada Grows and Grenada Greens, there is a higher degree of coordination of land use for food production and for development. This would include addressing tenure and access to land issues and the development of land banking to underpin food production. In addition, both scenarios support a higher degree of land and marine management, though they differ somewhat in how management is operationalised; a more co-management approach is adopted under Grenada Greens.

In the context of the Grenada Greens scenario, substantial societal dietary changes become evident, driven primarily by the diversification of alternative protein sources production. This scenario features stronger policy encouragement and support for expanding food production systems, with an emphasis on promoting variety and sustainability. Furthermore, institutional resources, such as gene banks and financial backing, play a crucial role in this scenario, enhancing Grenada's pursuit of greater food sovereignty. By fostering a more self-sufficient and resilient food system, Grenada Greens aims to create a healthier and more environmentally conscious society.

6.9.4. Governance

Much of the aforementioned discussion (Sections 6.9.1–6.9.3) focuses on the enabling conditions that influence and support the health and vitality of biodiversity and the capacity of ecosystems to provide services, whether those services improve or deteriorate. However, there are also policies and interventions, which directly affect the environment, some of which have already been discussed such as the importance of land use and protection policies, and restrictions and control of pollutants. More directly, accessing and generating finance are key factors. Securing both existing and emerging international and bilateral funding sources, as well as mobilising private financing, will be essential, as we have consistently emphasised in the scenarios. Mechanisms such as the generation of terrestrial and marine carbon credits can be directly associated with ecosystems services, but only if the necessary organisational frameworks are in place.

Implementing policies that promote transparency, accountability, access to information, and advocacy can empower society to influence decisions made on its behalf, thereby supporting sustainability. Additionally, establishing an environmental agency or a governance structure that is independent of, or buffered from, party affiliations or influence can ensure continuity and growth regardless of the ruling party. While statutory bodies were initially intended to serve this purpose, it has become evident that they may not fully achieve this objective. Therefore, exploring alternative mechanisms for environmental governance is essential to maintaining a sustainable trajectory for Grenada. Such mechanisms become part of the checks and balances that are the hallmark of good governance and avoid clientelism. Emphasisng the importance of subjecting all policies to a sustainability test and advocating for national accounts to go beyond traditional measures such as GDP acknowledges the need to address hidden issues like pollution and resource depletion. Traditional GDP accounting does not assign value to these aspects, which can lead to underestimating their impact on the economy and the environment. By addressing these shortcomings, the Grenada Greens scenario demonstrates a commitment to a holistic and sustainable development strategy that considers the long-term well-being of the country's people and ecosystems.

Pollution

Another area of concern is pollution of the environment. The degree of pollution varies across the scenarios but is most acute under the Grenada Goes scenario, arising from the poor provision of services such as wastewater management, solid waste management, improper storage of chemicals, landfills, dumping and disposal practices such as incineration. Under Grenada Goes, weak governance arrangements, lack of operational permits/licences coupled with fiscal constraints imply that even if there were regulatory requirements, the country’s weak ability to operationalise them would by default permit polluting practices to continue. In other areas such as chemicals and pollutants of emerging concern, more international cooperation would be required along the lines of the Basel, Rotterdam, Stockholm and the Minamata Conventions and the European Union’s Registration, Evaluation, Authorisation and Restriction of Chemical Substances (REACH) regulations. The application of technology such as blockchain, which both the Grenada Greens and Grenada Grows scenarios envisage, would allow more effective application and control of pollution from chemicals and agrochemicals within the country. Similarly, a global convention on plastic pollution would provide a framework within which Grenada could act to control pollution from this source within its national boundaries. Policies would address the manufacturing and importation of permitted types and uses of plastics, take-backs, disposal and reuse practices. However, tackling transboundary pollution would call for greater regional and sub-regional interventions.

Regional harmonisation of acceptable practices is part of the Grenada Greens scenario.

Sargassum is also a transboundary issue which affects Grenada and the Caribbean, more generally. Yet, they can exercise little control over the causes and sources of the seaweed. At best, the Caribbean can manage Sargassum, which can be regarded as a pollutant and/or potentially a resource. The extent to which it is a pollutant or a resource depends on the scenario. In Grenada Goes, Sargassum is likely to be, on, more of a pollutant than a resource. If regarded as a resource, then managing it becomes an economic challenge, which would be accompanied by the development of regulations around its harvesting, use and disposal of byproducts.

6.10. Conclusion: stories and suggestions

Guiding Grenada to a desirable 2050 state is a process. It is a process influenced by trends, by factors and events outside of Grenada's direct control, and by desires and decisions. Knowing where we would like to be and understanding the challenges likely to be faced is part of that process. The Grenada National Ecosystem Assessment provides the intellectual bedrock on which to build that future. The assessment, and this chapter in particular, does not seek to prescribe what actions should or could be taken. Rather, it provides insights and suggests options for consideration.

6.10.1. Stories

In this chapter, three future scenarios for Grenada have been developed using qualitative approaches, supported by quantitative information where available. The scenarios were developed through an interactive process of stakeholder- and expert-led consultations as well as extensive reviews of relevant literature. The narratives are based on an interplay of global trends, regional and national trends and circumstances; these broadly cover global and local conditions, demographic changes and economic activities, including food production, technological change, social and community infrastructure, and governance.

The scenarios present a range of plausible and consistent future developments for Grenada up to 2050, covering global and local conditions. They range from the 'worst case' scenario presented in Grenada Goes to the 'best' or 'preferred' case presented in Grenada Greens, with the Grenada Grows scenario representing the most probable outcome. This range of scenarios allows for an exploration of the potential state of biodiversity and ecosystem services under different conditions. These scenarios can provide a sound basis for policy makers and stakeholders in Grenada to consider and plan for potential future developments.

Table 6.8 provides a general summary of the main features of each scenario. Overall, the development of these scenarios provides a valuable tool for policy makers and stakeholders in Grenada to anticipate and plan for potential future developments, and to ensure that their decisions are informed by a comprehensive understanding of the potential risks and opportunities associated with different scenarios.

Table 6.8. Summary of scenario features

	Grenada Greens	Grenada Grows	Grenada Goes
Global conditions	At a global level, the world moves towards sustainability and inclusive development with human well-being garnering greater focus and investment. There is low material growth and reduced energy intensity and resource use. Regional focus of trade and development within an expanded and integrated Caribbean economic area. Increased access to financing structures such as Loss and Damage through the Bridgetown Initiative and agreement on reparations. CARICOM reinvigorated.	Initially characterised by a bipolar world of competing hegemonic economic blocs. Continued exploitation of fossil fuel led to a climate crisis which resulted in international cooperation to adapt to a warmer world. Increased funding flows to the Caribbean, channelled through the private sector. Increased importance of the OECS.	Global population has increased to 10 billion, with increased inequalities and poverty levels. Geopolitical challenges including migration, war and conflicts over water resources continue to threaten attainment of key development targets. The goal of limiting temperatures to less than 2°C has not been achieved. Weakened and ineffective CARICOM, dominance by and increased dependence on the USA by the region. Fragmented international collaboration and limited access to international funding.
Demographics	Population 128,000. Small family sizes. Important middle class. Dependency ratio 60%	Population 136,000. Ageing population, slowing growth. Dependency ratio 55%.	Population 122,000. High level of outward migration and high rates of unemployment. Dependency ratio 70%
Education	Sustained investment in quality education	Private sector-led educational improvements	Little improvement in quality of education
Energy	Uptake and use of renewable energy.		
Technology	Widespread adoption of new technologies and application across sectors. Application to environmental management.	Adoption of technology mostly in the business sectors	Little uptake and use of new technology – some niche areas
Economy	Diversified economy including food production systems, tourism, education, research and development, health and wellness, business services. Food exports. Growth of integrated economic production zone Grenville. GDP/capita US$17,200.	Diversified economy. Growth in manufacturing and light engineering as well as IT services and services provision. Tourism, education, construction and services continue to be important. Both terrestrial and marine food production have been growth areas. GDP/capita US$16,900.	Low skilled, emphasis on tourism remains. Other important sectors include education, construction and services, with agriculture and fisheries a long way behind. High youth unemployment. GDP/capita US$11,900.
Urbanisation	70% of population is urban. Planned urban environments. Emergence of Grenville as a major urban centre.	50% of population is urban.	50% of population is urban, growth of urban sprawl.
Land use	Establishment of PAs. Limited expansion into previously cultivated areas.	Establishment of PAs. Some expansion into previously cultivated areas.	Expansion into previously cultivated areas.
Community	Stable, prosperous society	Relatively prosperous society. Emergence of extra-national influences and private sector.	Increasing crime rates. Growth of elites.
Food production	Growth in commercial diversified food production sector. Use of technology.	Growing commercial food production	Subsistence agriculture prevalent

	Grenada Greens	Grenada Grows	Grenada Goes
Marine economy	Growth of offshore seaweed and fish farming	Nearshore coastal marine farming	Collapse of traditional fisheries
Government	Strong fiscal position, growth of collaborative governance arrangements. Sub-regional integration. Strong focus on sustainability.	Focus on economic growth. Partnerships with the OECS, small Civil Service. Fiscal space to provide services.	Weak fiscal position undermines governance
Environmental policies and regulation	Strong regulation and ability to implement policies	Good level of regulation, focus on adaptation rather than mitigation	Weak environmental management

6.10.2. Policy implications

In comparing the scenarios, we can identify commonalities across key policy areas, which indirectly or directly support biodiversity and ecosystem services. Indirectly supportive policies are those that facilitate the development of favourable conditions for the protection, maintenance, and growth of biodiversity and ecosystem services. Conversely, the absence of such policies could have an adverse or detrimental effect on biodiversity and ecosystem services. Directly supportive policies would include those that specifically address a particular environmental issue, such as pollution reduction or habitat restoration. This latter category is much more extensive and specific. Properly addressing these key policy areas will go a long way towards empowering Grenada to forge a path towards a future with desirable biodiversity and ecosystem services. An overview of the suggested supportive policies is given in Table 6.9.

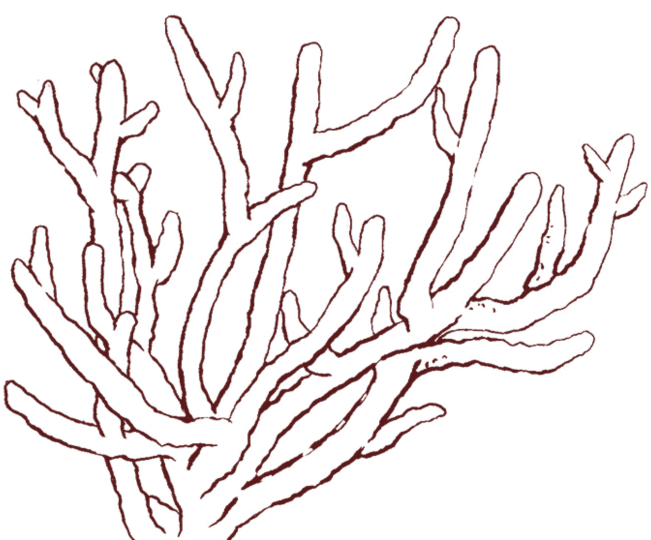
Table 6.9. Policy areas supporting biodiversity and ecosystem services

Indirect supportive policies	Direct supportive policies
• Renewable energy generation policies	• Physical development and land management policies, including PAs
• TVET and tertiary education promotion policies	• Land banking and co-management policies
• Economic diversification and support policies	• Sustainability assessment policy
• Enterprise development areas policy	• Gene bank promotion
• National sustainable building standards and regulations	• Grenada agribusiness development facility
• Blue-green preferential incentives policies	• Caribbean agricultural university
• National AICICT strategy and action plan	• Food production and sovereignty policies
• National environmental accounting standards	• Blue economy policies and management plan
• Updated national climate change adaptation policy	• Freedom and access to information policies
• Eastern Caribbean sustainable development plan – national counterpart plan	• Transfer of Conventions on hazardous substances and plastic pollution into national legislation
• Sustainable transport, shipping and freight policies	• Blue-green innovations institute
• National solid waste strategy	• Extended producer responsibility obligations
• Sustainable resource recovery company	• Packaging and waste protocols
• Democratisation of government policy and strategy	• Biodiversity strategy

Table 6.9 provides broad policy areas rather than detailed policy prescriptions, most of which are multipurpose, encompassing a range of intervention areas. For instance, physical development and land management policies would cover forestry, urban development zoning, agricultural areas, coastal and terrestrial PAs, and provision of sustainable services. National sustainable building standards and regulations would include not only performance standards but also materials, equipment, expected practices, and services. Regional and international relations are excluded from the table as they are more fluid, but common and shared approaches have a higher likelihood of promoting positive outcomes.

As stated at the beginning of the chapter, the scenarios presented are not predictions about the future, but rather serve to stimulate thinking about potential futures and guide the development and implementation of policies, plans, and programmes towards desirable outcomes for Grenada's people and environment.

Grenada's NEA process, and especially the scenario-building exercise, provided an opportunity to think through ecosystem management and biodiversity processes and establish what might be done to guide us towards different outcomes. Deciding precisely which future to aim for, working through the 'how' to get that done, and leading Grenada toward a desired future lies in the domain of democratic processes.



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Appendices

Appendix 1. Detailed descriptions of the scenarios

This Appendix provides detailed descriptions of the three scenario storylines. These were used to develop the summary narratives provided in Section 6.3.

The three scenarios described are:

- Grenada Greens
- Grenada Grows, and
- Grenada Goes

Grenada Greens foresight scenario

Context: low emissions + circular economy

Grenada Greens sets out what a person might expect to see when going about their business on 7 February 2050.

This national scenario is linked to Shared Socioeconomic Pathway (SSP) 1. The general description of SSP1 is given below. Note that the SSP describes global conditions and hence some of what is described may not be the case for Grenada. The national level scenario will be influenced by prevailing global conditions and developments and as is the case today will provide the macro conditions within which all nation states operate. This is not to say that nation states mirror in every respect what happens at the global level since each nation state still has agency to shape their future through local actions and responses. This brief description can be used as a guide to developing the national level scenario.

Box 6.28. Basic description of Shared Socioeconomic Pathway 1 (Hausfather, 2018)

SSP1. Sustainability – Taking the Green Road (Low challenges to mitigation and adaptation)

“The world shifts gradually, but pervasively, toward a more sustainable path, emphasizing more inclusive development that respects perceived environmental boundaries. Management of the global commons slowly improves, educational and health investments accelerate the demographic transition, and the emphasis on economic growth shifts toward a broader emphasis on human well-being. Driven by an increasing commitment to achieving development goals, inequality is reduced both across and within countries. Consumption is oriented toward low material growth and lower resource and energy intensity”.

Population and demographics

In 2050, the population of Grenada stands at 128,000 after peaking in 2040. Fertility rates have continued to decline to the extent that since 2020 it has dropped below the replacement rate of 2.1 births per female and by 2035 it had stabilised at 1.2 births per female. Infant mortality rates have stabilised at 12 deaths per 1000 live births whilst life expectancy has seen only a minor increase over time. Migration rates have fallen but in spite of the improved economic and social conditions, outward migration continues which is particularly marked in the 20-35 age cohort. This has been balanced by an increase in inward migration of older returning nationals as well as others attracted by the prospect of living and working in the Caribbean. In terms of the population age distribution this now looks more like a column structure rather than a pyramid, with a ‘pinch’ for the 20-35 age groups. The dependency ratio, the proportion of non-working age persons to the working age population (those under 15 years old and those over 65 years old), has shown a very gradual increase over time from a figure of around 50% in 2020 to 55% in 2050.

Life expectancy has increased from 72 years in 2020 to 80 in 2050. Under this scenario, unemployment rates are low (~15%) with a greater percentage of the population in work, with the retirement age increased to 68. Family structure has shown a continued trend in decreasing household size, particularly noticeable in the urban areas. The number of female-headed households has increased, in the 2020's the figure was around 47%, it now stands at 55%. The trend in urbanisation accelerated during the period 2020-2035 but since then demonstrated a much slower rate of increase. In 2050 approximately 70% of the population is urbanised and concentrated in the south-eastern part of the island.

Carriacou and Petite Martinique, while mirroring many of the trends seen on the mainland, have in contrast experienced little change in their overall population numbers- around 6,000. However, the age structure does differ, with a significantly higher percentage being in the over 65 years cohorts. Carriacou, in particular, benefits from influxes of seasonal long-stay visitors.

Economic activity

The persistence of high energy prices and impacts of global events on food production has provided the impetus for the adoption of a stronger and effective role for regional cooperation. This results in an economic transformation of the Caribbean region with agriculture, food security, and energy self-sufficiency being given a high degree of importance. Energy self-sufficiency was eventually achieved by 2035 and a significant substitution of food imports was achieved by 2040, reduced from 70% in the mid-2000s to 35% by 2040. The resulting foreign currency savings achieved from a reduced food import bill have been reinvested in the building of more resilient infrastructure. The revision of the CARICOM Single Market and Economy (CSME), a process begun in 2025, was eventually fully realised by 2030 which also provided the impetus for the growth of new industries based in part on agro-processing but not dominated by it. Education, together with research and development have emerged as growth sectors. Tourism remains a key economic sector but has been diversified and expanded beyond 'sun, sand and sea' offerings, exploiting new markets, such as medical tourism. The improved economic position of the region has been facilitated by the development of innovative financial instruments such as the Bridgetown Initiative which have been used to counter the economic impact of climate related disasters. The new financial instruments were developed out of the agreement on Loss and Damage under the Revised Warsaw International Mechanism in 2030 and revisions to the operations of the Green Climate Fund (GCF) and the Adaptation Fund. These proved to be catalysts for an expanded role for the Caribbean Development Bank (CDB) through the establishment of the Caribbean Sustainable Investment Mechanism in 2035. A greater political commitment to regionalisation and closer integration with Cuba, the Dominican Republic, Puerto Rico, the French and Dutch Caribbean- thus increasing the size of the Caribbean market considerably, was affected by a rationalisation and revision of the various international trade agreements governing the terms of trade between the region and other partners through CARICOM and the OECS. An important outcome of this deepening regional integration was the recognition that the cost of intra-regional transport had to be addressed as a prerequisite to promoting trade. The stronger bargaining position has allowed more favourable terms of trade to emerge. Technology transfer has been facilitated by improvements in the ease of doing business in the region. Through the adoption of the Revised CSME arrangements and the growth in regional cooperation/integration, intra-regional trade has grown enormously while extra-regional trade (imports and exports) is moderate. Foreign Direct Investment flows have been moderate up to 2035 after which they increased as a result of the increased attractiveness and growth of investment opportunities. Broad economic development was from 2030 guided by the institution of 5-year Sustainable Development Plans. The *1st Caribbean Sustainable Development Plan 2030-2040* and *2nd Caribbean Sustainable Development Plan 2040-2050* with their concomitant national counterparts, laid the foundation for targeted and coordinated development objectives and investment goals.

Reparations

In the 2010's the issue of reparations for slavery in the Caribbean began to gather momentum. There were localised forms of action whereby persons and institutions acknowledged that they had benefited from slavery and that they should undertake redemptive action. At another level, Caribbean states and CARICOM engaged in initiatives seeking action, recompense and acceptance of moral responsibility from those states which benefited from slavery. Through the late 2020s and 2030s, momentum towards restorative justice initiative gathered pace. Although not acknowledged at the time, the eventual progress made around the issue of climate related loss and damage was a key background factor in bringing about accord between Caribbean states and countries accepting moral responsibility for slavery. The UK and European governments began negotiations on the 2013 CARICOM "*Ten Point Plan for Reparatory Justice*''. Not all parts of the "Ten Points" were accepted, for example the claims for indigenous reparations were abandoned because the Caribbean governments themselves were shown to have failed to protect the interests of the indigenous communities under their care in Belize, Honduras and Guyana.

From the late 2030s, there has been an increasing number of programmes that have sought to specifically address legacy challenges such as: attending to the public health crisis due to poor nutrition; emotional brutality and stress due to slavery, genocide and apartheid; eradication of illiteracy; debt cancellation to address 'fiscal entrapment'; and technology collaboration, academic exchanges and knowledge transfer for greater access to scientific and technical advances. On the cultural side there has been an expansion of ties, exchanges and African knowledge programmes that have fostered closer links between the Caribbean and the African continent. The inflow of different forms of resources linked to reparations has been a contributory factor in the transitioning of the Grenadian economy.

Economy

The GDP in 2050 is estimated to be US$2,220 million or US$22,200 per person. Although by 2020, Grenada's Debt to GDP ratio had dropped to 60%, due to the COVID-19 Pandemic this increased to 78% in 2022 and peaked at 87% in 2024. In order to manage the economy and stimulate growth, the government aimed to cut the debt to GDP ratio back to 60% and to do so through a combination of debt forgiveness and a programme of debt-for-nature swaps in committing to the implementation of land and marine PAs. By 2030 through these measures, Grenada had reduced its debt to GDP ratio to 58% and in doing so, attracted significant foreign direct investment (FDI) whilst having phased out the Citizenship by Investment programme, as a result of international pressure.

In the early 2020s the number of persons classed as poor or in extreme poverty were 30% of the population, 40% were low income and 25% could be classed as middle income with approximately 3% in the upper income range. Unemployment rates were around 20% with higher rates among the youth and females, and higher levels of both poverty and unemployment outside of urban areas. Most of the working poor were concentrated in construction, agriculture and fisheries (agriculture and fisheries contributed ~7% of GDP yet employed 12% of the workforce). By 2050 the percentage of the population in the poor and low income categories had been substantially reduced to 10% and 25% respectively. Concomitantly, the number in the middle income range has increased to 40% of the population and those in the upper income to 15% of the population. In terms of contributions to GDP, in 2050 tourism contributes 30%, agriculture and fisheries 20%, education 20%, industry 10%, and services and the rest 20% of GDP. A contributing factor to the rebalancing of the economy was the growth of the food production sector.

The National Sustainable Development Plan and Action Plan 2020 - 2035 provided the basis for the transition of the Grenadian economy. However, the challenging economic fortunes of Grenada and the region up to 2025 meant that many of the initiatives were delayed or not able to commence. From 2030, development goals were set out in the *Caribbean Sustainable Development Plan - National Counterpart Plan*. As a result, the important economic sectors in 2050 include tourism, food production systems, education including research and development, health and wellness and to a lesser extent business services and technology. Incorporated into these sectors are circular economy approaches, the significant reduction of waste and minimisation of pollution, recovery and reuse of resources, and regeneration rather than extraction of resources.

Today in 2050 the overall unemployment rate stands at 7% with youth unemployment at 15%- still too high and one of the reasons for migration. Labour market participation rates have reached a high of 85% driven in part by the increase in youth employment in food production and supporting industries and the technology sectors. Much of this is down to improvements in the skills level of the workforce.

Tourism

Grenada's tourism product has diversified itself away from a reliance on 'sun-sand-sea', as well as its traditional tourist markets of Europe and North America, by expanding into Africa and South America. This has enabled it to minimise the effects of seasonal cycles and have a more consistent demand. Its offerings now include a strong ecotourism and nature-based subsector which benefited from the debt-for-nature swap programme, and the establishment of Land and Marine PAs with their emphasis on supporting and promoting biodiversity. Alongside ecotourism there is also health and wellness/medical, Orange (Arts, Events, Culture) tourism, and a growth in blended tourism allowing people to mix different tourism options within a single 'wrapper'. With the greater emphasis on sustainability and resilience, much of the tourism accommodation stock has been gradually replaced or upgraded with lower impact developments, a process that is still ongoing in 2050 as higher standards associated with sustainability accreditation are applied and audited.

While cruise ship tourism has continued, its slow growth due to health concerns has been outstripped by the growth in yacht tourism. Carriacou has emerged as the yachting hub for the southern Caribbean with the development of marina facilities in Tyrells Bay and associated infrastructure around Argyle in the 2030s. This has provided a much needed boost to the island's economy.

The increase in numbers and the diversification of tourism oriented offerings together with policies supporting local ownership has not only increased the numbers of people and businesses offering services, but has also increased local ownership and participation in the sector. Improved skills and training together with developments in technology have led to a decrease in the number of low skilled jobs and increase in incomes. Services to the sector have seen a marked increase that revolve around the circular economy approach, reducing waste generation which have created new opportunities. Technological developments allow for smart monitoring, tracking and reporting of materials and service flows allowing the use of AI to optimise performance and also enhance visitor experience- if they wish.

Food production systems

Both land- and marine-based food production systems have undergone significant transformations. Traditional food production systems have been transformed as a result of factors such as climate change, the regional drive for food security, and the impact of changes in global food production and supply that created a crisis in the late 2020s. This led to the emergence of a regional, integrated approach to achieve the goal of 80 by 40- the region meeting 80% of its food needs by 2040. This was achieved by 2038, two years ahead of schedule. It also involved a cultural shift in people's food tastes and approach to nutrition as new crops and foods have been introduced to the local diet and over the years there has been a growing uptake in vegetarian and vegan diets. One of the main hurdles to expanding agricultural production was access to land. By 2025, following on from the Food and Agricultural Organization (FAO) Land Bank project and building on approaches developed by CaneCo Grenada, support and access to farmland for persons entering the food production sector was facilitated by the establishment of the Grenada Agribusiness Development Facility which also manages land bank operations.

The impact of climate change on weather patterns and drying conditions as well as the prospect of increasing global temperatures led to efforts to diversify the range of available food crops, to adapt existing foods- plant and animal based- to be more resilient and to include desirable traits. These efforts included the development of existing edible plants through cross breeding, clustered regularly interspaced short palindromic repeats (CRISPR) gene editing and pentatricopeptide repeat (PPR) to become part of cultivated food crops. Additional initiatives focused on novel food sources such as insect farming using organic waste for adding protein to existing food products such as flours as well as an animal feed. Some of the research was carried out in the Caribbean, enabled as part of the expansion of the region's research and development capacity. With the integrated regional approach to food security, Grenada's food production systems were targeted with a range of food crops for which its climate and land attributes were suited. The eastern and northern parts of Grenada are still the traditional farming areas with previously abandoned lands brought back into cultivation. In order to meet food security targets, the agricultural industry underwent a major period of land reform and restructuring during the 2030s and early 2040s, marking a transition away from low-technology farming enterprises, and included farm consolidation, the emergence of small and medium sized farming enterprises and service providing companies. This included the emergence of a locally manufactured fertiliser industry using a variety of organic materials. The establishment of a Caribbean food certification system has facilitated some farming SMEs including apiculture and aquaponics.

The establishment of the Grenada Agribusiness Development Facility played a pivotal role in enabling the transition, which the government facilitated to encourage partnership investment in research and development. There is now a mix of field and protected agriculture. A part of the transformation of the agriculture sector has been the growth in importance of orchard and tropical fruit crops which capitalised and expanded the traditional nutmeg, spices and cocoa growing to include new varieties. Agricultural practices are in keeping with the transition to a circular economy, more reliance on locally manufactured organic fertiliser and animal feed, biological controls, and soil restoration practices. A growth subsector has been hydroponics of which young agribusiness entrepreneurs were early adopters in the mid to late 2020s. Their success was in part responsible for the triggering of a change in attitude towards farming and food production as a profitable business.

Although there has emerged more of an emphasis on crops, similar transformations have taken place in the livestock, egg and poultry, small ruminant, and dairy sector. Here, animal welfare concerns have had to be addressed and as a result, the short-lived move to large scale intensive livestock feedlots was phased out. Grenada is now self-sufficient in the pork, egg, poultry and small ruminant sectors and with greater regulation of environmentally friendly and climate smart agricultural practices extending into this sector.

The transformation process was not without social tension and resistance which delayed the transformation of the sector. The town of Grenville has emerged as the food processing capital of Grenada, from which its local economy has benefited. The town has become an agroindustry processing hub as well as the location of companies offering specialised agricultural services as well as training and research enterprises. One of the outcomes has been that attitudes towards a career in agriculture have changed dramatically, it is no longer seen as a low income, manual intensive industry but now extensively employs ICT, remote sensing, smart systems and AI to run all aspects of the businesses. It is fully integrated into local and regional food production supply chains.

Overall, facilitated by significant sector investment, Grenada is now a net exporter of a range of high value processed food crops though it still remains a net importer of other food products such as meat and dairy.

In the late 2020s marine-based food production underwent improvements due to restructuring and better fisheries management facilitated by the development and adoption of regional fisheries management as well as better fisheries management by the Grenada government in response to the over-exploitation of fish stocks. The development of the regional fisheries mechanism spurred investment in pelagic fisheries and at the same time transitioned the nature of fisheries activities. This became increasingly necessary as the combined effects of climate change and overfishing strained the economic viability of traditional fishing activities as the sector sought to move beyond artisanal formats. However, advances in marine aquaculture and increased capitalisation through FDI have led to the emergence of mariculture, once concerns over possible contaminants were fully addressed, as an important economic activity with the establishment of offshore fish and seaweed farms as part of an expanded value chain. Advances that led to increases in yield and mechanisation of harvesting brought start-up and operational costs down allowing the seaweed farming industry to become profitable. Seaweed is processed onshore into a range of products including food, biodegradable packaging and plastic alternatives, gelling/thickening compounds used in healthcare products and medicines, and fish feed. One of the side effects of these transitions has been decreased pressure on nearshore/reef fish due to establishment and expansion of marine PAs. At a smaller scale a niche conch and sea urchin farming subsector has emerged, also benefiting from the advances in ICT supported marine farming.

Similar to seaweed farming, technology transfers and advances in the use of machine learning and AI have increased efficiency and profitability, leading to the establishment of an offshore fish farming sector. The use of AI and ICT technologies continue to improve feed efficiency and monitoring of fish growth and health. These allowed the industry to address problems associated with negative impacts on biodiversity, disease and parasite transfer and pollution. The widespread use of blockchain technology has increased the transparency and accountability of the fish and seaweed farming and production systems together with independent certification systems. Production is undertaken by local companies serving the Caribbean market. The introduction and increased use of ICT and certification systems has revolutionised traceability and ethical sourcing allowing access to high value markets.

Education, research and development

Grenada was in a favourable position to benefit from the expansion of the tertiary education sector initiated by the OECS building on the example provided by SGU and driven by the development of PPP. The advances in remote learning driven by the 2020-2023 COVID-19 pandemic were integrated into classroom-based teaching, enabling universities to establish satellite campuses in the Caribbean, such as for example the Hartman University Town and Resort. These campuses attract foreign students who wish to combine high quality academic offerings with the experience of living in the tropics. The campuses included centres of excellence for postgraduate studies and research, attracting funding from international funding institutions. An example of this was the establishment of the Caribbean Agricultural University outside of Grenville in 2030. The new build facilities, attractive working and living conditions and a focus on a mix of academic and skills development has resulted in an inward migration of highly qualified graduates from within and outside of the region. One result has been an increase in the number of people with higher degrees. The higher skills levels and the establishment of innovation hubs have supported an increase in the number of start-up companies, as well as persons servicing other sectors of the economy such as food production. This upward transition in the general level of education has drastically reduced the emigration rate out of Grenada and increased employment opportunities. Grenada started to see the benefits towards the end of the 2030s and into the early 2040s. One result of this increase in level of education and skills has been that the Civil Service has also benefited with significant outsourcing of functions, increasing its efficiency, effectiveness and responsiveness, allowing it to focus on policy formation, legislation and regulatory environments- a service enabler rather than a service provider.

Health and wellness

Building on the presence of SGU, the expansion of the tertiary education sector and an emphasis on skills development positioned Grenada to develop as a regional leader in Health and Wellness provision (e.g. Hartman University Town and Resort) and Veterinary Medicine. This combines the provision of using state-of-the-art technology to deliver personalised wellness and medical care, biomonitoring, health and wellness programmes that have become part of the country’s tourism offerings. The success of this sector and the designation of Grenada by CARICOM as one of its Health Sector Centres of excellence attracted inward investment and spin-off growth. This has included the harnessing and development of tropical plants for medicinal purposes and other products. Whilst there have been advances in reducing the prevalence of non-communicable diseases, there have been increasing incidents of emerging diseases which have made the improvements in health and wellness an important containment strategy.

The Veterinary Medical School also benefited from expansion supporting the animal farming sector predominantly in the southern and eastern Caribbean given the relatively small size of the Grenadian animal farming sector. It has joint programmes with the Caribbean Agricultural University.

Business services and information technology

The global spread and development of interconnectivity, data mining, machine learning and AI together with 3D printing has allowed the service sector to expand the range of products and services that it can offer. The retention of skilled persons coupled with the opportunities coming from other sectors of the economy, such as food production, has increased the number of persons in this sector and allowed it to grow significantly. The blurring of the distinction between work and home and remote working has brought about other changes. Examples include the reimagining of urban environments as demands for physical retail and office space have decreased.

Transport

The transport sector includes air, sea and land transport systems. The growth in tourism has meant that air travel has continued to grow and by 2030, the MBIA underwent a complete upgrade to cope with the increase, with a new terminal constructed and a further terminal built in 2045. The growth of Grenville as an economic hub, led to the redevelopment of the Pearls International Airport, principally to handle freight and service the growing volume of trade.

The growth in regional trade outstripped the capacity of the St. George's Port to handle import and export cargo. However, finding a suitable alternative site was problematic but eventually in 2037 a compromise was found and Grenville was chosen as it had historically functioned as a port for many years already; a new port complex was developed with a special focus on servicing the mariculture sector.

The upgrading and development of the road transport system proved to be very problematic during the 2020s. Changes by manufacturers and a growing global momentum eventually led to a requirement that from 2040 all vehicles would have to be zero-emissions vehicles, so now in 2050 all vehicles are either electric or use other forms of renewable energy. Such changes were pivotal to Grenada meeting its NDC targets. The increasing urbanisation of Grenada around a limited number of urban centres, shifting demographic trends, changes in energy sources, the availability of semi-autonomous vehicles and the growing use of big data necessitated a change in approach to town planning and in particular the provision of public transport services. One effect of this has been the reduction in employment in transportation brought about through streamlining of and more efficient delivery services and the phasing out of fossil fuelled vehicles by 2045 ahead of the 2050 deadline.

Through the use of 'Networks of Things' (NoT) linked to data analytics and travel apps, a range of demand-responsive transport options provide an efficient transportation system, particularly since the number of private vehicles has decreased dramatically. Using these forms of transport is simple thanks to seamless booking and e-payment systems and a thriving entrepreneurial spirit among a range of commercial, social and government transport providers. A core feature is flexibility, with vehicles and services that adjust to the needs of individuals.

Inter-urban transport is integrated with the intra-urban transport system through the establishment of local transport hubs. For the transport of goods, again the combination of 'NoT' and data analytics allows for the optimisation of journeys and energy use efficiency. This information is shared with the Transport Agency, facilitating transport corridor condition monitoring for proactive maintenance and upgrades.

Energy

Grenada had transitioned to using 100% renewable energy by 2035, a transition made possible by improvements in energy storage technology. Energy is generated by a mix of technologies but mostly solar PV, wind turbines, waste-to-energy and biogas, and the Government has committed not to exploit hydrocarbon deposits within Grenadian territorial water. Attempts to develop geothermal energy proved unsuccessful and were abandoned, though in the late 2040s it started to attract renewed attention. There is still a power station as a backup and baseload source but this uses imported biofuels. Energy generation is decentralised, comprising a network of mini-grids. After the purchase of Grenlec by the Government in 2022, it gradually transitioned away from being an energy producer to a grid and power management company. Solar PV power generation is from a mix of individual household, community and private solar farms, whereas the wind farms are community and privately owned. Both Carriacou and Petite Martinique are power self-reliant. The development of renewable energy was for a time hampered by uncompetitive feed-in rates and resistance by Grenlec. However, in the mid to late 2020s, increasing fuel import bills, pressure from local power providers and a realisation by the Government that it was not going to achieve its renewables and NDC targets brought about a change of policy. A more conducive policy and regulatory environment was established by 2030 which led to the phasing out of energy generation from fossil fuels. The greatly increased generating capacity facilitated changes in the local transport sector.

By 2040 all high power cables had been 'undergrounded' as a resilience measure.

Telecommunications

The rise of the NoT, the arrival of 10G, Artificial Wisdom (AW), and Hyper Intelligence (HI) has significantly enhanced connectivity and interconnectivity, as well as real-time response rates. Accompanying this has been the enormous increase in the collection, analysis and application of data in all spheres and aspects of Grenadian life. Advances in signal analysis and active 'swarming' of devices has revolutionised the ways in which data can be collected and utilised in real time, ranging from detecting changes in local weather conditions, seismic activity, plant vitality, pollution and contamination, and the use of resources enabling micro-trading. The combination of ICT and blockchain technology has greatly expanded the uses to which they have been put, enabling a growth of peer-to-peer and business-to-business exchanges not only within Grenada but across the Caribbean, significantly lowering transaction costs. Remote and local sensing has now been blended. The successor to cell phones has replaced identification cards and other forms of identification. Anonymised data and app use with stringent privacy safeguards allows optimisation of the delivery of a whole range of services including personalised health and wellness care. Maintaining and expanding the physical infrastructure alongside the operation and maintenance of the services has supported significant job growth in this sector.

Utilities (water, sanitation and solid waste)

Projections made in the mid-2020s of the impact of climate change on water resources were largely ignored by planners and decision makers, partly because of the expected improvements arising from the Grenada Climate Resilient Water Sector (G-CREWS) project supported by the GCF. It wasn't until the disastrous prolonged drought of 2032-35 that attitudes changed. The earlier projections of a 20%-40% decrease in rainfall coupled with temperature increases of 1.5°C provided projections that water yields would drop by at least 25% with the flows in rivers decreasing dramatically in the dry season as groundwater supported base flows dropped. By 2050, the projections of a decrease in water availability of 25% overall and significantly more during the wet season were largely realised. At the same time, actual total demand for water has increased by 20%, particularly marked in the tourism and agricultural sectors.

However, the projected water deficits have been largely averted following the adoption of a raft of measures following the mid-2030s drought emergency. In fact, the volume of water abstracted from water resources has

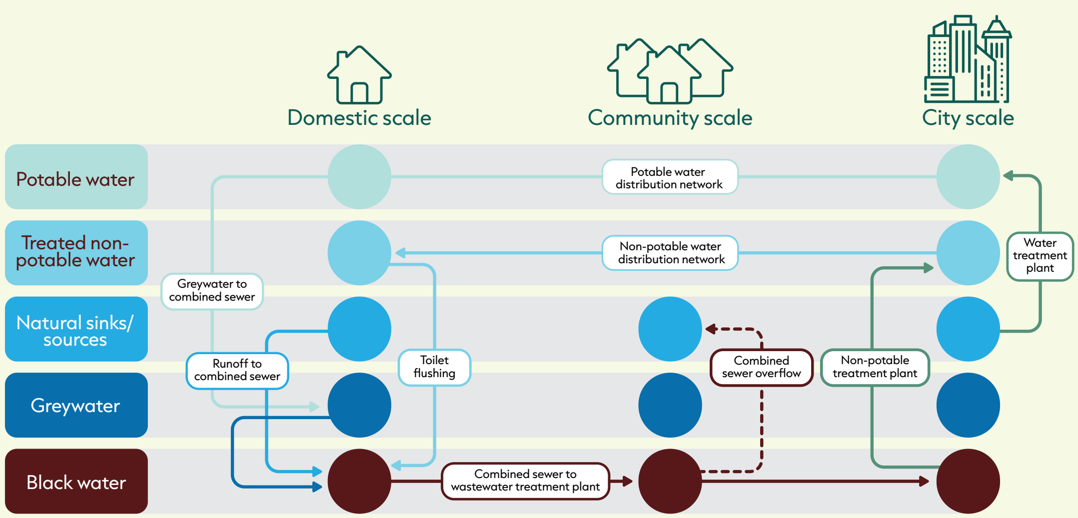

Figure 6.8. Central distribution of dual grade water (Twenty65, 2023)

dropped by 50% compared to abstraction in 2025. The reasons behind this are a combination of greater use efficiency, circular water reuse, and increased water capture and use, and a move to hybrid centralised/decentralised water systems, (Figure 6.8). Water, wastewater and stormwater have been integrated through a combination of municipal and domestic scale systems with dual quality supplies and the integration of 'under-the-sink' treatment. The integration of ICT and AI into systems operation and management as well as consumption optimisation has resulted in a significant decrease in per person usage (120l per person per day). The transition though was costly and was only fully realised by 2045.

One of the main challenges that was addressed was that of water storage to cope with increased climate variability. A series of major water storage dam projects were initiated in the Grand River, Pearl River and Beausejour River watersheds. These impoundments together with a reassessment of the trunk main transfer capacities and the development of groundwater resources have increased the security of supply, particularly during dry periods. Other efforts included an increased emphasis on rainwater harvesting at the property level and stormwater management measures within urban areas to offset demand during the 'new normal' average rainfall conditions helping to offset demand on traditional resources. These sources have been integrated into the urban water supply environment, reducing demand.

The greatest change though has been in the way water services are provided which has piggybacked on spread and adoption of technological advances that started to come to fruition in the late 2020's, supported by changes in planning and building codes.

Water distribution systems are now autonomously managed and maintained by waterbots which together with self-healing materials, ICT, data analytics and AW have reduced water losses and improved water supply operations and maintenance, reducing costs. At the same time, advances in water treatment technologies and water quality surveillance have allowed the tailoring of quality to suit different uses allowing water reuse within properties. Achieving this required significant investment in water services which was only completed by 2042. The reduction in water required by the domestic, industrial, business and tourism sector has allowed water to be directed to support agriculture though this sector too has been subject to strict water allocations and use efficiency monitoring backed up by the use of economic management instruments and reporting requirements.

The reduction in the amount of water abstracted has been influenced by the improvements in wastewater management and wastewater treatment technology. This has been accomplished by a mix of centralised and local area wastewater systems, the introduction of which was facilitated through the increase in urbanisation, accompanying planning and development requirements as well as the transition to a circular economy. Advances in resource recovery technology have been such that phosphorus and nitrogen are recovered for reuse in agriculture, whilst sludge is used as inputs into biodigesters for energy recovery and the biosolids pelletised also for reuse in agriculture. Within the urban environment the recovered water is reused within the water systems for purposes via dual plumbing. Outside of the greater St. George's, Gouyave Grenville metropolitan areas, decentralised and individual wastewater systems with more limited resource recovery facilities have been introduced. The result has been to drastically reduce land-based point source pollution. Monitoring of the performance of the distributed and individual wastewater treatment systems has aided the development of a collection, recovery and reuse business.

Overall responsibility for the provision of water and wastewater services continues to remain with National Water and Sewerage Authority (NAWASA). However, as an organisation, it has had to undergo significant transformation in how it does business in order to be able to keep up and adopt new technologies and working practices. Overall, skillsets have transitioned to a greater emphasis on technological skills. As part of this transition, NAWASA now includes partnership arrangements for specific parts of its operations. The improvements in water services in part linked to increased urbanisation required major capital investment. A result and condition of accessing finance for the expansion and upgrade during the 2030s was the requirement to move towards cost recovery. Much of the impetus for improving water resource use efficiency was driven by the Water Regulatory Agency, an independent body set up under the OECS to oversee the environmental and economic management of water resources and services. The Agency was set up in 2029 in response to the water crisis that hit the Eastern Caribbean between 2026-2028. OECS States recognised that individually they had limited resources to manage their water sector and that fresh thinking was required in the face of the climate crisis.

The solid waste handling and treatment industry has been transformed through a series of international, regional and local initiatives. The development of cheap substitutes for plastic, the introduction of extended producer responsibility obligations for the Caribbean in 2032 along with the adoption of the Wider Caribbean Packaging and Packaging Waste Protocol, and requirements for products to be designed for resource recovery which came into effect in 2045 after a 10 year transition have contributed to that transition. In 2023, the Grenada Solid Waste Management Authority (GSWMA) started to implement the *National Solid Waste Management Strategy* which set out actions to be undertaken over a 20-year period with revisions and updates every 5 years. The strategy, which included new legislation and regulations was revised, after a delay, in 2030 and led to the rebranding of GSWMA as the Grenada Sustainable Resource Recovery Company. The revised strategy increased the diversion and recycling rate targets but also adjusted the achievement dates. The revised strategy included a financial, economic appraisal and investment plan, which also covered energy from waste proposals not realised under the previous strategy. In implementing the plan, waste segregation at source was introduced, backed up by differentiated block collection tariff. After some implementation problems and customer resistance, recycling rates improved significantly. The *2035 National Solid Waste Management Strategy* noted the progress made in achieving most of the previous targets and focused on supporting the development of resource recovery programmes. Whilst the operation of the Perseverance Landfill site contributed to the achievement of the strategy goals, this was not the case with the Dumfries Sanitary Landfill in Carriacou due to operational and financing challenges. As a result, in 2040 a recommendation was made that the site be re-engineered, as a pilot, to test the feasibility of 'mining' the landfill to test the extent to which it was possible to recover resources.

Technology

Technological advances have been seen in the growth of the use and application of 3D printing. This growth has been spurred on by advances in computing power, the spread of AI, biomimicry/mechanic/biochemistry and the development of new materials and manufacturing processes. As a result of these technology developments, this has lowered the cost of production, improved reliability and at the same time increased the functionality and use of sensors.

The use of remote sensing, encompassing satellite-based systems to micro-drones coupled with data mining, machine learning and AI, the use of sensors and advances in communication technology have become routine tools for observation, monitoring and decision making. These advances have enabled the development of a range of tools including digital twins and real-time monitoring, the NoT, and the immersive reality (avatars). The rise and applications of these technologies are routine parts of the operation and management of food production systems, ecosystem management, management of the provision of goods and the delivery of services. The scale of development and technology transfer has lowered costs and at the same time a backlash against monopoly practices and the introduction of regulatory controls on the likes of Google and Amazon 'democratised' the Technology sector allowing the growth in SMEs. Access to data along with the widespread use of blockchain verification has increased confidence in data and its provenance. However, it has also given rise to an expansion of cybercrime and an increase in the use of surveillance. Society globally is concerned about the blurring of the distinction between the personal and the public with some states adopting a more intrusive stance in the name of public safety and order.

Social and welfare infrastructure

Declining fertility rates, coupled with the increase in the proportion of people in older age groups and the fall in overall population numbers has led to a significant reduction in the numbers of those in the primary and secondary school education system. There has also been an increase and concentration of the urban population. The improvement in the performance of the economy allowed the replacement and upgrading of school infrastructure, incorporating advances to make them more disaster resilient and integrated into a circular economy with more flexible use of spaces and multi-purpose uses to be able to serve communities. It was recognised in the late 2020s that the education system was significantly underperforming and without investment in teacher education and revisions to the curriculum, the ability of the economy to grow would be severely hampered. Investments were made in teacher education and efforts to make the profession more attractive; class sizes were reduced and the examination-based curriculum replaced by an emphasis on learning outcomes, and learning and skills development. The teaching role is supported by technology allowing for a more individually tailored learning experience, in effect, each child has their own teaching assistant. Other developments in the curriculum have included incorporating more physical activities, civics and connection with the environment as core features. As a result, the number of students going on to higher education or vocational training has increased, with an equal number of male and female students. As indicated, there has been an increase in tertiary level education opportunities with the expansion of universities and an emphasis on encouraging Caribbean integration.

Health services have been revolutionised by the advances in the use of technology as well as by the establishment of Grenada as a regional centre of excellence for health. It is now possible to track personal health status in much greater detail and to use the data collected to provide personalised health and wellness services including self-management at a lower cost. As a result, health outcomes for the population have improved and the prevalence of non-communicable diseases has decreased. This trend has been aided by changes in diet and nutrition brought about through the push for food security and the adoption of new food sources. Improvements in the management of risks from natural disasters such as hurricanes and heatwaves have resulted in a decrease in the number of persons adversely affected, whilst changes in transport have lowered accident rates. However, the increased occurrence of new and emerging diseases continues to challenge the health care services including the management of loneliness accompanying an ageing population and exacerbated by the management of new communicable diseases. Improvements in test and trace, changes in working practices and in education delivery, and the application of lessons learnt have to a degree lessened their impact. The rise in the number of persons affected by forms of dementia is among the greatest challenges being experienced by the health care and welfare sectors and has been exacerbated by changes in family and household structure. On the other hand, there have been advances in health and wellness care systems which have partially but not fully ameliorated what would otherwise have been a serious situation.

By 2050 with the improved economic position, better educational outcomes and improved working conditions, people and communities are now more politically engaged and effective consultation is the norm. The use of ICT has enabled greater connection and communication between communities, civil society and those in government. This development, starting in the mid-2040s has allowed the incorporation of the views of the Grenada diaspora on certain development issues- subject to conditions. On the other hand, it has allowed more polarisation of views and attitudes to develop, amplifying divisive minority views. Urbanisation and a greater consciousness of environmental issues has moved the environment up the political agenda and there is more social and environmental activism.

The Government continues to be involved in social protection and welfare services. The delivery of these services is now easier to accomplish due to several factors such as an improved economy, the use of ICT and AI, and the growth of a digital economy making targeted interventions easier to effect. Welfare services are delivered through different service providers under a programme instituted in 2042 aimed at using advances in technology to provide improved care.

Governance

Grenada is signatory to a number of key environmental agreements which set the backdrop for its management, conservation and restoration of its natural environment (See Chapters 1 and 5). Whilst many of these remain in force, having been periodically updated, a few have been revised or replaced. *The Paris Agreement* was revised and extended by the Gaborone COP35 in 2030 in light of developments in limiting GHG and agreement around Loss and Damage as well as changes to the GCF. Regionally, the Cartagena Convention and its Protocols (Annexes I to III) were overhauled, placing greater emphasis on sustainability and combating climate change. There were also successors to the SDGs and the Sendai Framework which came into force also in 2030.

During the mid-2020s the Government continued its personnel policy of restricting recruitment with the result that the Civil Service shrank significantly, and its effectiveness declined. As a result, CSOs increasingly took on semi-regulatory and proactive roles, basing their legitimacy on their representing the views and will of the people. By the late 2020s and early 2030s the Grenadian economy was starting to experience the benefits of economic growth and government revenues had improved considerably. Instead of expanding the Civil Service and seeking to expand its control, a system of polycentric governance emerged (see the work of Vincent and Elinor Ostrom) funded through the government and promoted through the reforming of the Public Service Commission. For some, this amounted to the outsourcing of government responsibilities to the private and third sector (e.g. trade unions, community organisations and social enterprises). However, the loss of the ability of the government to provide services had eroded trust and working with the private and third sector was seen as a way to rebuild that trust. The successful emergence of this form of collaborative governance owed much to the technological advances in data gathering and information sharing and the cross over from AI to AW and through the advances the ability to avoid bureaucratic inertia stifling progress. Coming with this has been a devolution of management responsibilities in delivering services as the role of communities, community-based organisations, CSOs and semi-autonomous government agencies have emerged. The adoption of collaborative governance involving the state and the people required a major legislative programme to legitimise and empower. This also gave legal effect to a range of regional initiatives targeting corporate social and environmental responsibility.

The ability to regulate and the enforcement of legislation has by the late 2040s been significantly strengthened but it has been supported by the development and use of a range of economic and management instruments such as legal partnership agreements, co-management arrangements, planning objectives and controls. Accompanying this has been a shift in the form and target of state subsidies and support, with much more targeted at supporting non-government entities that took on the roles that the state had let lapse in the late 2020s. As a result, the government in 2050 acts more as an aggregator and enabler.

While cabinet style politics continues, the rise of technology and the empowering of civil society has created opportunities for civil society to influence policies. A constant challenge though, still not fully addressed, has been stakeholder gridlock. and responses. This brief description can be used as a guide to developing the national level scenario.

Grenada Grows foresight scenario

Context: high emissions + circular economy

Grenada Goes sets out what a person might expect to see when going about their business on 7 February 2050.

The influences on which this scenario narrative draws include: Shared Socioeconomic Pathway 5 (SSP5) - Fossil-fuelled Development – Taking the Highway (high challenges to mitigation, low challenges to adaptation); Millennium Ecosystem Assessment's Technogarden Scenario; National Intelligence Council Global Trends 2040: A More Contested World – Tragedy and Mobilization Scenario. As well as these, inspiration is also derived from Latin America and the Caribbean 2030: Future Scenarios – Scenario 2: Governance on the Rise, from the GloLoCarSce – Island in the Sun scenario, and from Arup's 2050 Scenarios – Human Inc. These have been synthesised to provide a global backdrop against which Grenada would find itself. Approaching the development of Grenada's scenarios and pathways in this way recognises that there are factors which will influence the country's ability to shape the state of its ecosystems and biodiversity over which it can exercise only some control, whilst also recognising that the country does also have some agency to shape its responses to external factors, to internal challenges and to national aspirations.

Box 6.29. Basic description of Shared Socioeconomic Pathway 5 (Hausfather, 2018)

SSP5. Fossil-fueled Development – Taking the Highway (High challenges to mitigation, low challenges to adaptation)

"This world places increasing faith in competitive markets, innovation and participatory societies to produce rapid technological progress and development of human capital as the path to sustainable development. Global markets are increasingly integrated. There are also strong investments in health, education, and institutions to enhance human and social capital. At the same time, the push for economic and social development is coupled with the exploitation of abundant fossil fuel resources and the adoption of resource and energy intensive lifestyles around the world. All these factors lead to rapid growth of the global economy, while global population peaks and declines in the 21st century. Local environmental problems like air pollution are successfully managed. There is faith in the ability to effectively manage social and ecological systems, including by geo-engineering if necessary".

International relations

Coming on the back of the COVID-19 pandemic, the war in Ukraine which dragged on for nearly five years ending in a stalemate similar to that of the Korean conflict, resulted in massive global disruption. The repercussions persist through well into the later 2030s. The economic shocks affected all countries and the politics of Western countries, and posed grave threats to liberal democracies, especially in Europe. A UN report at the time noted: "The ripple effects of the conflict are extending human suffering far beyond its borders. The war, in all its dimensions, has exacerbated a global cost-of-living crisis unseen in at least a generation, compromising lives, livelihoods, and our aspirations for a better world by 2030." The war and its aftermath led to an acute energy crisis with high volatility around energy prices. The restrictions on the availability of Russian energy sources i.e. oil and gas added to the drive to exploit new sources of fossil fuels by Western nations to offset the loss of Russian energy. While the same market conditions also provided an impetus to the renewable energy industry the increased reliance on fossil fuels lead to increased GHG emissions. The emphasis of most of the Organisation for Economic Co-operation and Development (OECD) countries has been on climate adaptation rather than mitigating climate change. At the same time, the protracted war and its impact on the major grain production areas of Russia and the Ukraine as well as loss of fertiliser production created massive food shortages and triggered an inflationary spiral across the world. One effect of this was the emergence of a bi-polar world of two overarching economic blocks. A western bloc encompassing the United States, Western Europe and their allies, and China with Russia as effectively a client state.

The emergence of a bi-polar world has for the western bloc increased faith in competitive markets, innovation and participatory societies to produce rapid technological progress and development of human capital as the path to sustainable development. Adaptation to climate change has spurred investments in health, education, and institutions to enhance human and social capital. The push for economic and social development is coupled with the adoption of resource and energy intensive lifestyles around the world, but only for those who can afford it. These factors lead to rapid growth of the global economy with local environmental problems like air pollution being managed through adaptation measures. There is faith in the ability to effectively manage social and ecological systems.

By the early 2030s, the world was in the midst of a major crisis brought about by economic conditions and the effects of global warming. Rising ocean temperatures and acidity devastated major fisheries already stressed by years of overfishing. At the same time, changes in precipitation patterns and the high cost of inputs e.g. fertilisers and energy depressed harvests in key grain producing areas around the world, driving up food prices. With the disruption of distribution supply chains endemic famine became a feature of developing countries in the 2030s, while developed economies moved to secure food supplies through hoarding and reorientation of trading relationships. The inability of some governments to be able to meet basic human needs created widespread unrest. Rising sea levels and increasing extreme weather conditions led to rising humanitarian and economic harm.

Towards the end of the 2030s the ongoing crises famines kick-started a global movement that advocated bold changes to address environmental problems and led to a reinvigoration of the Conference of Parties (COP) and IPCC processes. The non-governmental organisations (NGO) and CSOs developed a larger global following than those governments that were perceived to have failed their populations and allying themselves to progressive 'Green' political parties to bring about systemic change. As the movement grew, it took on other issues including global health and poverty. Spurred by the environmental crisis and growing political unrest the two major political blocs came together to agree on a revitalised international order to address their common challenges and in 2040 agreed on a new date of 2050 for achieving SDGs.

This resulted in a new international organisation, the Human Security Council, in cooperation with developing countries, which focused on transnational security challenges. Open to both states and nonstate actors, membership required a commitment to verifiable actions to improve food, health, and environmental security. It was supported through increased access to funding provided by a new international financial architecture that replaced the likes of the World Bank, the GCF and the Asian Infrastructure Investment Bank. By 2038, global attitudes about the environment and human security were being transformed by growing recognition of the unsustainability of past practices. States, large corporations, and the private sector increasingly concentrated investments to advance technological solutions to food, climate, and health challenges and to provide essential aid to the hardest hit populations. Corporate goals expanded to embrace serving a wider range of stakeholders, including customers, employees, suppliers, and communities.

Caribbean societies and economies were severely affected by the economic crises of the 2030s and experienced first-hand the impacts of climate change; drying and droughts, wildfires, more powerful hurricanes and incidence of flooding associated with extreme rainfall events, and increased influx of Sargassum. During the 2040s there was a resumption of the growth of the number of persons in the middle classes. Both the middle classes and lower socio-economic groups were increasingly vocal in their demand on governments. The general global economic malaise of the 2030s gave rise to a lack of overseas migration opportunities whilst it also led to a deterioration in human development outcomes across the region. A situation which only by the end of the 2040s had begun to recover. Some of the deterioration in living standards was offset by technological improvements and the adoption and expansion of e-Government, open data, and ICT, the expansion of which enabled citizens to engage more directly with their governments and empowered the private sector. New technologies also have had a huge impact by connecting people and forging new social relationships. Concomitantly, the insecurity of the 2030s gave rise to a diminution of environmental efforts but the same insecurity through the 2040s gave rise to an increasing emphasis on the development of a circular economy by the private sector with the increasing scarcity of new raw materials. PPP have been crucial in creating the new opportunities, along with access to the new global funding opportunities. By 2040, the Caribbean started to realise increased government effectiveness, improved service delivery, and heightened transparency. Governments prioritised infrastructure and education as two vital public services needing greater investment. The increased deployment of technological innovations has been matched by a change in lifestyles and habits. Cooperation between governments in the region has increased and this allowed Caribbean states to better cope with natural disasters and the outbreaks of communicable diseases.

The turbulent years of the late 2020s through to the 2030s were characterised by slow economic growth in the Caribbean as economies suffered from global economic instabilities and lack of foreign investment. However, with the reorientation of world order during the 2040s there has been increased investment in the region resulting in higher growth rates and increased productivity during this catch-up phase. The private sector invested in training and skills development. Although the overall population has declined, the education and training investments have resulted in higher workforce participation rates and increased productivity. The global emphasis on a circular economy has by 2050 made significant progress in decoupling environment and resource use from economic growth. Since the 2020s GDP has grown by 8% with much of the gain made in the last 10 years.

Reparations

In the 2010's the issue of reparations for slavery in the Caribbean began to attract increasing attention in the region following the adoption by CARICOM of their 2013 "Ten Point Plan for Reparatory Justice" and the setting up of a CARICOM Reparations Commission. The matter was a popular one with many column inches dedicated to this issue in the press and in academia, catching the imagination especially in the light of the then prevailing poor economic conditions, global insecurities, and the effects of climate change and natural hazards. The issue was championed by a number of influential individuals and some governments such as Jamaica and Barbados among others. This resulted in localised forms of action whereby persons and institutions acknowledged that they had benefited from slavery. As a result, some forms of redemptive action were undertaken though these were limited. At the level of governments, regrets about slavery were expressed but there was little government to government engagement. In spite of continued attempts to keep the issue alive within the region throughout the 2020's and into the early 2030's, there was little positive response beyond. European governments stated that no direct reparation payments would be made and CARICOM attempts to elevate the matter drew a blank. Some governments sought alternative means of gaining recompense such as instituting differential levies on travellers from Europe but these proved counterproductive and were dropped in the face of overtures from North America. At an intellectual level, in the 2030s the issue became embroiled in competing ideological debates over the creole nature of Caribbean society, indigenous societies and of African kingdoms. As a result, much of the heat has gone out of the issue and now in 2050 it is confined to scholarly debate in academic recesses.

Population and Demographics

The population of Grenada continued to grow but at a decreasing rate plateauing in 2050 at 136,000. This has been brought about by a gradually declining fertility rate resulting in an ageing population in which only ~23% of the population are under 20 years of age. That said, some 60% of the population is of working age (between 20 and 65). Improvements in health care have led to a fall in infant mortality whilst life expectancy has stagnated, reversing previous gains (Figure 6.9). Migration rates would have increased, especially during the 2030s but strict immigration policies outside of the Caribbean curtailed this and in recent years, improved economic conditions have had an ameliorating effect. It is also noticeable that those under the age of 40 tend to be better educated and have better employment prospects.

Family structure has shown a continued trend in decreasing household size, particularly noticeable in the urban areas. However, poor households continue to be twice the size of the non-poor and with higher household dependency rates. In addition, households with older members tend to be poorer. These structural issues have contributed to the continuation of income inequalities in Grenadian society. The number of female-headed households has increased, in the 2020's the figure was around 47%, it now stands at 55%.

Urbanisation has proceeded at a slow pace. Urban growth has been driven more by changes in household sizes rather than increases in rural-urban migration of families to the urban areas in search of employment. Urbanisation has not been concentrated on St. George's but across the country. In 2050 approximately 50% of the population is urbanised.

Carriacou and Petite Martinique have not experienced any significant changes in population, with the total for the two islands being 8,000 and 2,000 respectively.

The improved economic fortunes, starting in the 2040s have improved the economic and employment conditions of the population. The percentage of the population in extreme poverty has halved to 15%, mostly concentrated in rural areas and some urban pockets. Those in the lower income groups now constitute 40% of the population with 40% being middle income. Unemployment rates have stabilised at around 15%; youth unemployment which was high up to 2040 has since then dropped dramatically because of inward investment in education and skills training. Unemployment continues to be concentrated among the unskilled but less so now among the youth. The

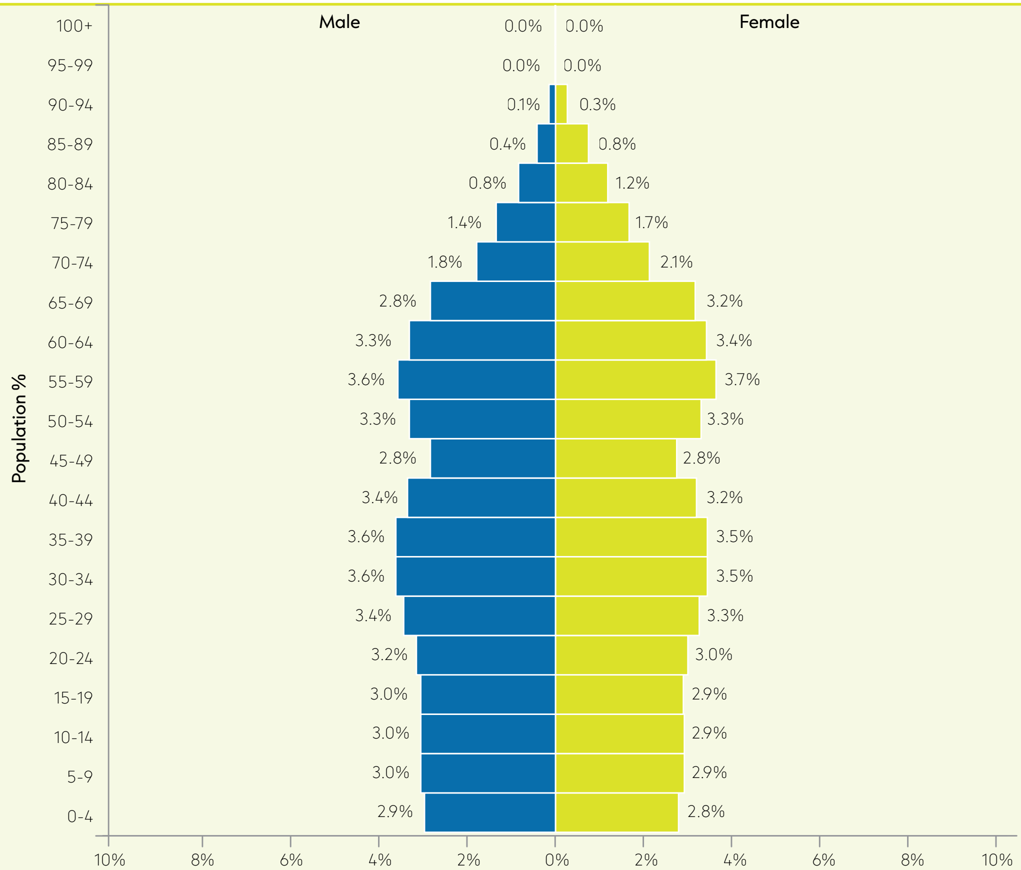

Figure 6.9. *Grenada's Population Pyramid in 2050* *(Population Pyramid, 2023)*

increase in employment has come because of economic growth opening up demand for persons with skills. At the same time, the tourism sector continues to have low-income jobs though these are not as numerous as in previous decades. Furthermore, expansion of localised manufacturing as well as food production has increased employment opportunities.

A trickle-down effect has been that there has been less outward migration, a degree of inward migration and a continued slow population growth. Beyond 2050, it is expected that there will be a slow decline in the total population and an increasingly aged one.

Climate change

Given the continued use of fossil fuels and the associated global GHG, a warming of 1.5°C above pre-industrial levels was reached by 2030 and by 2050 warming has reached 3°C. Accompanying the changes in temperature have been increased changes in rainfall patterns with a marked drying of the climate and increases in drought conditions becoming more common. Overall, rainfall is expected to decrease by at least 25% by 2050 with an increase in extreme precipitation events associated with hurricane activity. The drier conditions have resulted in frequent bushfires and air pollution from aerosols and Sahara dust has increased. The higher air temperatures have increased SST which has also had an effect on storm and hurricane activity; greater frequency and severity. The combination of higher temperatures and increased disasters (fires and hurricanes) have adversely impacted Grenada's terrestrial ecosystems. The climate changes have had severe effects on marine ecosystems which have also been severely adversely affected increasing ocean acidity, Sargassum tides, and pollution, particularly from microplastics, throughout the Caribbean.

Few attempts have been made to mitigate emissions at a global level whilst there has been an emphasis on developing adaptation measures as a means of alleviating adverse effects.

Throughout the 2020s developed countries continued to push back and prevaricate over how and what to agree on with respect to loss and damage mechanisms for developing countries. The increasing climate impacts during the 2030s added impetus and urgency to the matter. Eventually, by the end of the 2030s, agreement had been reached over the loss and damage with the signing of the Convention governing the Warsaw International Mechanism for Loss and Damage associated with Climate Change Impacts. This provided funding, technology transfers and exchange mechanisms which have contributed to global economic growth.

Geopolitics and Grenada

During the late 2020s China sought to increase its influence in the Caribbean Region; although the slowdown in its own economy was limiting, it did during this period provide investment and development funding. This enabled Grenada to invest in infrastructure projects especially in the energy sector. However, the West, and in particular the USA saw this as a direct challenge to its Monroe Doctrine and redoubled its efforts to tie the region economically into the western bloc's sphere of influence. Western businesses were encouraged to invest in the Grenadian economy, through concessionary trade and investment arrangements and by 'encouraging' the Grenadian government to reciprocate through favourable investment rules, employment conditions and environmental regulations and standards. Largely as a result of being treated as a regional bloc, the coordinating role of the OECS across trade and environment issues has increased, whilst the influence of CARICOM has decreased.

The interest of the western bloc in keeping China and its allies out of the region, the growth of western economies from the mid-2030s and on the back of the environmental crises, the revitalisation of international order and a reversion to rule-based relationships provided a further economic boost for the region and Grenada. After virtual economic stagnation up to 2040, the GDP has grown to US$2,300 million.

Economic activity

General

Grenada's economy is more diverse in 2050 than in the 2020s and 2030s as technological advances and closer ties with Western nations and particularly the USA have created new economic and employment opportunities. These have included growth in cloud laboratories, cloud manufacturing and light engineering as well as IT services and services provision. Tourism continues to be a feature of the Grenadian economy, but it is not as dominant as it once was. Education, construction, and services continue to be important. Terrestrial based food production has grown in importance. Traditional fisheries though have all but collapsed because of climate change impacts though in its place there has been a growth in other marine based food production activities.

The *National Sustainable Development Plan and Action Plan 2020-2035* set out a range of measures and interventions to strengthen society and the economy. The challenging economic fortunes of Grenada and the region meant that many of the initiatives were delayed or not able to commence because of fiscal constraints and even the slow growth of the economy up to the late 2030s hampered improvements. The Development and Action Plan, and its various iterations under successive administrations, aimed to provide the structural basis for growth. They did so by trying to address human and social challenges such as education attainment and access to healthcare and making the country and economy more resilient to climate change.

Whilst successive governments had tried to provide a supportive environment to encourage the growth of export, efforts have been hampered by the geopolitical conditions. However, geopolitical conditions started to improve from the early 2040s. The *Third National Development and Action Plan* signified a paradigm change in the relationship between government, private and third sector. This expanded the role envisaged for the private and third sector in the economy, opening the door for greater inward investment. It also acknowledged a greater role for the OECS Secretariat envisaged in the *2042 Revised Treaty of Basseterre* and the *Revised St. George's Declaration on Principles for Environmental Sustainability and Social Wellbeing*. Taken together, these measures have been able to effectively channel the increased investments from the new international financial architecture and boosted the economy.

Tourism

Grenada's tourism product has continued to rely on the 'sun-sand-sea' model though this had to adapt to the twin challenges of the economic recession of the 2020's and of climate change, particularly increased temperatures, Sargassum and hydrometeorological disasters. These factors initially shrank the tourism sector in the 2030s in spite of government efforts to grow the sector. However, as the sector globally became more adept at adapting to climate change and with the improved economic conditions through the 2040s, tourism stages something of a comeback. There is now a wider range of tourism accommodation from middle to high end and increased competition as well as growth in niche tourism products in part to compensate for the decline in beach tourism brought on by the impacts of climate change. Tourism demand remains largely tied to seasonal cycles. These cycles are dominated by influxes from North America, the European market, and South America. Employment conditions and pay in tourism have improved to recruit and retain the workforce.

The effects of climate change have all but wiped-out the ecotourism subsector though it is a particular feature of Carriacou and Petite Martinique attracting some 25,000 visitors per year and being one of the mainstreams of the local economy. Cruise ship tourism has continued to grow, though repeated health issues have damped demand from time to time. Yacht-based tourism has continued to be popular within its own niche market. Here again, new operators have sought to expand the sector through tie-ins with hotel and other tourism operators. Yacht tourism has benefited Carriacou through the development of marina facilities, though the main focus of the yacht tourism sub sector continues to be located on the southern coast of Grenada.

Both the traditional and Airbnb subsectors have access to the latest technological advances allowing them to optimise their performance and offerings to visitors. Because of the increasing threat from climate induced hazards and associated insurance costs, the tourism plant is now more resilient and able to resist the effects of hurricanes. *The 2040 Building Code and Planning Regulations* prioritised the need for disaster resilient infrastructure and requirements for minimising resource use being incorporated. At the same time the insurance sector played a significant role in ensuring that all properties meet regulatory requirements.

Food production systems

Grenada's agricultural sector has a long history of underperformance and failure to deliver on promised potential. Much of this can be ascribed to unsuccessful attempts to address the underlying structural problems identified in successive national agricultural plans. Looking back to the 2020s it is apparent now that the unsuccessful efforts led to its stagnation that, with a few exceptions, has characterised it up to 2050. The high cost of food imports experienced during the 2020s did have the effect of increasing demand for locally grown produce whilst the high prices paid for some agricultural exports offset to some extent the decline in the total area of permanent crops under cultivation. There are now some 7,000 farmers active in the sector- compared to 9,000 back in 2020 but there are a larger number who are informally engaged in agriculture, mostly as subsistence farmers to supplement other forms of income. This has brought more areas back into cultivation, reversing the previous trend, converting secondary forest back into cultivation. In 2020, 80% of the farmers were classed as small holders, basically engaged in subsistence farming. The average area under cultivation by a farmer has not changed significantly, a slight increase for food crops to 0.1ha as well as for permanent crops an increase to 1ha. The trend in mechanisation and improved agricultural practices has continued which has to a limited extent increased productivity among those for whom agriculture is a main income earner. The spike in imported fertiliser costs resulting from the global instability in the mid-2020's initially suppressed importation and agricultural production. However, it also spurred interest in the development of substitutes and alternatives; increasing the use of animal manure and Sargassum. The situation also gave rise to increasing adoption of organic agriculture and permaculture practices. As a result, the volume of imported fertiliser is now a quarter of what it had been. A similar but limited effect occurred with respect to the use of pesticides and other agrochemicals. The increase in pests, diseases and IAS, affecting crops and associated in part with climate change, continues to pose a significant challenge in moving away from the use of agrochemicals. Improvements in surveillance systems and ongoing research into pest control methodologies has had a positive impact. However, the increase in temperatures along with increased climate variability- floods and waterlogging, and increased dry spells and droughts, has adversely affected crop yields as well as animal health. The net effect has been an increased volatility of food security and swings in food prices. The incidence of food poverty among low income groups has increased- reflected in the increased numbers of families engaged in part-time subsistence farming.

By the early 2030's there were increasing concerns over the decline of the agricultural sector and a greater recognition of the limitations faced by the state in trying to bring about the changes envisaged in the National Agricultural Plan 2020-2035. This led to a re-evaluation and the emergence of a more targeted and incremental approach to trying to support the agricultural sector. The approach built on efforts to attract new entrants into the sector, alongside existing farmers, targeting selected geographic areas and working to develop supply chains and agroprocessing. It has built on the experience with climate smart agricultural practices and the uptake of onsite renewable energy generation to support transitions to smart agriculture. It has been the success of this programme that stemmed the collapse of the sector and stabilised it to some extent. The targeted interventions and better extension services have managed to encourage the uptake of technology and entrepreneurship among a small number of successful entrants and improve productivity. In 2050 there is an emerging class of more commercial food producers, constituting 35% of all farmers and farming on larger plots, alongside what continues to be subsistence farming- 65% of farmers. A side effect of this has been to increase female participation in the sector. An example of this approach was the development of insect farming to produce animal feed. By reducing feed cost, it supports the poultry and livestock sector which in turn has significantly reduced meat and dairy imports. On the flip side though, it has reversed the decline in abandoned lands and increased the area of pasturage. However, farms and other food production systems, especially but not limited to the commercial farms, have diversified and include in their activities the active provision of ecosystem services and the maintenance of biodiversity – for which they are paid under the Ecological Land Management Scheme. These changes in approaches have been facilitated by changes in land use and ownership to provide security of tenure particularly to subsistence farmers. This has allowed subsistence farmers better access to support services and financing.

The traditional fishing sector has all but collapsed in the face of the impact of climate change; coral reef bleaching and die-off, ocean acidification, loss of habitats, changes in fish behaviour and composition, and overharvesting of fish stocks. The presence of vast volumes of Sargassum compounded underlying negative trends affecting fishing effort and fish stocks. Throughout the 2020s and into the 2030s fishing effort, and the use of technology for monitoring and tracking and the use of Fish Aggregating Devices (FADs) increased but did not increase the amount caught. The rise in fish prices though continued to support the industry. This and efforts to replenish fish stocks led to a slow transition of people out of the industry and for others to diversify. The decline was also underpinned by a lack of sufficient investment in improving the fishing sector. As a result, there are small-scale fish farming efforts such as conch and sea urchin farming as well as a growth in aquaponics and hydroponics. The continued presence and large volumes of Sargassum contributed to the decline of fishing. However, the volumes involved and developments in harvesting Sargassum before mats landed led to the development of a Sargassum-based sector which has grown in importance, producing a variety of products such as bioplastics, fertiliser and food products. The industry is centred around Grenville, which has developed as a mini-industrial hub.

The loose Caribbean trading block, particularly within the OECS has improved market access conditions though the main food and nutrition policy is still one of food sovereignty and security at the national level, a policy broadly supported by the use of technology in food production.

Manufacturing and services

Manufacturing and services have been a growth sector giving rise to start-up companies which have proved to be a major factor in growing the economy. The growth and rapid development of 3D printing, the demand for services in the food production, transport, tourism, bio-pharmaceutical, utility, health care and environment sectors along with government agencies have created employment and other opportunities. Another feature that has enabled growth has been the development of cloud manufacturing and research facilities, attracting inward investment and skilled professionals.

Education

Education as an economic sector continues to rely on SGU's contribution through attracting overseas students and the provision of services to them. The closer ties with North America has, if anything, improved the performance and economic importance of this sector and encouraged it to expand its offerings and develop a new northern campus. There has been expansion with SGU's Windward Island Research Foundation (WINREF) having grown its research and development capabilities, attracting a small number of highly skilled professionals. SGU has successfully argued against the establishment of other (similar) educational institutions in Grenada, thereby retaining something of a sector monopoly.

Transport

The transport sector includes air, sea and land transport systems. The importance of tourism to the economy has meant that air travel has continued to grow and by 2035 the MBIA underwent a partial upgrade. The MBIA remains the country's main airlift hub alongside the Pearls and Lauriston Airports. The Pearls Airport near Grenville was recommissioned in the early 2040s whilst the Lauriston Airport on Carriacou had been upgraded in the 2030s. The Pearls Airport is predominantly a goods and produce export orientated facility whilst Lauriston services tourists and local air transport through the Grenadines.

Regional maritime trade was given a boost in 2025 when eventually agreement was reached within CARICOM for the free trade of goods and produce and the introduction of inter-island services. As a result, there was some upgrading of the St. George's Port to handle import and export cargo at the time.

Road transport transitions were slow through to the 2030s because of global economic conditions. The pace of introduction of zero-emissions vehicles, especially in the goods vehicles sector proceeded at a slow pace. As a result, uptake was also slow and petrol and diesel vehicles remained on the roads until 2040, though the use of biofuels in vehicles provided some amelioration. The growing global momentum from the late 2030s eventually led to a requirement that from 2040 all vehicles would have to be zero-emissions vehicles, so now in 2050 all vehicles are either electric or use other forms of renewable energy. This switch-over boosted investment in transport infrastructure and vehicle charging stations.

In terms of personal transport, although there has been a change-over to zero-emissions vehicles, individual vehicle ownership has decreased. The decrease has been driven by the introduction of car sharing and renting schemes through a public-private partnership that covers most of the larger urban centres, largely eliminating the need for private ownership of vehicles.

Utilities

Energy

The high and unstable energy situation from the mid to late 2020s prompted Grenada, along with other Caribbean countries, to address their energy security and redouble efforts to harness renewable energy. In this respect, Grenada has been largely successful in moving to being energy secure and largely carbon neutral. The self-sufficiency has been achieved through investment by the private sector, businesses and individuals investing in renewable energy systems. Installed capacity targets for renewable energy were eventually met by 2035; other NDC targets were missed, though by 2040, Grenada had achieved 50% reduction in GHG emissions and 70% by 2050. As a result of global economic growth and technological advances by 2050, 100% of all vehicles and public service vehicles are now running on renewable energy sources.

Power is generated through a mix of solar PV, wind energy, biogas and the power station that was converted to run on imported biofuels. The power station provides the base load power generation. Mini-hydropower schemes were considered but it was concluded that with the impact of climate change on river flows this would not be a viable option. As a result of inward investment in energy systems, the long-proposed waste-to-energy project was realised in the early 2040s and served to reduce the reliance on the use of biofuels imported from North America. An early issue was being able to meet demand for electrical energy and load shedding was a regular occurrence during the 2030s. To overcome this, the Government entered a public-private partnership to provide energy storage to address fluctuations in power generation. The spread of solar PV was hastened by the planning and building requirements to include it in new buildings and support schemes for retrofitting.

Water and sanitation

In the mid-2020s it became obvious that limiting global temperature rises to below 2°C was unachievable as countries and economies failed to curtail GHG emissions. The projected impact of climate change and variability on water resources given the failure to limit global heating were unfortunately realised. Decreases in rainfall of 25% coupled with the increases in temperatures and aridity have together resulted in a 25% decrease in overall annual water availability with the impact during the dry season being more severe. Changes in watershed characteristics brought on by higher temperatures and the effects of bushfires have compromised the water retention capacity of watersheds and severely decreased water yields. Changes in precipitation patterns and land cover have served to decrease aquifer recharge. The combined result of these climate change induced alterations to the local water cycle has been to severely reduce stream flows throughout the year with some smaller streams drying up for most of the year due to limited groundwater contribution to dry season baseflows. Surface water bodies such as Grand Etang, Lake Antoine and Levera Pond have recorded significant drops in water levels, curtailing the amount of water that can be abstracted. Higher water temperatures have contributed to poorer water quality in some cases.

Grenada's water supply relies heavily on run-of-the-river surface water abstraction and to a lesser extent from boreholes. The completion of the G-CREWS project in 2025, funded by the GCF allowed NAWASA to address a number of supply problems by reducing physical water losses, providing additional storage within the distribution systems and by promoting and introducing water savings devices. These measures did reduce consumption from 165l to 135l per person per day and physical losses from 29% to 20% of total production by 2030. As a result of conservation measures, tourism's water consumption has remained at 2020 levels even though the number of tourists and establishments have grown. These improvements, without the impact of climate change would have led to a substantial decrease in the amount of water abstracted. The full effects of the G-CREWS improvements were realised by 2027 though the measures were still not sufficient to cover the decrease in yields during the periodic droughts of the 2020s and rationing measures had to be introduced.

By the 2030s, increasing dryness and the accompanying increase in the number of prolonged dry spells resulted in decreases in stream flows, particularly during the dry season. These effects were progressively exacerbated by changes in watersheds brought about by climate change effects including bushfires. While unconstrained total water consumption has not increased, the available supply from surface and groundwater sources has decreased by 25%. To address the situation, there are now several local desalination plants at St. George's, Grenville, Gouyave and Sauteurs as well as on Carriacou and Petite Martinique. In addition, through the introduction of decentralised wastewater systems, treated wastewater is also being utilised. The need to increase the supply of water from alternative sources led to a major change in the governance of the water sector. Water services, including desalination and wastewater collection and treatment are now provided through a number of localised PPP arrangements, with NAWASA nominally being the public partner. NAWASA has largely been left responsible for water supply to rural areas. These arrangements have avoided water supply deficits in urban areas. The involvement of the private sector has greatly increased the efficiency of water services and improved water use efficiency. Physical losses have been further reduced such that by 2050 they account of 10% of production with a target of 5% by 2060. All this though has come at a price.

Abstraction from surface and groundwater sources continues, especially for irrigation. This poses a serious issue as the Water Resources Management Unit (WRMU) has struggled to effectively regulate the irrigation sector, with adverse effects on stream flows. The tensions between farmers/food producers and the WRMU have increased as stream flows have decreased – with some watercourses drying up during the dry season. Lakes such as Grand Etang and Antoine have seen dramatic drops in water levels and deterioration in water quality. Lake Levera has fared somewhat better, being located with a system of PAs created towards the end of the 2020s. In response to the increasingly drier drought conditions the agriculture and food production sector adopted measures such as building on earlier climate smart farming initiatives; adopting drought resistant crops and practices; investing in rainwater harvesting and capture infrastructure; and forming partnerships to use treated wastewater.

Wastewater management has improved in many urban areas, particularly the less dense and newer areas where the cost associated with providing local wastewater systems has been lower. The Grand Anse, St. George's and Gouyave sewer collection systems were upgraded during the 2030s to include both primary and secondary treatment but the treated wastewater was still disposed of via sea outfalls. By 2040, this was no longer acceptable and the greater emphasis on sustainability and availability of investment allowed wastewater systems to be upgraded and for the reuse of treated water. The improvements mean that the major urban areas, which account for the majority of the population, are now connected to sewerage collection systems. The reuse of wastewater has been supported by a number of factors: planning regulations, technological advances, sector regulation, and financial incentives for the private service providers. Whilst rural areas continue to rely on septic tanks, the technology has been improved through technological advances.

NAWASA's responsibility for the provision of water and wastewater has diminished and its role is now more of a regulator than as a service provider.

Solid waste

The GSWMA started to implement the *National Solid Waste Management Strategy* which set out actions to be undertaken over a 20-year period with revisions and updates every 5 years. Whilst progress was slow in improving the sector, since 2040 there has been an increased rate of improvement and success in introducing best practices. Again, this has been largely driven by the private sector but supported by changes in manufacturing practices to enable reuse and recycling, changes in the type and use of materials, and global action to minimise waste generation. There has been the introduction of waste management regulations and tipping fees, increasing recycling rates after the introduction of the waste segregation and collection initiative diverting construction and demolition waste as well as green waste. In fact, construction and demolition waste is largely reused and the widespread adoption of the use of cross laminated timber has significantly reduced how much is generated. Landfills are no longer a significant means of waste management and disposal; the former sites have transformed into resource reclamation undertakings. Pollution from former landfills is however an issue affecting groundwater, surface waters and the marine environment.

Technology

Technological advances over the last 30 years have seen developments in many areas such as the use and application of 3D printing, gene editing, biosensor, and ICT and the adoption of cloud manufacturing facilities. Since 2040, Grenada has increasingly benefited from these advances as companies seek to upgrade their social and environmental credentials in the face of global changes. Whilst labour is still relatively low cost, the improvements and investment in education, training and skills development has made Grenada more attractive. The sharing and adoption of technological advances has benefited the local economy by providing entrepreneurial opportunities in the support and services sector. Furthermore, the greater importance and growth in the food production sector has also provided opportunities for the uptake of a circular economy. Grenada has adopted the use of technology in many areas of the economy, government, utilities and the provision of social services (e.g. health and education).

The use of remote sensing, encompassing satellite-based systems and drones is now widespread in providing information to the agriculture and offshore marine sectors. This has been just one of the benefits of the spread of American interest in the Caribbean. The advances made by developed countries in the use of sensors and AI to manage urban areas and the provision of a swathe of social services and utilities has been shared with Caribbean countries including Grenada. The downside has been the greater use of technology in social oversight, particularly in relation to crime and security, and the sharing of information across jurisdictions. This has resulted in the decrease of certain categories of crime though not cyber-related crime.

Social and welfare infrastructure

Education

Although the population has remained relatively stable for some years, the expected gradual decline means that only 18% of the population are of school going age compared to nearly 25% in the 2020s. The *2030 Education Framework for Action* proposed two benchmarks as 'crucial reference points': allocate at least 4% to 6% of GDP to education, and/or allocate at least 15% to 20% of public expenditure to education. In 2018, Grenada was allocating 3.6% of GDP and 10% of government expenditure to education. Improvements in revenue collection and growth of the economy have allowed the amounts to increase to 6% of GDP. The increased allocation to education coupled with the fall in school aged population has increased the per pupil expenditure. Since 2040 there have been increasing partnerships with industry and the private sector, particularly at the secondary, tertiary and vocational education level. A spill-over effect has been changes and significant improvements in the educational system and in educational facilities. As a result, in 2050 there has been a marked improvement in learning outcomes and an increase in numbers going on to tertiary education. Successive reviews of the TVET programmes and policies up to 2035 had highlighted the limited opportunities and offerings in the post-secondary education system. Recognising that this was a severe impediment to development and economic growth, changes to the educational system including teacher training were initiated under *the 2037 – 2042 National Educational Strategy*. The benefits of the new strategy started to be realised by the mid 2040s with more skilled young people entering the workforce at a time when globally there were more resources and opportunities being made available. A drawback of the current system is that it is heavily oriented towards the needs of the private sector though with the growing emphasis on adaptation and social welfare has broadened the scope of what might otherwise have been limited opportunities. As things stand in 2050, Grenada's workforce has gradually transformed into a skilled workforce with access to good facilities.

Health and welfare

The fortunes of the Health and Welfare Sector have mirrored the performance of the economy and the ability to fund services. Throughout the 2020s there were on-going consultations and studies regarding the provision and implementation of a National Health Insurance (NHI) scheme. By 2050 a limited NHI scheme operates, providing access to healthcare for those least able to afford it but it is the private sector that provides most of the services through insurance-based schemes – often tied to employment. The failure to limit global heating and a focus on adaptation has had a negative effect on health outcomes particularly related to the social and environmental determinants of health; pollution, air quality, heat stress, communicable and non-communicable diseases. As a result, Grenada continues to be challenged by health outcomes and continues to be vulnerable to emerging communicable diseases. Technological advances along with lessons learnt from the COVID-19 pandemic have improved the capacity of the healthcare system but to a large extent the improvements have been in the areas of care and management of symptoms rather than addressing causes. Cheap wearable medical devices, connected to the Internet, are now common. These are complemented by strategies designed to change lifestyles and habits such as encouraging physical activity and the provision of urban green spaces. Other strategies, developed in cooperation through the OECS, are designed to address the emergence of new global diseases. These measures have helped ensure that communicable diseases like Ebola and Zika, have not again reached pandemic levels.

One of the more pressing problems is conditions associated with ageing, exacerbated by changes in family and household structure. Welfare support continues to be inadequate with most vulnerable groups reliant on community-based welfare organisations. Among the rural population, family ties and support networks are important rather than community cohesion.

Grenada is still vulnerable to a range of conditions which have knock-on effects on the environment. Food insecurity and poor diet continue to play a role in the prevalence of non-communicable diseases particularly in rural areas. Climate change and variability have played a role in the increasing intensity of storms and hurricanes which, in spite of improvements in housing and building stock, still impact vulnerable groups disproportionately. The changes in building codes, better early warning systems and the implementation of risk reduction measures have minimised their impact on infrastructure. The new building codes, introduced in 2038, have come about through an internationally-synchronised process of aiming to increase the resilience of both existing building stock and new builds. The development of these codes has been an exemplar of cooperation between big business and public benefit organisations. The regulations were jointly developed by international re-assurance companies and leading global NGOs. The continuing urban-rural divide has deepened with rural communities lacking good infrastructure and access to services though in the last decade this has slowly begun to be addressed.

Security

Whilst crime and public insecurity increased during the 2030s, linked to economic performance, since the start of the 2040s the efforts to bring them under control have been successful. However, the nature of crime has changed with more associated with cyber- and white collar-crime. While technology has enabled physical forms of crime to be successfully addressed, it has given rise to newer criminal opportunities.

The use of technology has greatly facilitated the application of environmental legislation, regulation and monitoring. Since 2040 and the emergence of new and revamped global environmental institutions, improvements have been made in tackling environmental issues and requiring compulsory conservation and adaptation measures. There are now stronger planning and Environmental Impact Assessment (EIA) requirements and better means of ensuring compliance through the use of a combination of technologies such as Block Chain, remote sensing and real-time monitoring.

Governance

Grenada continues to be a parliamentary democracy, which has been strengthened through changes to the representation of the people and the growth of the middle classes. This has been complemented by the widespread use of ICT in government and by the public giving greater access to and sharing of information. As a result, government by cabinet is now not as pervasive as in the past, as the wider public now has a greater 'voice' and ability to influence decision making. The other benefit of the adoption and advances in ICT in government (smart governance) is that it has reduced costs and increased efficiencies. This together with fiscal reforms have increased government revenues and enabled greater economic growth.

Grenada is a signatory to key environmental agreements which set the backdrop for its management, conservation and restoration of its natural environment. The renewed commitment of the global community since the crises of the 2030s has given rise to new conventions and institutions. While Grenada struggled to implement and meet many of the targets in the decades leading up to 2040, since then, with general improvement of the world order and targeting of assistance to countries like Grenada, more progress has been made. That said, much of the emphasis has been on adaptation and alleviating the effects of the global heating that has resulted from a failure to limit GHG emissions. A knock-on effect has been an increasing ability for states like Grenada to access funding for mitigation and adaptation interventions.

At a regional level, the OECS Secretariat exercises several shared functions that previously were carried out at the national level, for example in water resources management, forestry. This greater degree of cooperation and coordination has been a positive outcome from the *2042 Revised Treaty of Basseterre* and the *Revised St. Georges Declaration on Principles for Environmental Sustainability and Social Wellbeing*. This has enabled the more effective and efficient use of finances and other resources and enabled OECS countries to address shortages that were hampering effective management.

Prior to 2042, Grenada continued to develop strategies to address economic, environmental, and social conditions; their implementation and realisation had been hampered by a combination of factors. These included a lack of fiscal space to action recommendations, a lack of adequate human resources and the associated inability to effectively apply regulations, and an under-resourced governance structure (institutional framework, laws and regulations). During the mid-2020s the Government continued its personnel policy of restricting recruitment with the result that the Civil Service shrank significantly, and its effectiveness declined. Some of the slack has been taken up by

CSOs but their efforts were also hampered by resource constraints and they tend to be more local in their focus. However, after 2042, developments led to a change in direction and have resulted in a restructuring of governance arrangements.

The closer OECS ties have increased resources and the effectiveness of government ministries and entities, including those with responsibilities for the management of natural resources. This has been achieved through the development of co-management approaches involving government, the private and the third sector, and extra-regional support. In 2050, government ministries are mainly responsible for policy development and the legal implementation of the regulatory framework, with implementation carried out under collaborative co-management arrangements. The advances in technology and ICT have been enabling factors in allowing these arrangements to work alongside the increase in the pool of available resources, including appropriately trained and experienced human resources. The co-management approaches developed have been successful in avoiding the danger of state capture. As a result, although the environment has suffered degradation as a result of climate heating, greater efforts have been made to ameliorate the adverse effects.

Examples of national policies and strategies that have been developed include: *National Solid Waste Management Strategies 2040, Third National Biodiversity Strategy and Action Plan, Third National Communication to the United Nations Framework Convention on Climate Change NDC, National Adaptation Plans and National Climate-Water-Energy-Food Nexus Action Plan 2040-2055*, covering energy generation, water resources, food production, and coastal and marine management.

Ecosystems and the environment

Under this scenario, ecosystems are highly managed with technology and market forces being at the core of achieving solutions to environmental problems. The polluter pays principle is applied as a means of addressing environmental issues but is widely used as an offsetting mechanism, allowing undesirable environmental practices to go ahead if payment is made to offset and/or improve environments elsewhere. A system of payments to provide ecosystem services has been introduced which has aided the protection and conservation of critical ecosystems, though this has been done through the creation of ecological property rights as an enabling condition for financial transfers. This has led to the development of community corporations which have taken on the business of providing ecosystem services. A positive outcome has been to encourage terrestrial food production activities to embrace the provision of a range of services including ecosystems and biodiversity that complement food production. The community corporations and food producers engage in trade in carbon storage particularly with the more developed of the Western nations bloc. A constant challenge though, faced by these entities is the challenge of new diseases affecting biodiversity placing a strain on the ability to maintain ecosystem services- terrestrial and marine.

In the 2020s Grenada made a commitment to protect 20% of its land area under a Caribbean Challenge Initiative (CCI) and saw this as a major contribution towards its NDC target through carbon sequestration. Over the last 20 years there has been a change in approach to the management of ecosystems of which national parks and PAs are but one tool. Increasingly, ecosystems are being proactively managed to adapt them to better cope with the changing climate and other stressors such as wildfires in the case of the terrestrial areas and from pollution in the case of marine areas. This is being done through a variety of mechanisms mentioned above and supported by the introduction of new funding arrangements and financial transfers. While the total area under some form of protection has not increased, the area under active ecological management has increased though this takes the form more of a mosaic rather than contiguous areas of land, an issue which is only now being addressed as a means of protecting biodiversity. Monitoring, quantification and regulation of ecosystem services has improved enormously through the integration of remote observation and passive monitoring with emerging data mining techniques which have resulted in the emergence of the concept of smart ecosystems.

Grenada Goes foresight scenario

Context: high emissions + brown economy

Grenada Goes sets out what a person might expect to see when going about their business on 7 February 2050.

This national scenario can be linked to Shared Socioeconomic Pathway (SSP) 4 though there are elements of SSP3 as well. The SSP4 describes global conditions and hence some of what is described would not hold true for Grenada. The national level scenario will be influenced by global conditions and developments and sets the macro conditions within which nation states operate. This is not to say that nation states mirror in every respect what happens at the global level. Nation states still have agency to shape their future through local actions and responses. Furthermore, this narrative has similarities with Scenario Archetypes 'Order from Strength' from the Millennium Ecosystems Assessment, and a mix of 'Regional Competition' and 'Inequality' from the Global Scenarios Group.

Box 6.30. Basic description of Shared Socioeconomic Pathway 4 (Hausfather, 2018)

SSP4. Inequality – A Road Divided (Low challenges to mitigation, high challenges to adaptation)

"Highly unequal investments in human capital, combined with increasing disparities in economic opportunity and political power, lead to increasing inequalities and stratification both across and within countries. Over time, a gap widens between an internationally-connected society that contributes to knowledge- and capital-intensive sectors of the global economy, and a fragmented collection of lower-income, poorly educated societies that work in a labour intensive, low-tech economy. Social cohesion degrades and conflict and unrest become increasingly common. Technology development is high in the high-tech economy and sectors. The globally connected energy sector diversifies, with investments in both carbon-intensive fuels like coal and unconventional oil, but also low-carbon energy sources. Environmental policies focus on local issues around middle and high income areas".

Population and demographics

By 2050 the population of Grenada has fallen to around 122,000 people due to a combination of reasons, with the economic condition of the country playing a significant role. Fertility rates have not changed much over the 30 years since 2020 but there are disparities across the socio-economic groups. Fertility rates in the upper income groups have fallen to around 1.3 births per female whilst in the lower income groups there has been a slight rise to 2.2 births per female. Infant mortality rates after declining between the 1960s to the 2000s started to rise again in the 2030s to around 20 deaths per 1000 live births while life expectancy has stagnated, reversing previous gains. Due to the economic conditions, migration rates have increased significantly, replicating rates last seen in the 1960s to 1990s- rates of net outward migration of 25 persons per 1000 population. What is significant is that unlike previous migration trends, women are more likely to migrate than men, because of their higher educational achievements and lack of employment prospects for them in Grenada. In terms of the age population distribution, this now looks more like a column rather than a pyramid, with a marked 'pinch' for the 20-55 age groups. The dependency ratio, the proportion of non-working aged persons to the working age population, now stands at 70% in 2050, in part due to the loss of persons of working age. These were figures last seen in the 1970s and 1980s. Although the age of retirement was increased in 2035, this made little difference to the dependency ratio.

Family structure has shown a continued trend in decreasing household size, particularly noticeable in the urban areas. However, poor households continue to be twice the size of the non-poor and with higher household dependency rates. These structural issues, which continue to include low rates of educational attainment have contributed to the continuation of income inequalities in Grenadian society. The number of female-headed households has increased, in the 2020s the figure was around 47%, it now stands at 55%. Urbanisation has proceeded at a slow pace. Urban growth has been driven primarily by changes in household sizes rather than increases in the number of rural-urban migration of families migrating to urban areas in search of employment. Urbanisation has not been solely concentrated in St. George's but across the country. As of 2050, approximately 50% of the population is urbanised.

Carriacou and Petite Martinique have experienced a severe decline of their populations. This loss of population was accompanied by a gradual withdrawal of government services which further reinforced the trend. There is now a marked demographic divide on the two islands, with a small, subsistence-based local population and a seasonal population of more wealthy individuals. In 2048 the government started a consultation around the future status of Carriacou and Petite Martinique putting forward the idea that they could become wilderness reserves.

Backdrop

Events such as the war in Ukraine, its accompanying economic disruption which lasted through to the late 2020s, and the lingering effects of the COVID-19 pandemic sharpened global tensions and led to the emergence of a more fragmented trading environment. As a result, the world is now fragmented into economic and security blocs, in the case of the Caribbean it is centred on the United States. Caribbean states are caught in the middle of these global rivalries with some verging on becoming failed states. Global problems have receded in significance though climate change continues to be addressed and it did gain some traction to address mitigation and adaptation. After a period of competition in the 2030s between China and the US for influence in the Caribbean, the US reasserted itself as the dominant power in the Caribbean. Trade and financial connections with North America were strengthened and to an extent countries were able to benefit from concessionary financing- used as a tool to reinforce the emerging hegemony. However, this has not translated into a more coherent and coordinated response from CARICOM and has not resulted in greater regional integration.

Countries in the Caribbean with their limited resources and small, open markets were hit hard as both imports and exports suffered restrictions linked to rising sovereign debts, high shipping costs and an increasingly fragmented trading environment dominated by a few major players. The effects of the deep recession from the mid-2020s affected all major economies and resulted in a period of economic stagnation. The rising costs associated with high inflation and climate change strained societies and governments' capabilities to meet public demands in countries across the region. The growth of the middle classes has slowed, hit by increases in health care, education and other living costs. At the same time, there has been a continued expansion in low income jobs as the educational system has struggled to improve levels of attainment, with those that do go on to higher education emigrating in large numbers. Developed economies, especially those with low population growth rates have eased entry conditions for better educated and skilled immigrants but have also increased their reliance on low skilled workers. However, this has been of limited benefit to Grenada as North American countries have relied on cheap labour from Central America. The consequences of this have been a rise in inequality, lagging behind in participation in the emerging technologies sector, and an increase in crime and corruption. Over the 30 years since 2020, Grenada's GDP has risen by less than 0.5% per year, standing at US$1.455 billion as compared to US$1.287 billion in 2020. On the other hand, the challenges that national governments have faced have brought about more adaptive approaches to local government. A greater range of actors have emerged offering a wider range of services, particularly with respect to the growing urban areas.

Reparations

In the 2010s the issue of reparations for slavery in the Caribbean began to attract increasing attention in the Region following the adoption by CARICOM of their 2013 "Ten Point Plan for Reparatory Justice" and the setting up of a CARICOM Reparations Commission. The issue was championed by a number of influential individuals and some governments, Jamaica and Barbados among others. This resulted in localised forms of action whereby persons and institutions acknowledged that they had benefited from slavery. As a result, some forms of redemptive action were undertaken though these were limited. At the level of governments, regrets about slavery were expressed but there was little government to government engagement. In spite of continued attempts to keep the issue alive within the region throughout the 2020s and into the early 2030s, there was little positive response beyond. European governments stated that no direct reparation payments would be made and CARICOM attempts to elevate the matter drew a blank. Some governments sought alternative means of gaining recompense such as instituting differential levies on travellers from Europe, but these proved counterproductive and were dropped in the face of overtures from North America. At an intellectual level, in the 2030s the issue became embroiled in competing ideological debates over the creole nature of Caribbean society, indigenous societies and of African kingdoms. As a result, much of the heat has gone out of the issue and now in 2050 it is confined to scholarly debate.

Climate change

Analysis of proposed NDC mitigation targets indicate that globally they are not enough to stabilise the climate. As a result of the growth of energy demand and a continued reliance on fossil fuels, GHG emissions continued to rise. Difficulty in achieving international cooperation and slow technological change imply high challenges to mitigation. The limited progress on human development, slow income growth, and lack of effective institutions, especially those that can act across regions, implies high challenges to adaptation for many groups in all regions. The result of this has been that global temperatures have increased and the goal of limiting them to less than 2°C has not been achieved and air pollution from aerosols has increased. SST have increased along with increased sea level rises.

Geopolitics and Grenada

High and unstable energy prices from the mid to late 2020s prompted Grenada, along with other Caribbean countries, to address their energy security and redouble efforts to harness renewable energy. In this respect, Grenada has been largely successful with the private sector, businesses and individuals investing primarily in solar energy systems. While the installed capacity targets for solar and wind energy were eventually met by 2035, other NDC targets were missed. Initially Grenada assumed that geothermal energy would be the backbone of its mitigation efforts and would be developed. A lack of external support and investment resulted in this being shelved and as a result, the country could not meet its target of a 40% reduction in GHG emissions. On the other hand, by 2050, 60% of all vehicles and 100% of public service vehicles are now running on renewable energy sources and by 2055 100% across all categories will be achieved. Efforts to implement energy efficiency measures in building codes were partially successful though it was only by 2040 that the initial targets were met. This was due to the revision and strengthening of planning and development regulations and building codes in 2040. Throughout the 2040s efforts continued to improve energy efficiency and resilience. The levels achieved to date are: retrofitting of buildings 40% reduction, energy efficiency in hotels 30%, and new build 35% reduction. Plans to develop a landfill waste-to-energy project were stalled for many years and it was only in 2047 that sufficient finance was raised to undertake a detailed feasibility study. In 2020 Grenada made a commitment to protect 20% of its land area under a CCI and saw this as a major contribution towards its NDC target through carbon sequestration. Given the rate of abandonment of former agricultural lands and forest regeneration, this target has been increased to 25% though not all enjoy PA status. The major drawback has been in accessing multilateral and bilateral financial support and concessional financing to supplement the limited national resources and technical capacities.

Over the last 30 years the economy has struggled to grow. As a result, there has been little change in the overall income profile of the country. The number of Grenadians living in extreme poverty has halved to 15% but those in the low income group now constitute 50% of the population with 30% being middle income. Unemployment rates have stabilised at around 15% though youth unemployment remains double that, contributing to emigration pressures. Unemployment continues to be concentrated among the unskilled and youth. The increase in employment has come as a result of growth in low-income jobs. Educational attendance up to secondary level is high across all income groups being nearly 100% up to the age of 17. Those going on to some form of higher education after the age of 17, however, has dropped to 20% and has been at this level for the last 30 years.

The economy continues to be primarily reliant on tourism, education, construction and services as the main engines of growth with agriculture and fisheries a long way behind. The National Sustainable Development Plan and Action Plan 2020-2035 set out a range of measures and interventions to strengthen society and the economy. The challenging economic fortunes of Grenada and the region up to 2025 meant that many of the initiatives were delayed or not able to commence because of fiscal constraints and even after 2025 the slow growth of the economy hampered improvements. The Development and Action Plan, and its various iterations under successive administrations, aimed to provide the structural basis for growth by addressing the human and social challenges such as education attainment and access to healthcare, making the country and economy more resilient to climate change, and promoting both agriculture and the blue economy particularly with a view to increasing youth opportunities. There has been some success in growing the agricultural sector, but the blue economy has not lived up to expectations. Whilst successive governments have tried to provide a supportive environment to encourage the growth of export, efforts have been hampered by the geopolitical conditions described above. Grenada is by default part of the North American hegemonic block which dictates the terms of trade and similar efforts to expand into Latin America have been hampered. It is only the tourism and education sector that has benefited. This growing reality of increased dependence on tourism was tacitly acknowledged in the Second National Sustainable Development Plan and Action Plan 2035-2050.

Tourism

Grenada's tourism product has continued to rely on the 'sun-sand-sea' model though this has become increasingly under threat from the shorter term effects of the 2020's recession and longer term effects of climate change related events. In an effort to spur economic development, the country has allowed more tourist accommodation to be built but the increasing impact of hurricanes, storm surges and sea level rise along with increased blanketing of beaches by Sargassum has adversely affected many beachfront properties. In spite of this, there is now a wider range of hotel accommodation from middle to high end and increased competition in a relatively stagnant market both nationally and regionally. Accompanying this has been a growth in the numbers offering themed and theme park all-inclusive packages. From the early 2030s, new operators began developing mini-themed parks and developing tie-ins with hotels and this has become a feature of Grenada's tourism offerings. This was a way of offsetting the loss of beaches. Due to the rise in crime, tourist security has become an issue and now some of the coastal areas developed in the 2030s are given over almost exclusively to tourists. Not all tourist development has taken place along the coast, with inland destinations also proving to be popular as well as dual destination offerings, such as Carriacou. In spite of these efforts, tourism demand remains largely flat and tied to seasonal cycles. These cycles are dominated by influxes from North America as reliance on the European market declined due to the rising cost of living in that region. One of the beneficial results of these tourism developments has been an increase in employment and supporting services in this sector, albeit in low skilled and low paying jobs.

Alongside the growth in traditional tourism, accommodations offering the 'Airbnb' model started to take off. This has taken the form of offering a choice of type of accommodation including high-end bespoke offerings. The ecotourism subsector remains small in comparison to the mainstream hotel and tourism product, striving to set itself apart by offering 'authentic' experiences. Cruise ship tourism has continued, though repeated health issues have damped demand from time to time. Yacht-based tourism has continued to be popular within its own niche market. Here again, new operators have sought to expand the sector through tie-ins with hotel and other tourism operators. Yacht tourism has benefited Carriacou somewhat, but the main focus is along the southern coast of Grenada.

Both the traditional and Airbnb subsectors have access to the latest technological advances allowing them to optimise their performance and offerings to visitors. Because of the increasing threat from climate induced hazards and associated insurance costs, the tourism plant is now more resilient and able to resist the effects of hurricanes. The 2040 Building Code and Planning Regulations prioritised the need for disaster resilient infrastructure and requirements for minimising resource use being incorporated.

Food production systems

Grenada's agricultural sector has a long history of underperformance and failure to deliver on promised potential. Much of this can be ascribed to unsuccessful attempts to address the underlying structural problems identified in successive national agricultural plans. Looking back to the 2020s it is apparent now that the unsuccessful efforts led to its stagnation that, with a few exceptions, has characterised it up to 2050. The high cost of food imports experienced during the 2020s did have the effect of increasing demand for locally grown produce whilst the high prices paid for some agricultural exports offset to some extent the decline in the total area of permanent crops under cultivation. There are now some 7,000 farmers active in the sector- compared to 9,000 back in 2020 but there are a larger number who are informally engaged in agriculture, mostly as subsistence farmers to supplement other forms of income. This has brought more areas back into cultivation, reversing the previous trend, converting secondary forest back into cultivation. In 2020, 80% of the farmers were classed as small holders, basically engaged in subsistence farming. The average area under cultivation by a farmer has not changed significantly, a slight increase for food crops to 0.1ha as well as for permanent crops an increase to 1ha. The trend in mechanisation and improved agricultural practices has continued which has to a limited extent increased productivity among those for whom agriculture is a main income earner. The spike in imported fertiliser costs resulting from the global instability in the mid-2020s initially suppressed importation and agricultural production. However, it also spurred interest in the development of substitutes and alternatives; increasing the use of animal manure and Sargassum. The situation also gave rise to increasing adoption of organic agriculture and permaculture practices. As a result, the volume of imported fertiliser is now a quarter of what it had been. A similar but limited effect occurred with respect to the use of pesticides and other agrochemicals. The increase in pests, diseases and IAS, affecting crops and associated in part with climate change, continues to pose a significant challenge in moving away from the use of agrochemicals. Improvements in surveillance systems and ongoing research into pest control methodologies has had a positive impact. However, the increase in temperatures along with increased climate variability- floods and waterlogging, and increased dry spells and droughts, has adversely affected crop yields as well as animal health. The net effect has been an increased volatility of food security and swings in food prices. The incidence of food poverty among low income groups has increased- reflected in the increased numbers of families engaged in part-time subsistence farming.

By the early 2030s there were increasing concerns over the decline of the agricultural sector and a greater recognition of the limitations faced by the state in trying to bring about the changes envisaged in the National Agricultural Plan 2020-2035. This led to a re-evaluation and the emergence of a more targeted and incremental approach to trying to support the agricultural sector. The approach built on efforts to attract new entrants into the sector, alongside existing farmers, targeting selected geographic areas and working to develop supply chains and agroprocessing. It has built on the experience with climate smart agricultural practices and the uptake of onsite renewable energy generation to support transitions to Smart Agriculture. It has been the success of this programme that stemmed the collapse of the sector and stabilised it to some extent. The targeted interventions and better extension services have managed to encourage the uptake of technology and entrepreneurship among a small number of successful entrants and improve productivity. In 2050 there is now an emerging class of more commercial food producers, constituting 35% of all farmers and farming on larger plots, alongside what continues to be subsistence farming- 65% of farmers. A side effect of this has been to increase female participation in the sector. An example of this approach was the development of insect farming to produce animal feed. Reducing feed costs supports the poultry and livestock sector which in turn has significantly reduced meat and dairy imports. On the flip side though, it has reversed the decline in abandoned lands and increased the area of pasturage.

The traditional fishing sector has all but collapsed in the face of the impact of climate change; coral reef bleaching and die-off, ocean acidification, loss of habitats, changes in fish behaviour and composition, and overharvesting of fish stocks. The presence of vast volumes of Sargassum seaweed compounded underlying negative trends affecting fishing effort and fish stocks. Throughout the 2020s and into the 2030s fishing effort, and the use of technology for monitoring and tracking and the use of FADs increased but did not increase the amount caught. The rise in fish prices though continued to support the industry. This and efforts to replenish fish stocks led to a slow transition of people out of the industry and for others to diversify. The decline was also underpinned by a lack of sufficient investment in improving the fishing sector. As a result, there are small-scale fish farming efforts such as conch and sea urchin farming as well as a growth in aquaponics and hydroponics. The continued presence and large volumes of Sargassum contributed to the decline of fishing. However, the volumes involved and developments in harvesting Sargassum before mats landed led to the development of a Sargassum-based sector which has grown in importance, producing a variety of products such as bioplastics, fertiliser and food products. The industry is centred around Grenville, which has developed as a mini-industrial hub.

Education

Education as an economic sector continues to rely on SGU's contribution through attracting overseas students and the provision of services to them. The close ties with North America has if anything improved the performance of this sector. There has been some expansion with SGU's WINREF having grown its research and development capabilities, attracting a small number of highly skilled professionals. The focus though has remained on contributions to the medical and public health sector.

Transport

The transport sector includes air, sea and land transport systems. The continuing importance of tourism to the economy has meant that air travel has continued to grow and by 2035 the MBIA underwent a partial upgrade. The MBIA remains the country's main airlift hub. Proposed plans to redevelop the Pearls Airport near Grenville continue to be on hold. However, the planned upgrading of the Lauriston Airport on Carriacou went ahead and the island now has better air transport connections not just with the mainland but other islands of the Grenadines as well.

Regional maritime trade was given a boost in 2025 when eventual agreement was reached within CARICOM for the free trade of goods and produce and the introduction of inter-island services. As a result, there was some upgrading of the St. George's Port to handle import and export cargo at the time.

Road transport transitions have proved to be very problematic and slow. Changes by manufacturers and a growing global momentum eventually led to a requirement that from 2040 all vehicles would have to be zero-emissions vehicles, so now in 2050 all vehicles are either electric or use other forms of renewable energy. This has created problems for the country as its capacity to generate electrical power remains a limitation. Furthermore, the coverage of charging stations outside of the main urban centres is patchy. In order to cope with this situation, there has been an expansion of public transport using a mix of electrical buses and minibuses. Growth in vehicle ownership eventually slowed considerably as a result of weak economic growth.

Energy

Power is generated through a mix of solar PV, wind energy, biogas and the power station that continues to run on imported fuels. The power station provides the base load power generation. Mini-hydropower schemes were considered but it was concluded that with the impact of climate change on river flows this would not be a viable option. The feasibility of utilising waste to energy is in the final stages of being investigated and it is likely that will be implemented by 2055. This will allow less of a reliance to be placed on the use of biofuels imported from North America. A continuing challenge is being able to meet demand for electrical energy and as a result load shedding is a regular occurrence. In order to overcome this, the government has entered into a PPP to provide energy storage to address fluctuations in power generation. The spread of solar PV has been hastened by the planning and building requirements to include it in new buildings.

Utilities (water, sanitation and solid waste)

The projections made in the mid-2020s of the impact of climate change and variability on water resources were realised. Decreases in rainfall of 20%, the increases in temperature together resulted in a 25% decrease in overall annual water availability with the impact during the dry season being more severe. The impact was partly alleviated through the completion of the G-CREWS project funded by the GCF. However, the impact of the increase in the number of prolonged dry spells gave rise to increasing concerns. The decrease in population along with measures to improve domestic water use efficiency limited the growth in residential consumption so that in 2050 residential water consumption is lower than it was in 2020. As a result of conservation measures, tourism's water consumption has remained at 2020 levels even though the number of tourists and establishments have grown. While total water consumption has not increased, the available supply from surface and groundwater sources has decreased by 25%. In order to address the situation, there are now several local desalination plants at St. George's, Grenville, Gouyave and Sauteurs, as well as on Carriacou and Petite Martinique. These are powered by renewable energy and were funded through the Adaptation Fund, thus avoiding the use of PPP contracts to finance them though they are operated under management contracts. This has avoided water supply deficits, however abstraction from surface and groundwater sources continues, especially for irrigation. This poses a serious issue as the Water Resources Management Unit has struggled to effectively regulate the irrigation sector, with adverse effects on stream flows. Stream flows have decreased significantly with some drying up during the dry season as groundwater's contribution to baseflows decreases. Lakes and wetlands are also being adversely affected by the increasingly dry conditions with levels dropping, most notably Lakes Antoine and Levera.

Wastewater management has improved in many urban areas, particularly the less dense and newer area where the cost associated with providing local wastewater systems has been lower. The Grand Anse, St. George's and Gouyave sewer collection systems were upgraded during the 2030s to include both primary and secondary treatment but the treated wastewater is still disposed of via sea outfalls. The improvements mean that the major urban areas, which account for the majority of the population, are now connected to sewerage collection systems with some treatment. There is limited reuse of wastewater, which is anyway poorly supported by planning regulations. It is only the hotel sector that has implemented significant wastewater treatment and reuse programmes. Rural areas continue to rely on private septic tank systems.

Overall responsibility for the provision of water and wastewater services continues to remain with NAWASA. As an organisation, it has not undergone any significant improvement in its management and financial performance. Capital funding for infrastructure remains a challenge depending on government transfers as tariff levels have not been raised to the point where the utility is self-financing. Its adoption of new technologies though initially spurred through the GCF support in the mid 2020's stagnated as it struggled to recruit suitable personnel. One consequence of the funding challenges has been a gradual increase in water losses from leakage and burst pipes.

The solid waste sector similarly had a lacklustre performance. The GSWMA started to implement the National Solid Waste Management Strategy which set out actions to be undertaken over a 20-year period with revisions and updates every 5 years. There has been some success in the introduction of waste management regulations and tipping fees, increasing recycling rates after the introduction of the waste segregation and collection initiative diverting construction and demolition waste as well as green waste. Landfill is still the predominant method of waste management and disposal. Potential pollution has been addressed to an extent through the implementation of engineered landfill sites on Grenada. This though is not the case for Carriacou and Petite Martinique where the existing sites continue to be used.

Technology

Technological advances over the last 30 years have seen developments in many areas such as the use and application of 3D printing, gene editing, biosensor, and ICT. However, Grenada has derived few benefits from the advances due to a combination of high costs, barriers to entry and lack of access, and limited human resources. The relatively low skills of the Grenadian labour pool in most of the sectors where technology might otherwise be applied has meant that there has been limited uptake and application. There are exceptions such as in the tourism industry where due to their international linkages, they have been able to attract foreign investment and training. Generally though, Grenada continues to lag behind in the application and use of technology in many areas of the economy, government, utilities and the provision of social services (e.g. health and education).

However, due to the use of remote sensing, encompassing satellite-based systems and drones is now widespread in providing information to the agriculture and offshore marine sectors. This has been one of the benefits of the spread of American interest in the Caribbean- though it has come on the back of increased drug and smuggling surveillance and interdiction activities. In this respect, the Grenada Police Force has benefited from support from law enforcement agencies in North America.

Social and welfare infrastructure

The increase in the proportion of people in the older age groups and the decline in the overall population has meant that the numbers in the education system have fallen. At the same time there has been an increase and concentration of the urban population. The Education 2030 Framework for Action proposed two benchmarks as 'crucial reference points': allocate at least 4% to 6% of GDP to education, and/or allocate at least 15% to 20% of public expenditure to education. In 2018, Grenada was allocating 3.6% of GDP and 10% of government expenditure to education. Improvements in revenue collection and some growth of the economy has allowed the amounts to increase to 4.5% of GDP. The increased expenditure coupled with the fall in school aged population has increased the per pupil expenditure. However, the traditional approaches to education have continued. As a result, in 2050 there has only been a small improvement in learning outcomes and an increase in numbers going on to tertiary education. Successive reviews of the TVET programmes and policies have highlighted the limited opportunities and offerings in the post-secondary education system, meaning that few skilled persons are entering the workforce. Again, financing has been an issue. Proposals for an Enterprise Training Fund were eventually dropped by early 2030 but in its place a system of 'apprenticeships' co-financed by the government and private sector was put in place to improve employability and technical training. A drawback of this current system is that it is heavily oriented towards the perceived needs of the private sector and tends to be conservative in its offerings- hampered by Grenada's lack of access to new thinking and developments. As things stand in 2050, Grenada continues to have a predominantly low skilled workforce, which is limiting opportunities for economic development and a high level of outward migration of highly educated or skilled Grenadians.

Health services continue to struggle given the performance of the economy and the ability to fund healthcare services. Throughout the 2020s there were on-going consultations and studies regarding the provision and implementation of a NHI scheme. Similar to the Educational Trust Fund mechanism, proposals for imposing a levy on goods and services were ultimately considered to be burdensome and having a disproportionate effect on the lower income groups. A limited NHI scheme operates, however, providing access to healthcare for those least able to afford it alongside private healthcare insurance. As a result, Grenada continues to be challenged by health outcomes associated with non-communicable diseases and vulnerable to the emerging communicable diseases that continue to plague the region. Technological advances along with lessons learnt from the COVID-19 pandemic have improved the capacity of the healthcare system to a certain extent but the impacts on the economy and society are still worrying. One of the more pressing healthcare problems is conditions such as dementia associated with ageing, exacerbated by changes in family and household structure. Welfare support is even more inadequate with most vulnerable groups reliant on community based welfare organisations though this is more of a feature of urban rather than rural communities. Among the rural-based population, family ties and support networks are important rather than community cohesion.

Grenada is still vulnerable to a range of conditions which have knock-on effects on the environment. Food insecurity and poor diet continues to play a role in the prevalence of non-communicable diseases. Climate change and variability have played a role in the increasing intensity of storms and hurricanes, and poor air quality increasing respiratory conditions. The changes in building codes, better early warning systems and the implementation of risk reduction measures have minimised their impact on infrastructure. Much of this improvement has been funded through grants and programmes. Although half of the population is urbanised this has not improved social cohesion. The urban-rural divide has deepened with rural communities lacking good infrastructure and access to services. Per capita government spending on rural communities has decreased. This has increased the vulnerability of rural communities to natural disasters while that of urban populations has decreased.

An outcome of poor economic performance and high levels of under-employment has been an increase in crime and public insecurity. The Grenada Police Force is struggling to cope with gang and drug-related activities and has led to an increase in the para-militarisation of security forces. Given the social insecurities, environmental issues do not enjoy much public attention, unlike social issues and hence the enforcement of environmental legislation and regulation has dropped significantly.

Governance

Grenada continues to be a signatory to a number of key environmental agreements which set the backdrop for its management, conservation and restoration of its natural environment. But although it is a signatory, it is struggling to implement and meet many of the targets. Globally, few of the SDGs were met and mitigation of GHG emissions has failed to limit warming to 1.5^{o}C. The more fragmented nature of international relationships has meant that it has been increasingly difficult to develop consensus and action around the various international processes. While there have been successors to the SDGs and the Sendai Framework, these function more as targets to report against than stimuli for action and intervention. A knock-on effect has been increasing difficulties for states like Grenada to access funding for mitigation and adaptation interventions.

At the national level, Grenada has continued to develop strategies, yet their implementation and realisation has consistently been hampered by a combination of factors. These include a lack of fiscal space to action recommendations, a lack of adequate human resources which also weakens the ability to effectively apply regulations, and an under-resourced governance structure (institutional framework, laws and regulations).

During the mid-2020s, the Government continued its personnel policy of restricting recruitment with the result that the Civil Service shrank significantly and its effectiveness declined. Some of the slack has been taken up by CSOs but their efforts are also hampered by resource constraints and they tend to be more local in their focus. In this respect, the rise of urbanisation has given rise to more local forms of governance. The continuing weakness of the Grenadian economy restricts what the government can achieve and generally has weakened its ability to effect change. An adverse consequence of fiscal weakness and ability to access capital funds has been a tendency to accept proposals that promise development and jobs, but which are not necessarily in keeping with national environmental policies, a form of state capture.

Examples of National Policies and Strategies: National Solid Waste Management Strategies (2030, 2035 and 2040), Third National Biodiversity Strategy and Action Plan, Third National Communication to the United Nations Framework Convention on Climate Change, NDC, National Adaptation Plans and National Sector Adaptation Plans (Energy, Water & Sanitation, Food Production, Coastal and Marine Zone), the National Climate Change Policy and Action Plan (2025-2040), National Sustainable Development Policy and Action Plan.

A. Social drivers

A.1. Population and demographic change

Grenada's population has experienced both declines and steady growth over the years. Between 1960 and 1990, there were periods of decline due to significant outward migration linked to poor economic conditions and political turmoil. However, in recent decades, the population has steadily increased, with the total population estimated at 124,600 in 2023 (United Nations, 2022). Despite this growth, demographic changes suggest a steadily aging population, with a dropping age dependency ratio and fertility rates, and increasing death rates and life expectancy.

Historically, changes in Grenada's population have been largely influenced by economic conditions, with high rates of outward migration associated with economic downturns. Demographic changes have also been driven by improvements in social, educational, and economic conditions shaping women's choices in child rearing. The Grenada Greens scenario projects a slightly increased population of 128,000 by 2050, while the Grenada Grows scenario predicts a continued increase to 136,000, and the Grenada Goes scenario predicts a decrease to 122,000 due to outward migration resulting from poor economic conditions. In Grenada Greens, the decline in fertility rates is attributed to women's focus on their careers, cost of childcare, and economic well-being rather than having families. Dependency ratios vary across scenarios, with a high of 70% in Grenada Goes and 60% and 55% in Grenada Greens and Grows, respectively.

Whilst population and demographic changes do not necessarily directly drive changes in biodiversity and ecosystem services, the size and distribution of the population combined with other factors such as urbanisation and changes in livelihoods have an impact on resource use and habitats. Continued increase in population implies, all other things being equal, greater use of resources such as water, land for food production, energy, provision of housing and infrastructure, and the provision of services. On the other hand, decreases in population can have mixed effects depending on the accompanying socio-economic conditions. In Grenada Goes, the weaker economic conditions would lead to increased exploitation of natural resources such as bringing more land into subsistence cultivation. By contrast, in Grenada Greens there is less demand placed on natural resources both by a smaller population and more effective use of existing resources.

A.2. Urbanisation

Grenada's primary urban centre is the capital, St. George's, along with its surrounding areas. Other significant urban centres on the main island include Gouyave, Grenville, and Victoria, while Hillsborough serves as a major urban centre on Carriacou. The main drivers of urbanisation are usually employment and access to services. In the case of St. George's and its environs, which is the main centre of economic activity, a significant number of people commute from outside the urban area on a daily basis.

Urbanisation has progressed slowly in both the Grenada Grows and Grenada Goes scenarios, with only 50% of the population living in urban areas by 2050. Interestingly, the urban population is now more evenly distributed across the country, with greater increases experienced outside of St. George's and its environs. However, the quality of the urban environment varies significantly between the two scenarios. Grenada Goes has seen an increase in tourism development and informal developments and poorer quality environments, placing increased pressures on surrounding habitats and ecosystems, terrestrial and marine. By contrast, in Grenada Greens urbanisation has accelerated to reach 70% with much but not all of that increase having taken place in the south-eastern part of the island. In this scenario, the quality of the urban environment has improved, with better physical development planning and an emphasis on sustainability and improved urban spaces. At the same time, it has reduced pressures on habitats and ecosystems in rural areas.

Unplanned and informal urban development through poor infrastructure provision for solid waste management, wastewater (sewage) management, transportation, and pollution can have negative impacts on the environment. Furthermore, the introduction of non-native species and favourable conditions for the introduction and spread of pests and diseases pose a threat to both human and native species and ecosystems. Under both Grenada Greens and Grows scenario there is better provision of infrastructure and services which mitigate many of the negative impacts on terrestrial and marine environments as well as better surveillance and control of pests and diseases. Transportation transitions, relying on renewable energy systems, have brought about changes in urban design. However, in Grenada Goes, much of the improvement in infrastructure provision is relatively recent and therefore much of the damage to the environment has already been done. In Grenada Goes, the lack of investment in the provision of infrastructure and services has resulted in negative environmental impacts.

A.3 Poverty

The number of persons in extreme poverty has dropped to 15% under both Grenada Grows and Grenada Goes scenarios with extreme poverty concentrated in rural areas and some urban pockets. Extreme poverty is mostly associated with those employed in construction, subsistence farming and fishing. However, in Grenada Grows, those in the lower income groups constitute 40% of the population with 40% being middle income as compared to 50% and 30% in Grenada Goes. By contrast, in Grenada Greens, the percentage of the population in the poor and low income categories has been substantially reduced to 10% and 25% respectively. The percentage of the population in the middle income range has increased to 40% of the population and those in the upper income to 15% of the population. Overall, in Grenada Greens the population is economically better off as compared to the other two scenarios though there is a marked contrast in wealth between the urban and rural areas.

Limited economic prospects may lead to a focus on meeting basic needs at the cost of long term environmental quality. Poorer households face affordability issues in accessing services such as sanitation, energy and solid waste resulting in the use of less sustainable alternatives and practices. Those in poverty and on lower incomes are more concentrated in rural areas and therefore have a greater impact particularly on terrestrial ecosystems, though there is spillover into the marine environment. Studies have shown that income inequality and poverty are significant determinants of environmental pollution and need to be addressed to promote environmental sustainability (Ehigiamusoe, Majeed and Dogna, 2022).

A.4 Education

Although education is not a direct driver of change in biodiversity and ecosystem services, the level and quality of education has two indirect effects. One of the effects is that education can contribute towards greater environmental awareness and potentially positively influence people's behaviour, in combination with other factors. Another indirect effect is the general observation that having an educated population and workforce is an enabling factor supporting economic opportunities, job creation and income generation, underpinning a high skills-based economy. A skilled workforce encourages inward investment. The converse is that poor educational attainment contributes to the continuation of a low skills, low income economy.

This is not to say that having a skilled and educated workforce necessarily leads to improved environmental outcomes. This must be coupled with other policies and interventions. It is what can be called a necessary but not sufficient condition. Investment in and quality of the educational system are therefore factors that can influence the state of biodiversity and ecosystem services.

In the Grenada Greens scenario, there has been investment in education and an expansion of the tertiary education sector. This has created opportunities for Grenadians, OECS nationals and foreign students. The mix of academic and skills development has resulted in an inward migration of highly qualified graduates from within and outside of the region leading to the growth of innovation hubs and start-up enterprises.

Similarly, the Grenada Grows scenario posits increased educational expenditure leveraged through partnerships with industry and the private sector. As a result, there has been a marked improvement in learning outcomes and an increase in numbers going on to tertiary education with an emphasis on technical and vocational education, and training programmes. More skilled young people have entered the workforce at a time when globally there are more resources and opportunities being made available. A drawback of the system is that it is heavily oriented towards the needs of the private sector. The growing emphasis on adaptation and social welfare has broadened the scope of what might otherwise have been limited opportunities.

In Grenada Goes, there has been some increase in expenditure on education which, coupled with the fall in school aged population, increased the per pupil expenditure. However, there has only been a small improvement in learning outcomes and an increase in numbers going on to tertiary education, in part due to limited opportunities and offerings in the post-secondary education system. Proposals for an Enterprise Training Fund were eventually dropped and in its place, a system of 'apprenticeships' co-financed by the government and private sector is in place. As things stand, Grenada continues to have a predominantly low-skilled workforce.

B. Technological drivers

B.1 Energy generation and use

For the 3 scenarios, Grenada has transitioned to 100% renewable energy for power generation and this includes investment in energy storage technology through public-private partnership agreements. Energy is generated by a mix of technologies but mostly solar PV, wind turbines, waste-to-energy and biogas. The spread of solar PV has been hastened by the planning and building requirements to include it in new buildings. Attempts to develop geothermal energy proved unsuccessful and have been abandoned. Similarly, mini-hydropower systems have not been developed. Solar PV power generation is from a mix of individual household, community and private solar farms, whereas the wind farms are community and privately owned. Energy generation and distribution are separated and decentralised, comprising a network of mini-grids, with Carriacou and Petite Martinique being self-reliant. All high-power cables have been 'undergrounded' as a resilience measure. The greatly increased generating capacity has facilitated changes in the transport sector with all vehicles now running on forms of renewable energy. Grenada has achieved a 70% reduction in GHG emissions and met its Nationally Determined Contribution (NDC) targets.

One of the most notable effects of switching to renewables is that it has significantly reduced the cost of energy. The widespread availability and affordability of renewable energy have rendered previously uneconomical activities viable, allowing for new opportunities and growth. In the Grenada Greens and Grenada Grows scenarios, this transition has enabled a circular economy. The recovery and reuse of materials and resources are no longer constrained by the cost or availability of energy. Problems associated with plastic waste are now being addressed as it is viable to repurpose and recover hydrocarbons. In the agriculture and food production sectors, cheap energy facilitates the uptake of smart agriculture for a variety of food crops, allowing a transition to more intensive land use but requiring less overall area. The large areas of land required for the various types of animal husbandry have, to a large extent, been supplanted by 'laboratory grown meat'. Although large land areas are required in the case of solar powered generation, the impact has been minimised through advances in the types of solar panels available and their incorporation into buildings and infrastructure. Overall, in these two scenarios, less land is taken up for food production and there is less pressure on the abstraction of natural resources allowing better conditions for ecological regeneration. There would be similar beneficial effects for marine based food production systems that have transitioned away from traditional open sea fish capture.

Renewable energy generation is decentralised and dispersed allowing the opportunity for individuals, communities and other entities to benefit and the emergence of new energy business models. However, installing renewable systems requires upfront investment, which can be substantial and depending on the regulatory compliance regime, can also become a bureaucratic process. A danger is institutional and regulatory capture which would negate many of the potential benefits. This is more likely under the Grenada Goes scenario and could lead to a *'resource curse'* situation where benefits are concentrated in the hands of an elite with negative environmental consequences.

B.2 Artificial intelligence, computing and information and communications technology (AICICT)

Although not seen as a direct driver of change in biodiversity and the provision of ecosystem services, developments in the use of AICICT is an indirect driver, in that its use has the potential to benefit the environment in two main ways. One is through its use broadly to protect and conserve ecosystems and the other is through its use to optimise the use of resources and the delivery of services. Technological advances have filtered into every area of government, business and the home, displacing ways of working but also creating new business opportunities, optimising resource use and creating demands for new and alternative resources.

AICICT have become routine tools for observation, monitoring and decision making, 3D printing, gene editing, biosensors, and the adoption of cloud manufacturing facilities. The application of technologies are routine parts of the operation and management of food production systems, ecosystem management, management of the provision of goods and the delivery of services and spurred the growth of small and medium sized enterprises (SMEs). They have also provided opportunities for greater citizen and social involvement in the governance of institutions. The advances in monitoring, surveillance and early warning diagnostic systems allow for the better management of ecosystems and disaster response management. There are downsides such as the expansion of cyber-crime and the blurring of the distinction between the personal and the public.

In the Grenada Greens and to a lesser extent Grenada Grows scenarios, the investment in education, training, and skills development has led to the development of a highly skilled workforce. This has made Grenada more economically competitive and has provided new entrepreneurial opportunities in the support and services sector. While the adoption of new technologies and a circular economy approach has increased power consumption, it has also resulted in a reduction of resource use. The improved management of ecosystems and the protection of the environment have also been key priorities in these scenarios. However, in the Grenada Goes scenario, the country has not been able to take advantage of these advancements, leaving ecosystems in a more vulnerable state due to a lack of management and protection efforts.

B.3 Water, water use, water treatment and technology

The availability of water is primarily influenced by weather and climate, modulated through the land surfaces on which it falls and/or flows through. How much water availability will be affected depends on the climate change trajectory and the intensity of global heating. Irrespective of which climate pathway transpires, the general effects are similar: temperatures will increase, rainfall patterns will change with less rainfall and greater variability. Annual rainfall is expected to decrease by at least 25%, with the decrease being more marked during the dry season. Inter-annual variability exceeds the long-term trend in both the proportion of annual rainfall totals from extremely wet days and the number of days with heavy rainfall. The proportion of annual rainfall from extreme events tends to increase over time whilst the number of days with heavy rainfall decreases, implying that although extreme rainfall is less common, it increases in intensity. By 2050, these trends have become detectable with increased incidents of flash flooding. However, there is an increasing frequency of soil moisture deficits and low stream flows, decreases in lake water levels and dropping aquifer levels. Drier conditions that also give rise to increases in bush fires, adversely affect soil cover and, in some cases, dramatically increase run-off, erosion sedimentation and pollutant transport. At the same time, low stream and river flows are accompanied by decreasing dissolved oxygen levels and water quality.

There are two contrasting trends. First, annual average rainfall is expected to decrease. However, the pattern of precipitation is expected to change with more or the expected precipitation falling in shorter and more intense rainfall events. These changes will adversely affect aquifer recharge which contributes to maintaining base flows in rivers during the dry season. These changes, together with the increased erosion and sedimentation during flash flooding have adversely affected freshwater aquatic ecosystems and significantly reduced surface and groundwater availability especially during the dry season. The major difference between the Grenada Greens climate scenario and Grenada Grows and Grenada Goes is the intensity of the effect of drying and changes in rainfall with greater water stress in the latter case. The response of terrestrial ecosystems favours adaptations to hotter, drier conditions which in turn provide less water retention capacity.

The level of abstraction would further compound negative effects on the aquatic ecosystems. The three scenarios have differing impacts on the level of abstraction and hence their compounding effects on aquatic and terrestrial ecosystems.

In Grenada Greens, water use has increased by 20%, particularly marked in the tourism and agricultural sectors. However, this has not resulted in an increase in abstraction due to a combination of greater use efficiency through changes in water using fixtures and appliances, planning and building regulations, as well as embracing more progressive measures such as circular water reuse, increased localised water capture and use, and a move to hybrid centralised/ decentralised water systems. In other words, harnessing technological advances to optimise water provision and recover resources. As a result, levels of abstraction and the need for potable water rationing decreased and the impact of development on water resources has been minimised. Inter-annual climate variability poses a challenge so that water storage dam projects together with distributed storage at the property level – brought in as a statutory requirement- now provide buffering capacity. The downside is that the alterations of stream flows have negatively impacted the aquatic systems of the rivers on which they are located. Better land management practices including nature-based solutions and control of bushfires have mitigated the worst effects of increased runoff and flash flooding events. The concept of maintaining environmental flows in aquatic ecosystems is a mandatory requirement.

Although many of the same technological improvements are available in the Grenada Grows scenario, a combination of population growth and more severe impact of global heating has put greater abstraction pressure on water surface and groundwater resources. Lakes' water levels are lower and rivers and streams routinely run dry during the dry season. Outflow from Grand Etang Lake has declined dramatically, outflow from Levera Pond has all but vanished, and the water level at the once great Lake Antoine has declined dramatically. There is in this scenario a greater reliance on desalination for potable water supply, which buffers inter-annual variability. The uptake and use of technological solutions such as desalination, are addressing the historical deterioration of ecosystems by offsetting abstraction but the combination of global heating and higher water demands continue to put pressure on aquatic ecosystems. Flash flooding and the accompanying erosion and sediment transport have seen some improvement through better land management practices associated with commercial farming developments but remains problematic.

In the Grenada Goes scenario, water resources are affected by the same climate factors as for Grenada Grows. The differences though are twofold. The first is that the population has not grown. The second is that the uptake and use of technology is hampered by the underlying socio-economic conditions. There are some measures that can be implemented to conserve water and increase water use efficiency such as changes in building codes around water devices. At the same time, physical losses from the distribution system, after some initial improvement early in the scenario, would have increased again. In this scenario, although water demand has not significantly increased, the availability of water from surface and groundwater sources has reduced. Hence water rationing increases but for different reasons. The impact on aquatic ecosystems is comparable to that observed under the Grenada Greens scenario; however, the underlying causes differ. There are few interventions to address flash flooding, erosion, mobilisation of pollutants and sediment transport. In most cases, ad hoc hard engineering solutions are employed with some effect, but marine pollution caused by run-off is a continuing issue, especially downstream of urban areas and subsistence farming areas.

B.4 Agroindustrial technology

The production and processing of food, the exploitation of terrestrial and marine resources for food and fibre, and the spaces designated for these activities all have significant consequences for biodiversity and ecosystem services. These processes not only redistribute resources between various functional systems, but also generate emissions and discharges with varying degrees of impact. The technologies employed in food production systems can either complement or disrupt natural processes.

In the Grenada Goes scenario, there is effectively a continuation of small-holder farming and amongst this group of farmers limited levels of mechanisation and adoption of technology to increase production and productivity. Whilst there has been a switch in the type of fertiliser used, the use of agrochemicals for pest and disease control continues. In contrast, the emerging commercial farming subsector has adopted technology and climate smart agriculture. It is very unlikely that in this scenario the application of genomics will find much traction and therefore would have little to no impact on biodiversity. The effect of the changes has been to decrease pollution from agrochemicals. However, there has been an increase in small and large livestock as well as pig and poultry production as a feature of a mixed subsistence food production system. The effect has been to increase overgrazing and increase production of animal waste, both of which are poorly managed. The farming of tree and orchard crops such as nutmeg, spices, mangoes and soursop continues to be an important component of agriculture and provides one of the niche growth areas available. With respect to the fisheries and marine sector, the impact of warming oceans and the decline of fish stocks and coral reef ecosystems has adversely affected returns on investment. As a result, there has been a lack of investment in the sector and uptake of technology. The one bright spot has been the emergence of aquaponics which has seen some investment and uptake of technology especially among the larger scale producers.

In the Grenada Grows scenario, food production systems, agriculture and fisheries are making greater use of technology in areas such as pest and disease surveillance systems but the uptake and use in improving production has been limited. In part, this is a result of the continued decline in the importance of the sector, particularly fisheries which has all but collapsed. The uptake of technology and agroprocessing is limited to the emerging commercial agriculture subsector. In the marine food production sector, the shift towards aquaculture, including seaweed cultivation and offshore fish farming, has necessitated the use of technology and is subject to increased regulatory oversight. Adoption and application of genetic engineering technologies e.g. those that use Clustered Regularly Interspaced Short Palindromic Repeats is probable in efforts to select desirable traits in plants and animals, enabling them to either adapt to climate change or enhance productivity. This technology may also result in the development of new crop varieties and cultivars. The impact on biodiversity and ecosystems will necessitate vigilant monitoring and regulation, as the effects could be either beneficial or detrimental.

In the Grenada Greens scenario, the adoption and utilisation of agrotechnology are most prominent due to its focus on high-tech farming methods. This scenario emphasises the use of cloning, as well as the development of new and innovative food sources, such as insect farming. The implementation of these advanced technologies and practices is relevant to this scenario, as they contribute to sustainable agriculture, increased crop yields, and food security while minimizing the environmental impact and efficiently utilizing available resources. The agricultural sector has increased in importance to the economy, reliant on technological advances.

With its reliance on technology, such as AICICT, the sector has been a catalyst for the growth of support services, processing, and export. Similar changes have occurred in the offshore sea farming sector, again reliant on technological advances. Unlike Grenada Grows, it is likely in this scenario that the uptake of new and modified organisms will not be on the same scale as there could be a greater reliance for some foods on better management of the growing environment rather than selecting for a changed growing environment.

The outlook for the marine-based blue economy is a lot brighter in the Grenada Greens scenario, especially as the management of the marine environment has been much improved, in response to the effects of climate change. The uptake of technology in the small-scale fisheries sector is driven by regional CARICOM-level and OECS-level policy and action plans. This has led to increased investment in the sector at the national level and areas such as research and development are severely lacking in resources 50 years prior. This thrust in research and development, while propelled by the private sector, is guided and incentivised by reformed fisheries legislation and frameworks and the regional fisheries body (RFB), WECAFC (Western Central Atlantic Fishery Commission). Technology integration and development in the sector is also driven by the "Caribbean Blue Revolution" and the growth of the blue economy, with Grenada, one of the few islands making strides in the aquaculture sector, particularly in mariculture, as technology advances have mitigated against issues of pest and disease and praedial larceny of fish farms.

In 2050, Grenada has made advances in data collection and management, with the adoption of appropriate ICT and vessel monitoring systems (VMS) has been used for some years to manage the sector by the Fisheries Division and has been a useful tool in the reduction and deterrence of illegal, unreported and unregulated (IUU) fishing.

Intra-regional trade is now at its highest, with more efficient logistics, cheaper transportation (by air and sea) and scalability, supported by improved ICT solutions and capacity development of the sector.

Phytosanitary conditions have also improved through the establishment of the state-of-the-art labs, use of newer technology in quick freezing, preservation, processing, packaging and storing of fish and fish products. These developments will be concentrated in Gouyave, Grenville and Petite Martinique, regional fishing hubs. In these fishing communities, there is a movement to smart fishing utilising community-level integrated technological solutions, which other smaller fishing communities and Carriacou also adopt.

Overall, there has been significant development, through the use of technology, in fishing gears and methodologies, wide adaption to offshore FADs (especially on the east coast), and safety-at-sea with a decrease in incidents at sea. These advancements are further guided and encouraged by the revised Caribbean Network of Fisherfolk Organisations (CNFO) Region Code of Conduct for Caribbean Fisheries.

Technology development and adoption in the sector has been steered by national, regional and international commitments. Grenada is known an exemplar of ecosystem approach to fisheries, focused on sustainable management and use of the fishery resources and the maintenance aquatic biodiversity.

In terms of the impact of the uptake of technology in food production, the Grenada Greens scenario has the greatest positive impact on maintaining biodiversity and ecosystem services through the minimisation of negative impacts and relieving pressure on the use of land space and land use change. The benefit must be supported by the closed loop and circular nature of the type of food production systems employed. By contrast the other two scenarios have at best a neutral impact given their lower level of adoption.

C. Environmental drivers

C.1 Climate change

Average daily maximum and minimum temperatures will continue to rise with increasing intensification of the hot season, high to extremely high heat impact and more frequent and more intense heat waves by 2050 as described in Chapter 3. The number of extreme heat events will become a nearly year-long occurrence by the 2040s. The number of hot days and hot nights will likely occur during most days of each year by 2050, while cool days are expected to disappear much sooner. The number of days with temperatures greater than 35°C will increase under RCP 4.5 these would occur mostly during the months of July through to October whilst under RCP 8.5 this would extend to include June and November. This change seems to be unavoidable, as it has been seen irrespective of what RCP scenario is looked at. A consequence of the drier climate is the expected increase in frequency and severity of bushfires.

The frequency of category 4 and 5 hurricanes is expected to increase by up to 30% with storms becoming up to 11% stronger in terms of maximum wind speeds. Sea level rise will continue being about 0.25 metres by 2050, which when combined with stronger winds and storm surges poses an increased threat of coastal flooding. Warmer oceans along with rising sea levels are seen as inevitable even under the best-case climate scenarios. SST are expected to continue to rise at a rate of 0.26°C per decade within the southern and eastern Caribbean ecoregions though there is some evidence that the trend may be accelerating. Sea surface rises include a projected rise of 0.77°C to 2.5°C by the end of the century.

The trends in rainfall and drought have been discussed above.

According to the International Monetary Fund [IMF] (2019), a 1°C increase in temperature could lead to a 1.4% decrease in real GDP per capita. Even before climate change is factored in, there is a 1% probability in any year that a disaster will impose direct and indirect losses of more than 35% of GDP. Unless addressed, the estimated change in temperatures (middle scenario) would cause real GDP and private investment to fall by about 5% and private employment by 6% respectively. At the same time, out-migration and interest rates would increase perceptibly, by around 5–6%. The IMF believes that the negative effects of climate change are likely underestimated by the model.

In addition to the economic effects, the intensification of tropical storms as a result of climate change is also likely to have severe impacts on Grenada's terrestrial and coastal ecosystems. There is evidence that the impact of tropical storms on forests and woodland brings down significant numbers of trees and contributes to landslides and mass debris flows in rivers. Recovery and regeneration of forests and woodland ecosystems occur over decadal timescales and regeneration will be particularly problematic given the additional stressors of increasing temperatures and drier conditions. Limited modelling of forest responses to increasing temperatures indicates several responses: a shift in elevation and range of species depending on their heat tolerance; changes in the life cycles of plants and of pollinating species; changes in ecosystem composition and diversity; and a decline in abundance of some important species. Shifts to drier adapted ecosystems will also have an adverse effect on water yields from catchments. If this is accompanied by further land use change from forests and woodlands to pasture or cultivated land then habitat fragmentation would reinforce the negative trend on biodiversity and ecosystems. These trends would be compounded by bushfires which would clear land, compromise the resilience of ecosystems, and contribute to excess runoff, erosion and the mobilisation and transportation of pollutants.

Similarly, climate changes will have a negative effect on agriculture, food production and food security through stressors such as higher temperatures, drier conditions, and more variable and intense rainfall. There may be opportunities for adaptive responses through crop selection adapted to the changing conditions and adaptive farming practices. If not, negative responses could include encroachment on forest and woodland areas.

With respect to coastal and marine ecosystems, there appears to be consensus that the rises in SST and accompanying ocean acidification have already had significant adverse effects. The climate induced changes have been negatively reinforced by unsustainable fishing practices. Coral reef ecosystems and the fisheries that they support are impaired. Storm surges and sea level rise, accompanied by development of coastal fringes removing coastal habitats and increased runoff and land-based sources of pollution have contributed to the decline of marine habitats and ecosystems. The loss of the protective services they provide has a negative effect on most of the main tourist infrastructure as well as the seaport.

By 2050, the difference between the projected climate conditions, RCP 4.5 low emissions and RCP 8.5 high emissions, are not that great, the trends accelerate and diverge towards the second half of the century. The adverse impacts of climate change on biodiversity and ecosystems are ameliorated in the Grenada Greens scenario as more emphasis is placed on sustainability and conservation through positive interventions and adaptations. The use of intelligent surveillance systems, the establishment of nature protection areas, in line with protecting at least 30% of land and marine areas, and the use of technologies such as biotechnology, synthetic biology and gene editing along with the adoption of novel foods e.g. seaweed, insects, and algal bioreactors relieving pressure on traditional farming and food production systems contribute to maintaining existing ecosystems. The Grenada Grows scenario has some similar features but it emerges from a period in which environmental protection had not been a priority. It is therefore a scenario in which terrestrial and marine ecosystems had been degraded and now efforts are being made to restore them but recognising that restoration must take place within the context of a changed and changing climate. In both cases, efforts would have been initiated and supported by cross-sectoral policy interventions. By contrast, Grenada Goes ecosystems continue to experience loss of biodiversity and struggle to maintain what is left. The impact is particularly acute for the coastal and marine environment.

C.2 Land use and land use change

It is generally acknowledged that land use and land cover changes are among the most significant drivers of declines in biodiversity and ecosystems including the conversion and fragmentation of habitats by agricultural expansion for crop production, plantations, and animal husbandry. Land use and land cover changes usually involve the replacement of complex natural ecosystems with simplified systems, reducing the range of ecosystem services that they can deliver. Whilst conversion to farmlands can provide an increase in food and fibre services, it is offset by decreases in other ecosystem services such as water yields, erosion control, carbon sequestration, etc. When combined with the effects of climate change, land use and cover changes have a negative feedback effect on biodiversity and the maintenance of viable, functional ecosystems resulting in land degradation. Such changes increase exposure and vulnerability to IAS, pests and diseases, and replacement of native species.

Since the ending of plantation-based agriculture in the 1940’s, there has been a decrease in the area of land given over to crop lands and pasture. The decrease has been accompanied by increased secondary forest regrowth on formerly cultivated lands, particularly at the lower elevations. Rain and elfin forests, dominating the upper and higher elevations, are relatively intact. Woodland agriculture is now the dominant land use category. Declines in coastal mangroves are mainly attributed to land use change due to tourism. There also appears to be a recent trend of clearing of riparian forested areas for cultivation.

In the Grenada Goes scenario, subsistence agriculture expands into previously cultivated areas and the trend to clear riparian areas increases. Thus, in this scenario, we see changes in land cover, particularly in dry woodland with accompanying impacts on stream and river aquatic ecosystems, which are already under pressure from over-exploitation. There are also changes with pasture for grazing and animal husbandry increasing. In the Grenada Greens scenario, although there is expansion of food production systems, there is little to no expansion into forest and woodlands areas. The potential for an increase in land-based sources of pollution has been largely contained through the closed loop nature of the production systems. The adoption of environmentally friendly policies and the increase in PAs minimises the impact of anthropogenic activities on forest and woodland ecosystems. However, this does not insulate them from the effects of global warming. In the Grenada Grows scenario, there has historically been some expansion of cultivated areas, but by our timeline this trend has been halted and a more hands on approach to ecosystem maintenance is prevalent, sometimes with unintended consequences. However, it has resulted in reductions in biodiversity and of ecosystem services though the changes are marginal.

C.3 Pests, diseases and IAS

Susceptibility to pests, diseases and IAS is a function of exposure and resilience of ecosystems. With respect to the marine environment irrespective of which timeline is considered, existing trends such as the spread of lionfish and the annual inundations of Sargassum together with the effects of coral bleaching and overfishing, land-based sources of marine pollution will have combined to reduce marine biodiversity and the services that ecosystems can provide. These trends are unlikely to change under the Grenada Goes scenario. At the other end of the spectrum, in the Grenada Greens scenario a more positive outcome is likely with a more middle ground situation emerging under the Grenada Grows scenario.

The Grenada Greens scenario has the slowest change in climate. This reduces negative impacts on and stabilises the health of marine ecosystems and fisheries resources. Sea level rise and SST increases have lower impacts on them. Due the adoption of ecosystems-based fisheries management in the management of Grenada's resources and governance overall, consequences of pollution and other anthropogenic activities have reduced. Although, transportation and movement has increased, through economic growth nationally and regionally, strengthened Integrated Coastal Zone Management at national and regional levels, and the pressure to adhere to global measures, has also controlled the spread of pests, invasives and diseases in the marine environment through spillage and ballast water. Pest and diseases control has also been manged through more stringent customs processes and phytosanitary standards and testing. The slowed SST have also limited the spread and range of invasives, and the influx of Sargassum. Although local markets for Sargassum and Sargassum seaweeds products are now affected, local industries focus on growing other species to meet demands and less government resources are required to management of any impacts onshore. On the other hand, offshore renewable energy development poses a new threat to marine and fisheries habitats and resources, however the institutional framework for managing environmental impacts has strengthened over the years and the industry will be held to high environmental and social standards.

The greater mobility and integration with regional and global trading implied by the Grenada Greens and Grenada Grows scenarios suggests that the country will be more exposed. It is likely that in Grenada Greens there will be a higher degree of surveillance and an enhanced capacity to deal with pests, diseases, and IAS. How the existing set of pests, diseases and IAS are likely to respond to changing environment conditions cannot be predicted with certainty. In the absence of natural predators or other constraints on their spread they are likely to thrive. Already introduced species are replacing indigenous terrestrial and aquatic flora and fauna, as some are also better adapted to the changing conditions. Similarly, climate change can create conditions that are more favourable to the spread and establishment of new IAS and can also lead to the emergence and spread of new diseases and pests. Additionally, climate change can weaken the resilience of ecosystems, making them more vulnerable to these threats. This is particularly relevant to small island developing states like Grenada, which are highly vulnerable to the impacts of climate change. Therefore, it is important to consider the potential interactions between climate change, biodiversity, and IAS when developing policies and strategies for managing these issues in Grenada.

C.4 Natural resource use

Natural resources include biotic and abiotic resources, some of which are inexhaustible/renewable and others exhaustible/non-renewable. Renewable resources include sunlight, air, and to an extent, water. Non-renewable resources include biotic resources such as plants and trees, animals, and abiotic resources such as mineral ores, and fossil fuels.

There are concerns that some abiotic natural resources such as beach sand and quarry stone and aggregates are being exploited in an unsustainable way in addition to high abstraction rates of water resources. There is concern regarding over-exploitation of forests and non-timber forest products contributing to habitat loss. There are also concerns regarding the over-exploitation of freshwater fauna leading to decline in species abundance. A natural resource value associated particularly with plants and some marine species is their pharmaceutical potential. Yet, there is little evidence that this is something to be concerned about.

Under the Grenada Greens and to a much lesser extent the Grenada Grows scenarios there is a pronounced adaptive and integrated management approach to all ocean resources. While tourism and the rise of the blue economy relies heavily on these resources, resource recovery occurs. For fisheries resources, the success of the MPA network in Grenada, Carriacou and Petite Martinique, has led to the increased fishing of “spill over”. The development of FADs and offshore fisheries has also decreased pressure on nearshore resources and reef fisheries. The revision of fisheries regulations and improved monitoring and surveillance has allowed for sustainable use of fisheries resources. This is further driven through regional (OECS) level management plans, particularly for shared/migratory fish stocks. Pressures on natural resources have also been lessened through the growth of the aquaculture sector. The focus on self-sufficiency (reduced imports) and intra-regional trade also contributed to the reduced pressure on national and local resources.

There is a continued and successful effort to reduce microplastics in the ocean environment, with funding and investment in research, led by the Government of Grenada and St. George’s University. Marine plastic has been reduced greatly through legal frameworks and the work of the civil society organisations (CSOs) in Grenada. This includes the abandonment of fishing gear which is a danger to marine life (mammals, turtles, fish and seabirds). Grenada, as part of the circular economy, is now leading the OECS in economic valuation of natural resources and marine spatial planning. These studies and the data generated has fuelled policy development and investment in conservation and sustainable use through the national revenue and overseas development assistance (ODA). Grenada has been leveraging its rich [recovered] resources through carbon crediting mechanisms (using mangrove, coral reef and seagrass ecosystems) and debt-for-nature swaps.

The two scenarios based around the adoption of a circular economy approach, coupled with the availability of low-cost energy and technological advances implies that resource recovery has become a viable alternative to the continued exploitation of natural resources. This would include sand, aggregate, wood and water resources. On the other hand, the availability of low cost and stable energy would make Grenada an attractive country to do business in and there could well be a surge in the provision of remote laboratories and manufacturing facilities. A situation could arise where local recycled resources are no longer sufficient to meet demand, and this could give rise to increased pressures either for importation or use of local natural resources. On the other hand, it is likely that abiotic resources such as sand and minerals, and biotic resources such as plants and trees would see increased extraction under Grenada Goes.

C.5 Pollution

Sources of pollution include: biochemical agricultural runoff; runoff and leachates from landfill and dumping; from commercial, manufacturing and agro-processing activities; untreated wastewater and sewage; and littering- both terrestrial and marine. The potential effects of these sources of pollution on biodiversity and ecosystems have been discussed in Chapter 2, so the focus here is on how these would be addressed in each of the three scenarios. Whilst it is possible to manage sources of and hence the effects of pollution, it is unlikely that even under the best case that it can be eliminated. The Grenada Greens scenario provides the best opportunities to manage pollution whilst Grenada Goes is the least likely to provide effective management with Grenada Grows nearer to Grenada Greens.

Grenada Greens offers more effective municipal solid waste management services (collection, disposal and repurposing, and addressing legacy issues) coupled with the recycling and reuse opportunities touched on under energy generation and use. Littering and associated plastic pollution could be reduced through a combination of societal and technological measures. In addition, improvements in sanitation and wastewater management would address issues of untreated sewage, and nutrients entering the environment. Similarly, nutrients, animal waste, and agrochemicals associated with food production systems would be better managed, reducing runoff and eutrophication of water bodies. It is likely that a broad spectrum of chemicals of emerging concern, and substances associated with the development of new materials and processes would be subject to international regulatory control. In the Grenada Goes scenario, public services such as solid waste management, dumping and wastewater management would continue to face numerous difficulties in being able to address the pollution challenges outlined. The continued use in rural areas of septic tanks means that these remain potential sources of pollution. Expansion of small-holding/subsistence agriculture would be accompanied by a continuation of practices around the applications of fertilisers and agrochemicals, and the disposal of animal waste. Some of the negative trends could be offset, through the access to cheap energy, by the growth of enterprises using waste products as productive inputs and repurposing them.

The negative effects of pollution on biodiversity and ecosystem services in the Grenada Greens scenario would be greatly reduced and would provide positive maintenance and support. By reducing this as a stressor it would contribute to the health of ecosystems. On the other hand, the lack of success in addressing and reducing pollution in Grenada Goes would have the opposite effect, particularly on water bodies and the marine environment.

D. Economic drivers

D.1 Economic performance

Grenada's estimated population, depending on the source consulted, is 124,600 and the GDP is given as US$1.2 billion according to data from the World Bank (World Bank, 2023). Since the early 1970's the country's GDP growth rate has varied wildly, often from one year to another. Since 1990, GDP has grown at an average annual rate of approximately 2%. Although by 2020, Grenada's Debt to GDP ratio had dropped to 60%, due to the COVID-19 crisis this increased to 78% in 2022 though it is expected to decrease in line with the previous trend.

In the early 2020's the number of persons classed as poor or in extreme poverty were 30% of the population, 40% were in the low-income range and 25% could be classed as middle income with approximately 3% in the upper income range (Figure 6.10).

Unemployment rates were around 25% according to the UNDP (2016), see Figure 6.10, and IMF (IMF, 2022) with higher rates among the youth and females, and higher levels of both poverty and unemployment outside of urban areas. Most of the working poor were concentrated in construction, agriculture and fisheries (agriculture and fisheries contributed ~7% of GDP yet employed 12% of the workforce).

The main earner of foreign income is tourism which is the mainstay of the economy and is also a major employer. Food products such as nutmeg, fish and cocoa beans are also important export earners. According to the IMF (2022) there is scope to leverage the medical facilities and knowledge of St. George's University (SGU) to improve health services for visitors, increase job opportunities in fishing and eco-tourism ventures, and promote environmentally sensitive use of Grenada's ocean resources. It is clear from this overview that tourism, agriculture and fisheries are the main sources of impact on biodiversity and ecosystems; tourism in the coastal margins, agriculture in the lower elevation dry forest, and fisheries in the demersal and pelagic zones.

In the Grenada Grows scenario, economic conditions improve; GDP has risen to US$2.3 billion or US$16,900 per person. Extreme poverty rates have dropped to 15% with more people moving into the low income band and a substantial increase in the number in the middle income band. Unemployment rates have dropped though rates continue to be high for the unskilled; youth and female employment rates have increased as the skill levels of these groups have

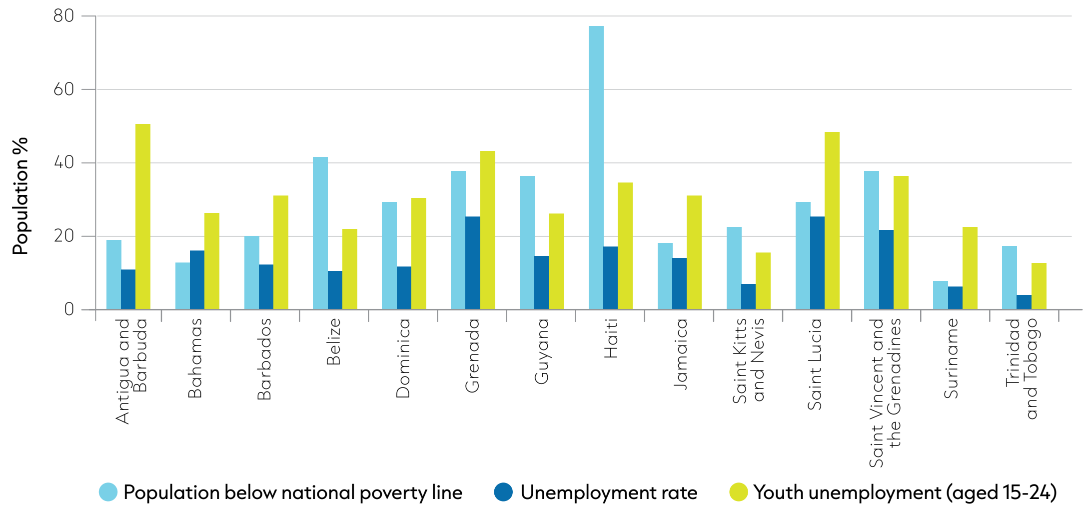

Figure 6.10. Population below national poverty line, unemployment rate and youth unemployment in the Caribbean (OECD, 2019)

increased. The economy has diversified with tourism declining relatively in its economic contribution, and it still tends to be a relatively low-skilled area of the economy. The economic growth areas are associated with education, manufacturing, and food products and agroprocessing, much of which is for export. On the back of the growth in export commerce, trade and export related services have developed supported by the adoption of new technologies.

The economic growth provides fiscal space that enables government to provide better environment and natural resource management. Furthermore, in this scenario, the principles of circular economy underpin economic development and encompass a transition towards a blue and green economy. With respect to the blue economy, coastal based developments have been subject to rigorous environmental conditions encompassing 'planning gains' for the environment. Marine based tourism, including yacht cruising tourism centred on Carriacou, has developed along with supporting services. The big economic change is the importance of aquaculture and sea-based fish and seaweed-based farming. With respect to the green economy, the big gain has been the renewable energy sector which has enabled the development of green jobs across a variety of sectors. These include the growth of repurposing of resources for further use in construction and manufacturing, the development of new food products and the expansion of agroprocessing, and the greening of transportation.

The impact on biodiversity and ecosystems is somewhat mixed. Resource abstraction and use has declined particularly with respect to land based economic activities. Overall land-based biodiversity and ecosystem functioning is more impacted by climate related stressors than by economic development. The growth of areas to accommodate the new industries and economic enterprises generally impacts the low elevation woodlands rather than the higher elevation ecosystems. The growth of the marine based economies, on top of the stresses induced by climate change have side effects on marine ecosystems with continuing biodiversity loss and alterations of marine ecosystems. Coastal ecosystems are somewhat better protected but still subject to development stresses, though this is offset by the PAs and how they are managed.

In the Grenada Greens scenario, we would see many of the features of the Grenada Grows scenario but with more consideration for long-term sustainability and environmental impacts. The GDP is slightly lower at US$2.2 billion (World Bank, 2023) but with the lower population it is US$17,200 per person suggesting that people are somewhat better off under this scenario. Extreme poverty is much reduced as is the number of people in the low-income category, with some 40% of the population falling in the middle income category. Similarly, youth and female employment has increased substantially, again for similar reasons. In this scenario the economy is even more mixed than in Grenada Grows. Regionalisation of trade across the Wider Caribbean has expanded employment and export opportunities particularly in the food production sector. Land-based food production has adopted many organic agriculture principles. Environmental safeguards, certification and traceability are important factors that have helped green this sector. Tourism has diversified to include health and the purple economy (The Change Oracle, 2022). Innovation hubs have supported the expansion of offshore manufacturing facilities as well as supporting agro-industries.

In this scenario, environmental sustainability is an important feature and therefore has a more positive impact on biodiversity and the maintenance of ecosystem services.

In the Grenada Goes scenario, Grenada's economy has stagnated, GDP is around US$1.45 billion (World Bank, 2023) or US$11,900 per person, as compared to US$9,010 in 2021. This suggests a continuation of limited fiscal space for the government. Although poverty levels are expected to have dropped, the majority of the population continues to fall in the low-income category and the economy continues to be predominantly low-skilled. Youth unemployment continues to be high. The economy continues to rely on the tourism sector which has continued to grow in importance, and on construction. In this scenario, apart from the renewable energy sector and the emerging commercial farming sector, there has been limited growth in the green economy and green jobs. For the blue economy, coastal development and "squeeze" of the coastal environment would have continued. It is anticipated that unsustainable fisheries practices would have continued. One possible outcome for Grenada in order to improve its financial position is the exploration and development of offshore hydrocarbon resources. However, this scenario is specific to Grenada Goes. In contrast, the other scenarios do not include the exploitation of hydrocarbon resources as a means of economic development.

The limitations on government finances and the extent to which it can effectively regulate activities suggests that in this scenario the weak economic conditions would be an indirect driver of biodiversity loss and ecosystem services.

E. Political drivers

E.1 Governance

Governance describes the arrangements governing who has power, how decisions are made and implemented, the opportunities for those interested and affected by those decisions to have their voices heard, and accountability for the consequences. This entails the institutional and organisational arrangements (who does what), the enabling environment (how organisations are empowered), and management instruments (the tools used to effect desired outcomes). Governance arrangements evolve to meet existing and new challenges and cope with the circumstances within which they operate. Grenada is a Westminster style democracy with an elected government and an apolitical Civil Service. The aim is to govern in the best interests of citizens and society, as conceived by the ruling parliamentary party, to the extent that the resources available to the country allow. Nature, environment and sustainability must be balanced against other competing considerations.

In the Grenada Goes scenario there are severe governance challenges across the board. The weakness of government finances, the hollowing out of the Civil Service and the burgeoning challenges associated with economic development and international relations has reduced the effectiveness of government to provide environmental leadership. The ability to develop environmental legislation is challenging, the monitoring and management of natural resources is underfunded and under resourced, and there is little effective ability to enforce regulations. This situation is compounded by an economic reliance on tourism and its continued development. This has resulted in a tendency to acquiesce to tourism sector demands and other developments at the expense of environmental concerns. Some of the slack has been taken up by CSOs and community-based organisations acting on localised issues. A worrying emerging trend is state capture by privileged sections of society and criminal organisations.

In the Grenada Grows scenario, there is closer collaboration and integration with the OECS which has brought about changes to the governance structure particularly with respect to environmental matters. Environmental policy and legislation are largely set at the sub-regional level with national adoption. Regulation and enforcement are also a shared responsibility meaning that greater resources and expertise are mobilised leading to more effective actions. This has enabled Grenada and other Eastern Caribbean states to offset their financial and resource challenges and in Grenada's case, the shrinking of the Civil Service. A second reinforcing strand is the adoption of co-management with civil society, social enterprises and community-based organisations. These governance changes have supported the greater and more effective use of technology in environmental surveillance and more effective interventions to conserve and protect biodiversity and ecosystems.

In Grenada Greens scenario the partnership with the OECS described above also pertains. In this scenario the earlier shrinking of the Civil Service was not reversed with the marked improvement of government finances. Instead, there has been the emergence of collaborative governance systems in which non-government organisations have taken on greater governmental responsibilities. This is supported by central government financial support coupled with the implementation of dynamic economic incentives. Environmental valuations are conducted and incorporated into a system of national economic accounting. The role of government ministries has been redefined moreso to a policy goals-oriented mission and operational matters devolved. Technological advances have been crucial in enabling the changes in governance.

E.2 Environmental policies and regulation

Grenada is signatory to international conventions that address issues that affect or have a bearing on the maintenance and protection of biodiversity and ecosystems. In addition, there are regional policies and action plans through the OECS and the CARICOM in which Grenada is guided or participates. For example, the *St. George's Declaration of Principles for Environmental Sustainability in the OECS and the Eastern Caribbean Regional Ocean Policy.* At the national level the laws, policies and actions plans are discussed in Chapter 5, but cover: Biodiversity Strategy, *Revised Draft National Forestry Policy, Integrated Coastal Zone Management Act*, *Land Policy, Climate Change Policy, National Adaption Plans, Nationally Determined Contributions (NDC)*, *National Water Policy*, and the *Sustainable Development Plan*.

However, some of these policies are outdated and need to be reviewed whilst others lack the supporting legislation. The IMF in its 2019 Climate Change Policy Assessment (IMF, 2019) highlighted two points which are relevant. First, that Grenada has an implementation capacity deficit and second, the scale of the financing required and the challenge to raise the finance even with the assistance of the private sector. On the positive side, international standards have begun to influence the development landscape in the Caribbean, particularly for developments seeking credit/funding from international banks where demonstrating compliance with performance standards is increasingly required. For example, the International Finance Corporation Performance Standards (IFC PS), PS6- Biodiversity Conservation and Sustainable Management of Living Natural Resources. International crediting agencies are also now requiring critical habitat assessment and biodiversity management plans.

In the Grenada Greens scenario, it can be anticipated that some of the challenges facing the development and implementation of environmental policies would have been addressed and performance standard requirements for developments introduced. The need for revision and the enactment of legislation to give effect to policies would have been undertaken. Furthermore, the implementation capacity deficit would have been addressed through a combination of organisational change, adoption of co-management and partnerships, technological advances and incentive-based regulation. Greater protection would be afforded to natural ecosystems through land policies and national physical development plans, similarly coastal and marine areas would also benefit. That said, there will remain financial challenges and challenges around the management and regulation of biochemical pollution. The overall thrust would be on prevention of damage to ecosystems, protection and maintenance whilst still balancing issues of access.

In contrast to this, Grenada Goes is anticipated to see a continuation of the implementation deficit, the continued presence of outdated policies and financial challenges around the implementation and enforcement of regulations. International requirements would result in some environment policies being addressed. Grenada Grows would see a halfway situation but with more emphasis on mitigating and maintaining access to resources through offsets and the use of cap-and-trade mechanisms.

E.3 Geopolitics and regionalisation

This indirect driver addresses the degree to which Grenada would be integrated with the regional and global community and the degree to which those communities have developed agreements and protocols across a wide range of issues including the flow of goods and services, standards and compliance regimes, support mechanisms in terms of knowledge transfer and financing mechanisms.

In the Grenada Greens scenario, there would have been a global emphasis on addressing climate heating and supporting sustainability transitions. This is a more integrated world in which the value of biodiversity and ecosystems are recognised. Furthermore, the level of regional integration is highest in this scenario. Overall then, this scenario has the stronger indirect drivers supporting investment in maintaining biodiversity and nature's services. This is not the case in the Grenada Goes scenario where there is more national emphasis, recognising of course that no country would be isolated from the international community. There will be international pressures but, in this timeline, it is unlikely that in spite of rhetoric that there would be much concrete action and incentives.

E.4 Transparency, accountability, and rule of law

This is an indirect driver that if exercised and embedded in regulatory processes provides protection and can help address causes of degradation, and sensitising stakeholders of the need for remedial action. It provides a means for holding to account those engaging in either inaction, neglect, or antisocial behaviour and practices. It also promotes the dissemination of good practices. Transparency, accountability, and the rule of law can be seen as features of governance. Effectiveness depends on having in place the necessary mechanisms requiring the provision of reliable and unbiased information on a regular basis, the identification of responsibilities, mechanisms for holding to account, and the ability and willingness to impose sanctions. The adoption of the *Escazú Regional Agreement on Access to Information, Public Participation and Justice in Environmental Matters in Latin America and the Caribbean* (UN, 2018) provides the foundation for the implementation and development of measures that support transparency, accountability, and the rule of law with respect to environmental matters.

In the Grenada Greens scenario, the Escazú Regional Agreement and its successors would be fully implemented and supported by the provision of high-quality information. In the Grenada Goes scenario, although the agreement would have been ratified, the ability to implement it together with the ability to provide information would be problematic and further complicated by the influence of elites.

Glossary

Term	Definition	Source
	Chapter 1	
Biodiversity	The variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part. This includes variation in genetic, phenotypic, phylogenetic, and functional attributes, as well as changes in abundance and distribution over time and space within and among species, biological communities and ecosystems.	The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (n.d.) *Glossary.* Available at https://www.ipbes.net/glossary (Accessed 2 February, 2021).
Civil society organisations (CSOs)	CSOs include non-governmental organisations, community groups, labour unions, indigenous peoples movements, faith-based organisations, professional associations, foundations, think tanks, charitable organisations, and other not-for-profit organisations.	The World Bank (2021) *Civil Society Policy Forum: Overview*. Available at: https://www.worldbank.org/en/events/2020/12/22/civil-society-policy-forum (Accessed 28 February 2021).
Disaster preparedness	Activities and measures taken in advance to ensure effective response to the impact of hazards, including the issuance of timely and effective early warnings and the temporary evacuation of people and property from threatened locations.	International Strategy for Disaster Reduction (2009) *UNISDR Terminology on Disaster Risk Reduction.* Geneva, Switzerland: United Nations International Strategy for Disaster Reduction (UNISDR). Available at: https://www.undrr.org/publication/2009-unisdr-terminology-disaster-risk-reduction (Accessed 29 January 2021).
Disaster risk management	Processes for designing, implementing, and evaluating strategies, policies, and measures to improve the understanding of disaster risk, foster disaster risk reduction and transfer, and promote continuous improvement in disaster preparedness, response, and recovery practices, with the explicit purpose of increasing human security, well-being, quality of life, and sustainable development.	Intergovernmental Panel on Climate Change (IPCC) (2018) 'Annex I: Glossary' in Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.) *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. Available at: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_AnnexI_Glossary.pdf (Accessed 23rd July 2021)
Disaster management	The organisation and management of resources and responsibilities for dealing with all humanitarian aspects of emergencies, in particular preparedness, response and recovery in order to lessen the impact of disasters.	International Federation of Red Cross and Red Crescent Societies (IFRC) (2021) *About disaster management.* Available https://www.ifrc.org/en/what-we-do/disaster-management/about-disaster-management/ (Accessed 23 July 2021)
Ecosystem	A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit	Secretariat of the Convention on Biological Diversity (2005) *Handbook of the Convention on Biological Diversity Including its Cartagena Protocol on Biosafety.* 3rd ed. Montreal: Canada. Available at: https://www.cbd.int/doc/handbook/cbd-hb-all-en.pdf (Accessed 29 January 2021).

Term	Definition	Source
Environmental goods and services	Environmental goods and services are products manufactured or services rendered for the main purpose of: • preventing or minimising pollution, degradation or natural resources depletion; • repairing damage to air, water, waste, noise, biodiversity and landscapes; • reducing, eliminating, treating and managing pollution, degradation and natural resource depletion; and • carrying out other activities such as measurement and monitoring, control, research and development, education, training, information and communication related to environmental protection or resource management.	Eurostat Statistics Explained (2020) *Glossary: Environmental goods and services sector (EGSS*). Available at https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Environmental_goods_and_services_sector_(EGSS)#:~:text=Environmental%20goods%20and%20services%20are,for%20the%20main%20purpose%20of%3A&text=carrying%20out%20other%20activities%20such,environmental%20protection%20or%20resource%20management (Accessed 28 February 2021)
Environmental sustainability	Meeting the resource and services needs of current and future generations without compromising the health of the ecosystems that provide them, and as a condition of balance, resilience, and interconnectedness that allows human society to satisfy its needs while neither exceeding the capacity of its supporting ecosystems to continue to regenerate the services necessary to meet those needs nor by our actions diminishing biological diversity.	Morelli, J. (2011) 'Environmental Sustainability: A Definition for Environmental Professionals', *Journal of Environmental Sustainability,* 1(1). Available at: https://scholarworks.rit.edu/cgi/viewcontent.cgi?article=1007&context=jes (Accessed 23 July 2021).
Ecosystem services	The benefits people obtain from ecosystems. In the Millennium Ecosystem Assessment, ecosystem services can be divided into supporting, regulating, provisioning and cultural. This classification, however, is superseded in IPBES assessments by the system used under 'Nature's Contributions to People'. This is because IPBES recognises that many services fit into more than one of the four categories. For example, food is both a provisioning service and also, emphatically, a cultural service, in many cultures	The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (n.d.) *Glossary.* Available at https://www.ipbes.net/glossary (Accessed 2 February, 2021).
Environmental mainstreaming	The informed inclusion of relevant environmental concerns into the decision of institutions that drive national, local and sectoral development policy, rules, plans, investment and action.	Dalal-Clayton, B. & Bass, S. (2009) *The Challenges of Environmental Mainstreaming: Experience of Integrating Environment into Development Institutions and Decisions*. London: International Institute for Environment and Development, p. 11.
Environmental policy integration	Moving environmental issues from the periphery to the centre of decision-making, whereby environmental issues are reflected in the very design and substance of sectoral policies.	Nunan, F., A. Campbell, A., and E. Foster (2012) 'Environmental mainstreaming: The organisational challenges of policy integration'. *Public Administration and Development*, 32(3), p. 262.
Intergenerational equity	Meeting the needs of the present without compromising the ability of future generations to meet their own needs' (the Brundtland Commission Report, 1987). It also pertains to the level of 'social mobility' between generations in absolute terms (whether children are richer or poorer, healthier, or more educated than their parents), or in relative terms (whether children are higher or lower on the social ladder than their parents). This can be measured by the share of inequality coming from factors over which people have no control, such as race, gender, birthplace, or parents' education (Brundtland, 2012).	Onuzo U, Garcia AF, Hernandez A, Peng Y & Lecoq T. (2013) *Intergenerational Equity. Understanding the Linkages between Parents and Children: A Systematic Review.* London: The London School of Economics and Political Science. Available at: https://www.unicef.org/socialpolicy/files/LSE_Capstone_Intergenerational_Equity.pdf (Accessed 29th January 2021). WCED (1987) *Our common future. Report of the World Commission on Environment and Development*. G. H. Brundtland, (ed.). Oxford: Oxford University Press.

Term	Definition	Source
Local/indigenous/ traditional knowledge	Local knowledge refers to the understandings and skills developed by individuals and populations, specific to the places where they live. Local knowledge informs decision-making about fundamental aspects of life, from day-to-day activities to longer-term actions. This knowledge is a key element of the social and cultural systems which influence observations of, and responses to climate change; it also informs governance decisions. Indigenous knowledge refers to the understandings, skills and philosophies developed by societies with long histories of interaction with their natural surroundings. For many Indigenous peoples, Indigenous knowledge informs decision making about fundamental aspects of life, from day-to-day activities to longer term actions. This knowledge is integral to cultural complexes, which also encompass language, systems of classification, resource use practices, social interactions, values, ritual and spirituality. Indigenous and local knowledge systems are social and ecological knowledge practices and beliefs pertaining to the relationship of living beings, including people, with one another and with their environments. Such knowledge can provide information, methods, theory and practice for sustainable ecosystem management. Traditional Knowledge - Knowledge, innovations and practices of indigenous and local communities around the world. Developed from experience gained over the centuries and adapted to the local culture and environment, traditional knowledge is transmitted orally from generation to generation. It tends to be collectively owned and takes the form of stories, songs, folklore, proverbs, cultural values, beliefs, rituals, community laws, local language and agricultural practices, including the development of plant species and animal breeds. Traditional knowledge is mainly of a practical nature, particularly in such fields as agriculture, fisheries, health, horticulture, forestry and environmental management in general	UNESCO (2018) *Local and Indigenous Knowledge Systems – What is Local and Indigenous Knowledge*. Available at http://www.unesco.org/new/en/natural%E2%80%93sciences/priority%E2%80%93areas/links/related%E2%80%93information/what%E2%80%93is%E2%80%93local%E2%80%93and%E2%80%93indigenous%E2%80%93knowledge (Accessed 29th January 2021). The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (n.d.) *Glossary.* Available at https://www.ipbes.net/glossary (Accessed 2 February, 2021). United Nations Educational, Scientific and Cultural Organization (UNESCO) Institute of Statistics (2021) *Glossary: Traditional Knowledge*. Available at: http://uis.unesco.org/en/glossary-term/traditional-knowledge (Accessed 23rd July 2021).
Multilateral environmental agreements (MEAs)	A generic term for treaties, conventions, protocols, and other binding instruments related to the environment. Usually applied to instruments of a geographic scope wider than that of a bilateral agreement (i.e., between two States).	United Nations Environment Programme (UNEP) (2007) *Glossary of Terms for Negotiators of Multilateral Environmental Agreements.* UNEP Division of Environmental Law and Conventions. Available at https://www.cbd.int/doc/guidelines/MAs-negotiator-glossary-terms-en.pdf (Accessed 29 January 2021)

Term	Definition	Source
Non-governmental organisations (NGOs)	Groups and institutions that are entirely or largely independent of government and that have primarily humanitarian or cooperative, rather than commercial, objectives. They are private agencies in industrial countries that support international development; indigenous groups organised regionally or nationally; and member-run groups in villages. NGOs include charitable and religious associations that mobilise private funds for development, distribute food and family planning services, and promote community organisation. They also include independent cooperatives, community associations, water-user societies, women's groups, and pastoral associations. Citizen groups that raise awareness and influence policy about environmental and social issues are also NGOs.	The World Bank (1990) *How the World Bank Works with Nongovernmental Organizations*. Washington, D.C.: The World Bank, pp. 7-8. Available at: http://documents1.worldbank.org/curated/en/118901468780890205/pdf/multi-page.pdf (Accessed 28 February 2021).
Policy	Policy includes formal policy, laws and regulations and also includes informal policy which may be unwritten rules, guidelines or common practice.	Geoghegan, T.Y. Renard and N.A. Brown (2004) *Guidelines for Participatory Planning: A Manual for Caribbean Natural Resource Managers and Planners*. Caribbean Natural Resources Institute Guidelines Series 4. Laventille: CANARI.
Policy instrument	Environmental policy includes all government measures aimed at: 1) assessing the state of environment pollution, 2) evaluating this pollution in relation to the threat it poses to either human welfare (anthropocentric) or ecosystems (ecocentric), and 3) controlling polluting activities by means of regulations, economic incentives and/or training, moral persuasion, information campaigns and collaborative contractual arrangements with selected target groups. Set of means or mechanisms to achieve a policy goal.	Knoepfel, P. (2007) *Environmental Policy Analyses: learning from the past for the future-25 years of research*. pringer Science & Business Media. Available at: Google Books <http://booksgoogle.com> (Accessed 29th January 2021). The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (n.d.) *Glossary.* Available at https://www.ipbes.net/glossary (Accessed 2 February, 2021).
Policy makers	Policy makers include not only those in a country with formal responsibility for making policy, usually a group of elected political representatives, but also the technical officers in government at all levels who contribute to drafting and recommending policy, as well as the range of stakeholders from civil society organisations, other government agencies, academia, media, inter-governmental bodies, and donor and technical assistance agencies who also contribute to influencing, recommending and drafting policy.	Geoghegan, T.Y. Renard and N.A. Brown (2004) *Guidelines for Participatory Planning: A Manual for Caribbean Natural Resource Managers and Planners*. Caribbean Natural Resources Institute Guidelines Series 4. Laventille: CANARI.
Resilience	The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions. Resilience means the ability to "spring back from" a shock. The resilience of a community in respect to potential hazard events is determined by the degree to which the community has the necessary resources and is capable of organising itself both prior to and during times of need. The level of disturbance that an ecosystem or society can undergo without crossing a threshold to a situation with different structure or outputs. Resilience depends on factors such as ecological dynamics as well as the organisational and institutional capacity to understand, manage, and respond to these dynamics.	International Strategy for Disaster Reduction (2009*) UNISDR Terminology on Disaster Risk Reduction*. (pdf) Geneva, Switzerland: United Nations International Strategy for Disaster Reduction (UNISDR). Available at: https://www.undrr.org/publication/2009-unisdr-terminology-disaster-risk-reduction (Accessed 29 January 2021). The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (n.d.) *Glossary.* (online) Available at https://www.ipbes.net/glossary (Accessed 2 February, 2021).

Term	Definition	Source
Sustainable use	'Sustainable use' means the use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations.	Secretariat of the Convention on Biological Diversity (2005) *Handbook of the Convention on Biological Diversity Including its Cartagena Protocol on Biosafety*. 3rd ed. (pdf) Montreal: Canada. Available at: https://www.cbd.int/doc/handbook/cbd-hb-all-en.pdf (Accessed 29 January 2021)
Sustainable use (of biodiversity and its components)	The use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations. Development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987) and balances social, economic and environmental concerns	The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (n.d) *Glossary.* (online) Available at https://www.ipbes.net/glossary (Accessed 2 February, 2021). Intergovernmental Panel on Climate Change (IPCC) (2018) 'Annex I: Glossary' in Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.) *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. Available at: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_AnnexI_Glossary.pdf (Accessed 23rd July 2021) WCED (1987) *Our common future. Report of the World Commission on Environment and Development*. G. H. Brundtland, (ed.). Oxford: Oxford University Press.
Chapter 2		
Agroecosystem	An ecosystem, dominated by agriculture, containing assets and functions such as biodiversity, ecological succession and food webs. An agroecosystem is not restricted to the immediate site of agricultural activity (e.g. the farm), but rather includes the region that is impacted by this activity, usually by changes to the complexity of species assemblages and energy flows, as well as to the net nutrient balance.	The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (n.d.) *Glossary.* (online) Available at https://www.ipbes.net/glossary (Accessed 2 February, 2021).

Term	Definition	Source
Alien species	Species occurring in an area outside of its historically known natural range as a result of intentional or accidental dispersal by human activities. Alien species are not necessarily invasive species.	UNEP (2007) *Glossary of Terms for Negotiators of Multilateral Environmental Agreements.* (pdf) UNEP Division of Environmental Law and Conventions. Available at https://www.cbd.int/doc/guidelines/MAs-negotiator-glossary-terms-en.pdf (Accessed 29 January 2021).
Invasive species	A species that invades natural habitats.	
Invasive alien species	Species whose introduction and/or spread by human action outside their natural distribution threatens biological diversity, food security, and human health and well-being. 'Alien' refers to the species' having been introduced outside its natural distribution ('exotic', 'non-native' and 'non-indigenous' are synonyms for 'alien'). 'Invasive' means "tending to expand into and modify ecosystems to which it has been introduced". Thus, a species may be alien without being invasive, or, in the case of a species native to a region, it may increase and become invasive, without actually being an alien species.	The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (n.d.) *Glossary.* (online) Available at https://www.ipbes.net/glossary (Accessed 2 February, 2021).
Critically Endangered	A species is Critically Endangered when the best available evidence indicates that it meets any of the criteria A to E for Critically Endangered (see *IUCN Red List Criteria*) and it is therefore considered to be facing an extremely high risk of extinction in the wild.	International Union for Conservation of Nature and Natural Resources (IUCN) (2021) *The IUCN Red List of Threatened Species*. Version 2021-1. (online) Available at https://www.iucnredlist.org
Data deficient	A species is data deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. A species in this category may be well studied, and its biology well known, but appropriate data on abundance and/or distribution are lacking.	International Union for Conservation of Nature and Natural Resources (IUCN) (2021) *The IUCN Red List of Threatened Species*. Version 2021-1. (online) Available at https://www.iucnredlist.org
Endangered	A species is endangered when the best available evidence indicates that it meets any of the criteria A to E for endangered (see *IUCN Red List Criteria*), and it is therefore considered to be facing a very high risk of extinction in the wild.	International Union for Conservation of Nature and Natural Resources (IUCN), (2021) *The IUCN Red List of Threatened Species*. Version 2021-1. (online) Available at https://www.iucnredlist.org
Extinct	A species is extinct when there is no reasonable doubt that the last individual has died. A species is presumed extinct when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the species's life history.	International Union for Conservation of Nature and Natural Resources (IUCN) (2021) *The IUCN Red List of Threatened Species*. Version 2021-1. (online) Available at https://www.iucnredlist.org
Forest	A minimum area of land of 0.05- 1.0ha with tree crown cover (or equivalent stocking level) of more than 10–30% with trees with the potential to reach a minimum height of 2–5m at maturity in situ. A forest may consist either of closed forest formations where trees of various stories and undergrowth cover a high proportion of the ground or open forest.	The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (n.d.) *Glossary.* (online) Available at https://www.ipbes.net/glossary (Accessed 2 February, 2021).
Freshwater	Water contains less than 1,000 milligrams per litre of dissolved solids, most often salt.	UNEP-WCMC (2014) *Biodiversity A-Z.* (online) UNEP-WCMC, Cambridge, UK. Available at www.biodiversitya-z.org (Accessed 29 January 2021). USGS (2013) *Dictionary of Water Terms*. (online) Available at https://www.usgs.gov/special-topic/water-science-school/science/dictionary-water-terms?qt-science_center_objects=0#F (Accessed 29 January 2021).

Term	Definition	Source
Important Bird Area (IBA)	IBAs are: • Places of international significance for the conservation of birds and other biodiversity • Recognised world-wide as practical tools for conservation • Distinct areas amenable to practical conservation action • Identified using robust, standardised criteria • Sites that together form part of a wider integrated approach to the conservation and sustainable use of the natural environment The selection of Important Bird and Biodiversity Areas (IBAs) is achieved through the application of quantitative ornithological criteria, grounded in up-to-date knowledge of the sizes and trends of bird populations. The criteria ensure that the sites selected as IBAs have true significance for the international conservation of bird populations, and provide a common currency that all IBAs adhere to, thus creating consistency among, and enabling comparability between, sites at national, continental and global levels.	BirdLife International (2021) *Important Bird and Biodiversity Areas (IBAs).* (online) Available at https://www.birdlife.org/worldwide/programme-additional-info/important-bird-and-biodiversity-areas-ibas
Key Biodiversity Area (KBA)	Key Biodiversity Areas (KBAs) are sites that contribute significantly to the global persistence of biodiversity. The criteria used to identify KBAs incorporate elements of biodiversity across genetic, species and ecosystem levels, and are applicable to terrestrial, freshwater, marine and subterranean systems. KBAs have delineated boundaries and are actually or potentially manageable as a unit. KBAs provide an effective bridge between assessment processes and conservation planning and an important step towards conservation action.	KBA Standards and Appeals Committee (2020) *Guidelines for using A Global Standard for the Identification of Key Biodiversity Areas*. Version 1.1. Prepared by the KBA Standards and Appeals Committee of the IUCN Species Survival Commission and IUCN World Commission on Protected Areas. Gland, Switzerland: IUCN. viii + 206 pp. Available at: https://portals.iucn.org/library/node/49131
Marine	Comprises all ocean and coastal waters, including intertidal zones and saltwater marshes, as well as adjacent coastal and riparian land areas, and extending, in the case of watercourses, up to the freshwater limit.	UNEP-WCMC (2014) *Biodiversity A-Z.* (online) UNEP-WCMC, Cambridge, UK. Available at www.biodiversitya-z.org (Accessed 29 January 2021). UN (1992) *Environment and Development (Terminology bulletin: 344)*. New York, USA: United Nations.
Marine litter	Marine litter is any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment.	UNEP (n.d.) *Marine Litter*. (online). Available at: https://www.unep.org/explore-topics/oceans-seas/what-we-do/working-regional-seas/marine-litter
Marine Protected Area (MPA)	A globally applicable, general term to describe any protected area in the marine realm which aims to conserve nature and maintain healthy oceans. Marine and Coastal Protected Areas (MCPAs) - "an area within or adjacent to the marine environment, together with its overlying waters and associated flora, fauna, and historical and cultural features, which has been reserved by legislation or other effective means, including custom, with the effect that its marine and/or coastal biodiversity enjoys a higher level of protection than its surroundings.	UNEP-WCMC (2014) *Biodiversity A-Z. (online).* UNEP-WCMC, Cambridge, UK. Available at www.biodiversitya-z.org (Accessed 23 July 2021) Convention on Biological Diversity (2004) COP 7 Decision VII/5: Marine and coastal biological diversity.
Terrestrial	Occurring on, or inhabiting, land.	UNEP-WCMC (2014) *Biodiversity A-Z. (online).* UNEP-WCMC, Cambridge, UK. Available at www.biodiversitya-z.org (Accessed 23 July 2021)

Term	Definition	Source
Wetland	Areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres. Wetlands include a wide variety of inland habitats such as marshes, peatlands, floodplains, rivers and lakes, and coastal areas such as saltmarshes, mangroves, intertidal mudflats and seagrass beds, and also coral reefs and other marine areas no deeper than six metres at low tide, as well as human made wetlands such as dams, reservoirs, rice paddies and wastewater treatment ponds and lagoons. Areas that are subject to inundation or soil saturation at a frequency and duration, such that the plant communities present are dominated by species adapted to growing in saturated soil conditions, and/or that the soils of the area are chemically and physically modified due to saturation and indicate a lack of oxygen; such areas are frequently termed peatlands, marshes, swamps, sloughs, fens, bogs, wet meadows, etc.	Ramsar Convention Secretariat (2016) *An Introduction to the Convention on Wetlands (previously The Ramsar Convention Manual)*. (pdf) Gland, Switzerland: Ramsar Convention Secretariat. Available at: https://www.ramsar.org/sites/default/files/documents/library/handbook1_5ed_introductiontoconvention_e.pdf (Accessed 23 July 2021) The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (n.d.) *Glossary.* (online) Available at https://www.ipbes.net/glossary (Accessed 2 February, 2021).
	Chapter 3	
Adaptation	In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects.	Intergovernmental Panel on Climate Change (IPCC) (2018) 'Annex I: Glossary' in Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.) *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. Available at: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_AnnexI_Glossary.pdf (Accessed 23rd July 2021)
Climate change	Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.' The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes.	Intergovernmental Panel on Climate Change (IPCC) (2018) 'Annex I: Glossary' in Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.) *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. Available at: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_AnnexI_Glossary.pdf (Accessed 23rd July 2021)

Term	Definition	Source
Climate change impacts	The consequences of realised risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather and climate events), exposure, and vulnerability. Impacts generally refer to effects on lives; livelihoods; health and well-being; ecosystems and species; economic, social and cultural assets; services (including ecosystem services); and infrastructure. Impacts may be referred to as consequences or outcomes, and can be adverse or beneficial.	Intergovernmental Panel on Climate Change (IPCC) (2018) 'Annex I: Glossary' in Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.) *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. Available at: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_AnnexI_Glossary.pdf (Accessed 23rd July 2021)
Climate (change) resilience	The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure while also maintaining the capacity for adaptation, learning and transformation.	Intergovernmental Panel on Climate Change (IPCC) (2018) 'Annex I: Glossary' in Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.) *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. Available at: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_AnnexI_Glossary.pdf (Accessed 23rd July 2021))
Climate variability	Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).	Intergovernmental Panel on Climate Change (IPCC) (2018) 'Annex I: Glossary' in Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.) *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. Available at: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_AnnexI_Glossary.pdf (Accessed 23rd July 2021))
Ecosystem-based Adaptation	Ecosystem-based Adaptation (EbA) is a nature-based solution that harnesses biodiversity and ecosystem services to reduce vulnerability and build resilience to climate change.	IUCN (2017) *Ecosystem-based adaptation*. Available at: https://www.iucn.org/resources/issues-brief/ecosystem-based-adaptation (Accessed 18th February 2021)

Term	Definition	Source
Mitigation	A human intervention to reduce emissions or enhance the sinks of greenhouse gases.	Intergovernmental Panel on Climate Change (IPCC) (2018) 'Annex I: Glossary' in Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.) *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. Available at: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_AnnexI_Glossary.pdf (Accessed 23rd July 2021)
Representative Concentration Pathways	Scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases (GHGs) and aerosols and chemically active gases, as well as land use/land cover. The word representative signifies that each RCP provides only one of many possible scenarios that would lead to the specific radiative forcing characteristics. The term pathway emphasises that not only the long-term concentration levels are of interest, but also the trajectory taken over time to reach that outcome. Four RCPs were selected from the published literature and are used in the Fifth IPCC Assessment as a basis for the climate predictions and projections: RCP2.6 One pathway where radiative forcing peaks at approximately 3 W m-2 before 2100 and then declines RCP4.5 and RCP6.0 Two intermediate stabilisation pathways in which radiative forcing is stabilised at approximately 4.5 W m-2 and 6.0 W m-2 after 2100 RCP8.5 One high pathway for which radiative forcing reaches greater than 8.5 W m-2 by 2100 and continues to rise for some amount of time	IPCC, Data Distribution Centre (no date) *Definition of terms used within the DDC pages*. Available at: https://www.ipcc-data.org/guidelines/pages/glossary/glossary_r.html (Accessed 29th January 2021)
Chapter 4		
Anthropocentric	Anthropocentrism refers to a human-centered or 'anthropocentric' point of view. In philosophy, anthropocentrism can refer to the point of view that humans are the only, or primary, holders of moral standing. Anthropocentric value systems thus see nature in terms of its value to humans; while such a view might be seen most clearly in advocacy for the sustainable use of natural resources, even arguments that advocate for the preservation of nature on the grounds that pure nature enhances the human spirit must also be seen as anthropocentric.	Padwe, Jonathan (2013) 'Anthropocentrism. Oxford Bibliographies', in D. Gibson (ed.) *Ecology: Anthropocentrism.* Oxford University Press Editors. Available at: https://www.oxfordbibliographies.com/view/document/obo-9780199830060/obo-9780199830060-0073.xml . (Accessed 29th January 2021)
Bioactive compound	Bioactive compounds can be defined as nutrients and nonnutrients present in the food matrix (vegetal and animal sources) that can produce physiological effects beyond their classical nutritional properties.	Cazarin, C.B.B, Bicas, J.L, Pastore, G.M, and Junior M.R.M (2022) 'Chapter 1 – Introduction', in Cazarin, C.B.B, Bicas, J.L, Pastore, G.M, and Junior M.R.M (eds.) *Bioactive Food Components Activity in Mechanistic Approach.* Available at: https://doi.org/10.1016/B978-0-12-823569-0.00004-7

Term	Definition	Source
Biocentric	Biocentrism refers to all environmental ethics that extend the status of moral objects from human beings to all other living things in nature. In a narrow sense, it emphasises the value and rights of organic individuals, believing that moral priority should be given to the survival of individual living beings. Biocentric ethics, as an environmental ethic, considers that all living things have their own "good" and therefore proposes expanding the status of moral object to nonhuman living things.	Yu, Mouchang and Yi Lei, (2012) 'Biocentric Ethical Theories', In Teng, Teng and Ding Yifan (eds.) *Environment and Development: Encyclopedia of Life Support Systems*. (e-book) United Nations Educational, Scientific, and Cultural Organization, 2012. Available at: https://www.eolss.net/Sample-Chapters/C13/E4-25-07-03.pdf (Accessed 29th January 2021)
Bioprospecting	A systematic and organised search for useful products derived from bioresources including plants, microorganisms, animals, etc. that can be developed further for commercialisation and overall benefits of the society.	Oyemitan, I.A. (2017) 'Chapter 27 – African Medicinal Spices of Genus Piper,' in Kuete, V. *Medicinal Spices and Vegetables from Africa*. Academic Press. Available at: https://doi.org/10.1016/B978-0-12-809286-6.00027-3.
Carbon sequestration	The process of capturing and storing atmospheric carbon dioxide. It is one method of reducing the amount of carbon dioxide in the atmosphere with the goal of reducing global climate change.	United States Geological Survey (USGS) (no date) *What is carbon sequestration*. Available at: https://www.usgs.gov/faqs/what-carbon-sequestration (Accessed 29th January 2021).
Culture	The set of distinctive spiritual, material, intellectual and emotional features of society or a social group, that encompasses, not only art and literature, but lifestyles, ways of living together, value systems, traditions and beliefs.	UNESCO (2001) *UNESCO Universal Declaration on Cultural Diversity.* (online) Paris: UNESCO. Available at http://portal.unesco.org/en/ev.php-URL_ID=13179&URL_DO=DO_TOPIC&URL_SECTION=201.html (Accessed 29 January 2021).
Debushing	Vegetation clearing along roadsides and drains.	NOW Grenada (2022) *Debushing programme commences*. Available at: https://nowgrenada.com/2022/08/debushing-programme-commences/ (Accessed 29 January 2021).
Ecotourism	Sustainable travel undertaken to access sites or regions of unique natural or ecological quality, promoting their conservation, low visitor impact, and socio-economic involvement of local populations.	The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (n.d.) *Glossary.* (online) Available at https://www.ipbes.net/glossary (Accessed 2 February, 2021).
Genetic material	Any material of plant, animal, microbial or other origin containing functional units of heredity.	Secretariat of the Convention on Biological Diversity (2005) *Handbook of the Convention on Biological Diversity Including its Cartagena Protocol on Biosafety.* (pdf) 3rd ed. Montreal: Canada. Available at: https://www.cbd.int/doc/handbook/cbd-hb-all-en.pdf (Accessed 29 January 2021)
Genetic resources	Genetic material of actual or potential value.	Secretariat of the Convention on Biological Diversity (2005) *Handbook of the Convention on Biological Diversity Including its Cartagena Protocol on Biosafety.* (pdf) 3rd ed. Montreal: Canada. Available at: https://www.cbd.int/doc/handbook/cbd-hb-all-en.pdf (Accessed 29 January 2021)

Term	Definition	Source
Human well-being	A state of existence that fulfils various human needs, including material living conditions and quality of life, as well as the ability to pursue one's goals, to thrive, and feel satisfied with one's life.	Intergovernmental Panel on Climate Change (IPCC) (2018) 'Annex I: Glossary' in Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.) *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. Available at: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_AnnexI_Glossary.pdf (Accessed 23rd July 2021)
Nature's Contributions to People	All the contributions, both positive and negative, of living nature (i.e. diversity of organisms, ecosystems, and their associated ecological and evolutionary processes) to the quality of life for people	The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (no date) *Glossary.* Available at https://www.ipbes.net/glossary (Accessed 2 February, 2021).
Non-Timber Forest Products	Goods derived from forests that are tangible and physical objects of biological origin other than wood.	Forest Resources Assessment (2015) *Terms and Definitions*, *Forest Resources Assessment Working Paper 180*. (pdf) Rome: Food and Agriculture Organization 0f The United Nations. Available at: http://www.fao.org/3/a-ap862e.pdf (Accessed 29 January 2021)
Non-use values	Non-use values are derived either from current direct or indirect use of the environment. For example, there are individuals who do not use the tropical forest but nevertheless wish to see them preserved 'in their own right'. These 'intrinsic' values are often referred to as existence values.	Moran, D. and C. Bann (2000) *The Valuation of Biological Diversity for National Biodiversity Action Plan and Strategies: A Guide for Trainers*. (pdf) Prepared for the United Nations Environment Programme (UNEP). Available at https://www.cbd.int/financial/values/g-valueunepguide.pdf (Accessed 29 January 2021)
Provisioning services	The products people obtain from ecosystems; may include food, freshwater, timber, fibres, medicinal plants.	UNEP-WCMC (2014) *Biodiversity A-Z.* (online) UNEP-WCMC, Cambridge, UK. Available at www.biodiversitya-z.org (Accessed 29 January 2021) Hassan R, Scholes R, Ash N (eds.) (2005) *Millennium Ecosystem Assessment: Ecosystems and Human Wellbeing, Volume 1, Current State and Trends*. Washington: Island Press.
Species	An interbreeding group of organisms that is reproductively isolated from all other organisms, although there are many partial exceptions to this rule in particular taxa. Operationally, the term species is a generally agreed fundamental taxonomic unit, based on morphological or genetic similarity, that once described and accepted is associated with a unique scientific name.	The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (n.d.) *Glossary.* (online) Available at https://www.ipbes.net/glossary (Accessed 2 February, 2021).

Term	Definition	Source
Supporting services	Ecosystem services that are necessary for the production of all other ecosystem services. Some examples include biomass production, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling, and provisioning of habitat.	UNEP-WCMC (2014) *Biodiversity A-Z*. (online) UNEP-WCMC, Cambridge, UK. Available at www.biodiversitya-z.org (Accessed 18th February 2021) Hassan R, Scholes R, Ash N (eds.) (2005) *Millennium Ecosystem Assessment: Ecosystems and Human Wellbeing, Volume 1, Current State and Trends*. Washington: Island Press.
Total economic value	The framework commonly used for valuing natural resources is known as the Total Economic Value (TEV). This comprises use values (direct, indirect and option value) and non-use values.	Moran, D. and C. Bann (2000) *The Valuation of Biological Diversity for National Biodiversity Action Plan and Strategies: A Guide for Trainers*. (pdf) Prepared for the United Nations Environment Programme (UNEP). Available at https://www.cbd.int/financial/values/g-valueunepguide.pdf (Accessed 29 January 2021)

Term	Definition	Source
Value	Value systems: Set of values according to which people, societies and organisations regulate their behaviour. Value systems can be identified in both individuals and social groups (Pascual *et al.*, 2017). Value (as principle): A value can be a principle or core belief underpinning rules and moral judgments. Values as principles vary from one culture to another and also between individuals and groups (IPBES/4/INF/13). Value (as preference): A value can be the preference someone has for something or for a particular state of the world. Preference involves the act of making comparisons, either explicitly or implicitly. Preference refers to the importance attributed to one entity relative to another one (IPBES/4/INF/13). Value (as importance): A value can be the importance of something for itself or for others, now or in the future, close by or at a distance. This importance can be considered in three broad classes: 1) The importance that something has subjectively, and may be based on experience, 2) The importance that something has in meeting objective needs, and 3) The intrinsic value of something (IPBES/4/INF/13). Value (as measure): A value can be a measure. In the biophysical sciences, any quantified measure can be seen as a value (IPBES/4/INF/13). Non-anthropocentric value: A non-anthropocentric value is a value centered on something other than human beings. These values can be non-instrumental or instrumental to non-human ends (IPBES/4/INF/13). Intrinsic value: This concept refers to inherent value, that is the value something has independent of any human experience or evaluation. Such a value is viewed as an inherent property of the entity and not ascribed or generated by external valuing agents (Pascual *et al.*, 2017). Anthropocentric value: The value that something has for human beings and human purposes (Pascual *et al.*, 2017). Instrumental value: The value attributed to something as a means to achieving a particular end (Pascual *et al.*, 2017). Non-instrumental value: The value attributed to something as an end, regardless of its utility for other ends. Relational value: The values that contribute to desirable relationships, such as those among people or societies, and between people and nature, as in "Living in harmony with nature" (IPBES/4/INF/13). Integrated valuation: The process of collecting, synthesising, and communicating knowledge about the ways in which people ascribe importance and meaning of NCP to humans, to facilitate deliberation and agreement for decision making and planning (Pascual *et al.*, 2017).	The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (n.d.) *Glossary.* (online) Available at https://www.ipbes.net/glossary (Accessed 2 February, 2021). Pascual, U., Balvanera, P., Díaz, S., Pataki, G., Roth, E., Stenseke, M., Watson, R.T., Dessane, E.B., Islar, M., Kelemen, E. and Maris, V. (2017) 'Valuing nature's contributions to people: the IPBES approach', *Current Opinion in Environmental Sustainability*, 26-27, pp.7-16. https://doi.org/10.1016/j.cosust.2016.12.006 IPBES (2016) *Plenary of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services Fourth Session IPBES/4/INF/13.* Kuala Lumpur, 22–28 February 2016. Available at: https://ipbes.net/sites/default/files/downloads/IPBES-4-INF-13_EN.pdf (Accessed 2 February 2021).

Term	Definition	Source
Chapter 5		
Ecosystem based Approaches	Ecosystem-based Approaches focus on ecosystem restoration and enhancement of ecosystem services to protect society against negative impacts of climate change	European Climate Adaptation Platform Climate-ADAPT (no date) *Ecosystem based approaches.* Available at: https://climate-adapt.eea.europa.eu/en/eu-adaptation-policy/sector-policies/ecosystem (Accessed 2 February, 2021).
Payment for Ecosystem Services	Payment for Ecosystem Services (PES) is a type of market-based instrument that is increasingly used to finance nature conservation. Payment of ecosystem services programmes allow for the translation of the ecosystem services that ecosystems provide for free into financial incentives for their conservation, targeted at the local actors who own or manage the natural resources.	IPBES (2019) *Policy instrument – Payment for Ecosystem Services.* Available at: https://www.ipbes.net/policy-support/tools-instruments/payment-ecosystem-services (Accessed 2 February, 2021).
Chapter 6		
Critical uncertainty	An uncertainty that is key to your focal issue and likely to have a significant impact on outcomes. They are usually unstable or unpredictable and can include things like climate change, natural disaster, new technology or products, government regulations.	A. Cashman, 2021, personal communication, 2 February.
Drivers	In the context of IPBES, drivers of change are all the factors that, directly or indirectly, cause changes in nature, anthropogenic assets, nature's contributions to people and a good quality of life. Direct drivers of change can be both natural and anthropogenic. Direct drivers have direct physical (mechanical, chemical, noise, light etc.) and behaviour-affecting impacts on nature. They include, inter alia, climate change, pollution, different types of land use change, invasive alien species and zoonoses, and exploitation. Indirect drivers are drivers that operate diffusely by altering and influencing direct drivers, as well as other indirect drivers. They do not impact nature directly. Rather, they do it by affecting the level, direction or rate of direct drivers. Interactions between indirect and direct drivers create different chains of relationship, attribution, and impacts, which may vary according to type, intensity, duration, and distance. These relationships can also lead to different types of spill-over effects. Global indirect drivers include economic, demographic, governance, technological and cultural ones. Special attention is given, among indirect drivers, to the role of institutions (both formal and informal) and impacts of the patterns of production, supply and consumption on nature, nature's contributions to people and good quality of life.	The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (no date) *Glossary.* Available at https://www.ipbes.net/glossary (Accessed 2 February, 2021).

Term	Definition	Source
Foresight	A collection of forward-thinking methodologies that are generally applied to improve institutional planning or policy making for potential future situations, hazards or opportunities.	FAO (2014) *Food Safety and Quality Programme: Horizon Scanning and Foresight – An overview of approaches and possible applications in Food Safety (emphasis on possible applications by FAO's Food Safety Programme): Background Paper 2 FAO Early Warning/Rapid Alert and Horizon Scanning Food Safety Technical Workshop*.(pdf) Rome, 22-25 October 2013. FAO. Available at http://www.fao.org/3/I4061E/i4061e.pdf (Accessed 18 February, 2021).
Horizontal Scanning	A specific foresight methodology that utilises various steps to identify issues at the edge of current thinking that may have significant impact in the medium to long term future.	FAO (2014) *Food Safety and Quality Programme: Horizon Scanning and Foresight – An overview of approaches and possible applications in Food Safety (emphasis on possible applications by FAO's Food Safety Programme): Background Paper 2 FAO Early Warning/Rapid Alert and Horizon Scanning Food Safety Technical Workshop*.(pdf) Rome, 22-25 October 2013. FAO. Available at http://www.fao.org/3/I4061E/i4061e.pdf (Accessed 18 February, 2021).

Term	Definition	Source
Scenarios	A plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g., rate of technological change, prices) and relationships. Note that scenarios are neither predictions nor forecasts, but are used to provide a view of the implications of developments and actions. Representations of possible futures for one or more components of a system, particularly for drivers of change in nature and nature's benefits, including alternative policy or management options. Exploratory scenarios (also known as "explorative scenarios" or "descriptive scenarios") are scenarios that examine a range of plausible futures, based on potential trajectories of drivers – either indirect (e.g. socio-political, economic and technological factors) or direct (e.g. habitat conversion, climate change). Target-seeking scenarios (also known as "goal-seeking scenarios" or "normative scenarios") are scenarios that start with the definition of a clear objective, or a set of objectives, specified either in terms of achievable targets, or as an objective function to be optimised, and then identify different pathways to achieving this outcome (e.g. through backcasting). Intervention scenarios are scenarios that evaluate alternative policy or management options – either through target seeking (also known as "goal seeking" or "normative scenario analysis") or through policy screening (also known as "ex-ante assessment"). Policy-evaluation scenarios are scenarios, including counterfactual scenarios, used in ex-post assessments of the gap between policy objectives and actual policy results, as part of the policy-review phase of the policy cycle. Policy-screening scenarios are scenarios used in ex-ante assessments, to forecast the effects of alternative policy or management options (interventions) on environmental outcomes.	Intergovernmental Panel on Climate Change (IPCC) (2018) 'Annex I: Glossary' in Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.) *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*. Available at: https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_AnnexI_Glossary.pdf (Accessed 23rd July 2021) The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (n.d.) *Glossary* (online). Available at https://www.ipbes.net/glossary (Accessed 2 February, 2021).
Trends	A pattern of change over time, over and above short-term Fluctuations	Hassan R, Scholes R, Ash N (eds.) (2005) *Millennium Ecosystem Assessment: Ecosystems and Human Wellbeing, Volume 1, Current State and Trends*. Washington: Island Press.

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NEA NATIONAL ECOSYSTEM ASSESSMENT INITIATIVE

BESNet Biodiversity and Ecosystem Services Network