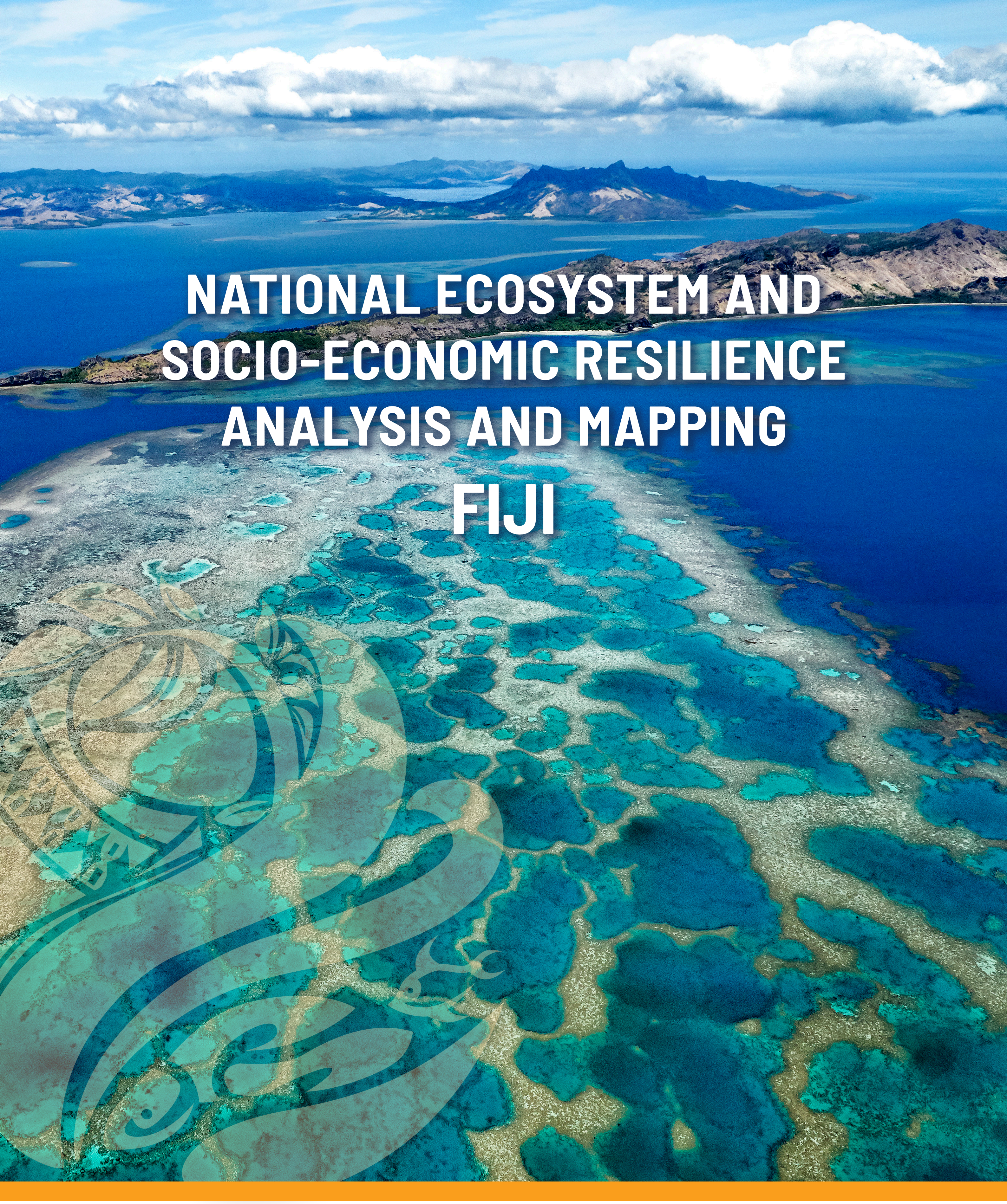
NATIONAL ECOSYSTEM AND SOCIO-ECONOMIC RESILIENCE ANALYSIS AND MAPPING

FIJI



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SPREP's vision: The Pacific environment, sustaining our livelihoods and natural heritage in harmony with our cultures.

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NATIONAL ECOSYSTEM AND SOCIO-ECONOMIC RESILIENCE ANALYSIS AND MAPPING

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A report prepared by the Pacific Ecosystem-based Adaptation to Climate Change Project (PEBACC)

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CONTENTS

ACRONYMS

BMU	German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
CMIP	Climate Model Intercomparison Project
DoE	Department of Environment
EbA	Ecosystem-based Adaptation
EIA	Environmental Impact Assessment
ENSO	El Niño-Southern Oscillation
EMA	Environmental Management Act
EEZ	Exclusive Economic Zone
ESRAM	Ecosystem and Socio-economic Resilience Analysis and Mapping
FLMMA	Fiji Locally Managed Marine Area Network
FAO	Food and Agriculture Organization
FJD	Fiji dollar(s)
FRDP	Framework for Resilient Development in the Pacific
FSC	Fiji Sugar Corporation
GDP	Gross Domestic Product
GIS	Geographic Information System
GSR	Great Sea Reef
GCM	Global Climate Model
IKI	International Climate Initiative
LMMA	Locally Managed Marine Area
LULC	Land Use/Land Cover
MACBIO	Marine and Coastal Biodiversity Management in Pacific Island Countries
MPA	Marine Protected Area
NDVI	Normalised Difference Vegetation Index
NCCCT	National Climate Change Country Team
NEC	National Environment Council
NGO	Non-governmental Governmental Organisation
TLFC	iTaukei Land and Fisheries Commission
PACCSAP	Pacific-Australia Climate Change Science and Adaptation Planning programme
PCF	Pacific Climate Futures
PEBACC	Pacific Ecosystem-based Adaptation to Climate Change (this project)
rcp	representative concentration pathways
REDD+	Reducing Emissions from Deforestation and forest Degradation + forest conservation
SPREP	Secretariat of the Pacific Regional Environment Programme
TC	Tropical Cyclone
WDPA	World Database on Protected Areas
UNOC	United Nations Ocean Conference

GLOSSARY

Dalo	a starchy root crop, also known as taro (*Colocasia esculenta*)
iTaukei	indigenous Fijian
Mataqali	traditional landowners, clans
Qoliqoli	traditional fishing grounds
Tabu	forbidden, usually with respect to use or approach
Tikina	district; provincial sub-division
Yaqona	a root crop also known as kava (*Piper methysticum*)

EXECUTIVE SUMMARY

This ecosystem and socio-economic resilience analysis and mapping (ESRAM) report is a baseline study to identify vulnerabilities in ecosystem services at the national, provincial and community scales to determine needs for adaptation planning to mitigate the effects of climate change. The report is an analysis at Fiji's national scale with an emphasis on seeking the mechanisms of change that create vulnerabilities from both climate- and non-climate-related forces.

This report emphasises the following facts:

- Climate change is expected to increase air and sea temperatures, sea levels and levels of ocean acidification – rainfall is likely to be more intensive, followed by periods of drought. This will intensify marine and land-based management, particularly agriculture and sediment delivery to the marine environment, which can cause harm.
- At the 2017 United Nations Oceans Conference, Fiji committed to a set of ambitious measures that will begin the reversal of the decline of the ocean's health. This is in order to achieve the UN Sustainable Development Goal 14 – Conserve and sustainably use the oceans, seas and marine resources for sustainable development – by increasing resilience to pollution and ocean acidification. Follow through on this commitment will increase resilience of the marine ecosystems of Fiji.
- The Great Sea Reef (GSR) is among the most important reefs of the world and extends the length of Macuata Province to the Yasawas. The GSR provides vital marine resources and supports the designation as a Ramsar Convention site near Labasa. Integration of marine and terrestrial management among government agencies will ensure success for true ridge-to-reef management.
- There are serious environmental repercussions associated with TC Cyclone Winston, involving potential degradation of native forest reserves on Taveuni and other native forest patches across the country.
- The effects of TC Winston, flooding and droughts of 2016 are recent and accessible for Fijians to engage in future adaptation to climate change.
- Land tenure is a driver in decision-making. Lessees have minimal incentives to invest in ecosystem health (forests, soils, future environmental resources), and choose to invest the minimum to achieve the maximum output.
- There are valuable aspects to traditional Fijian vanua management that can be applied and expanded in the 21st century with a range of stakeholders who have not been included before. Expansion of the best is a good starting point.
- The qoliqoli of Fiji are near or exceeding maximum harvest levels. Concentrated marine management is necessary.
- Cross political and social boundaries of terrestrial managers with marine representatives to achieve true ridge-to-reef outcomes.

Needs identified:

- There is a need to link ecosystem-based functions with the socio-economic and political landscape – managing for natural resources as an investment into the future requires time, resources and change in behaviours to create more choices.
- A need to track, monitor and link ongoing projects of all types with the context of resource use, potential community confusion, and conflicting missions.
- A need to identify, map, quantify, address, mitigate and geographically bind the cumulative effects of projects in an ecological and social context.
- A need to address the challenge of political boundaries in connected landscapes for successful ridge-to-reef ecosystem management.

- A need to cross ministerial mission boundaries to address environmental concerns across disciplines, especially for projects not requiring fully developed environmental impact assessments, through use of best management practices, such as maintaining stream buffers in road maintenance projects.
- A need for centralised planning resources, or a multidisciplinary task-force to increase awareness of actions to ecosystem services at local levels, and make these available during the planning and implementation process for all proposed projects or interventions. This also includes an autonomous operating budget for outreach.
- A need to organise outside donor-driven projects so that common mission goals are met in meaningful ways, and all relevant parties work to increase durability of projects and build long-lasting environmental awareness and choices for communities: smart investment strategies to yield long-term dividends.
- A need to localise management and oversight obligations to increase capacity and ownership, while still managing cohesively for ecosystems.
- A need for community organisations to prioritise and address their own resource concerns, allowing for clear linkages of community concerns to emerge both laterally and vertically through the political structure (inter-agency and community-district-provincial-divisional-national structures).
- A need to allow for appropriate investment or incentives for land users to ensure sustainability through improving soil fertility, diversifying crops or protecting forests.
- A need for a transparent and central data exchange, if Fiji is willing to accept outside partners to assist in natural resource management.

1. INTRODUCTION

1.1 THE PEBACC PROJECT

Increased sensitivity of the Pacific Islands to environmental, social and economic change has prompted the need to seek and implement strategies that strengthen communities through interventions that buffer the supply and diversity of ecosystem services. The Secretariat of the Pacific Regional Environment Programme (SPREP) with funding from the German Federal Ministry of Environment International Climate Change Initiative, has initiated a four-phase project to seek and implement a strategy to strengthen communities through ecosystem-based adaptation (EbA) and management activities. The Pacific Ecosystem-based Adaptation to Climate Change (PEBACC) project is focused to identify, prioritise and implement EbA strategies to meet critical needs in three countries (Fiji, Vanuatu and Solomon Islands) at three different scales: a national, provincial and a focused island scale.

The key objective of the PEBACC project is to identify what climate change factors and what suite of other circumstantial factors are limiting socio-economic resilience, particularly as it pertains to ecosystem services and the resilience of these services through time, and to prescribe a range of EbA actions that can broaden the range of possibilities for communities through the enhancement of ecosystem services.

There are five major milestones of the five-year PEBACC project.

- **Ecosystem and socio-economic resilience analysis and mapping (ESRAM).** A baseline study to identify vulnerabilities in ecosystem services at the national, provincial and community scales to identify needs for adaptation planning.
- **EbA options assessment.** A range of EbA activities that would build resilience in targeted areas. Options are prioritised based on a range of criteria including benefits, feasibility, durability and cost.
- **Implementation plans.** A plan of action for deployment of funding and capacity support to be delivered at appropriate scales.
- **Implementation of EbA options.** Commence activities according to the implementation plans, with monitoring and adaptation where appropriate.
- **EbA and policy implications.** Synthesis of how EbA activities support community and resource resilience, and what successful approaches should be considered for future policy for the host country and communities.

This report presents the national scale ESRAM synthesis. The scope of this document is to present an overview of the following at the national scale:

- capture the current condition, potential future conditions and ecosystem services important nationally;
- identify the vulnerable resources and the stressors or additional factors (forces) – both climate change and local activities that threaten ecosystem services; and
- identify a pathway for developing adaptation options to increase resilience of critical ecosystem services and livelihoods at the national level.

1.2 FIJI IN CONTEXT

The Fijian archipelago is approximately 18,700 km^2 with ~80 per cent of the 900,000 inhabitants living in the coastal areas, at least partially dependent upon fish and marine resources for subsistence. The Fijian population is composed of ~57 per cent indigenous Fijians and 37 per cent of Indian origin, with many that have family dating back to the period of indentured labourers (ca. 1879–1916). The remainder of the population have origins in other Pacific Islands, Europe and China. The quality of life in Fiji for residents is generally high, with the World Bank categorising Fiji as an upper middle-income nation based on a GDP per capita of approximately USD 5,000. Population is growing slightly, with all growth occurring in the urban population.

Fiji experiences a tropical climate influenced by a complex current regime caused by the occurrence of numerous islands, archipelagos and seamounts. These currents divert oceanic circulation to create localised eddies that are a patchwork of nutrient-rich and nutrient-poor water bodies varying over short time frames. The major currents in the South Pacific region are driven by the easterly trade winds, and the South Pacific thermocline waters are transported westward in the South Equatorial Current towards the Southwestern Pacific Ocean. Around Fiji, two main currents flow westward – the North Equatorial Current and the South Equatorial Current, both equatorial branches of two basin-scale circular circulation patterns.

Produce of the land: sweet mangoes on sale along the Kings Road, Viti Levu.

1.3 ESRAM METHODS

Analysis at the national scale is designed to be a 'broad brush' view of the major factors that may influence resilience, or the capacity to adapt to and rebound from the effects of climate change. The national scale analysis is largely focused on the influences of policy and practices that proliferate across sectors and the country, without the emphasis of site-specific circumstances. Examples include the management of land tenure, government protocols in place that influence or manage that tenure, past and projected future land and marine resource use activities, as well as the general patterns and trends in climate that have been observed and are predicted to be observed.

Considerable efforts were made to gather existing spatial and quantitative data from a wide range of governmental and non-governmental organisations working in Fiji. This resulted in some summary information with spatial data, but not across all sectors or spatial completeness across all divisions in Fiji. This ESRAM document provides a summary overview at the national level of the more detailed efforts for both Macuata Province and Taveuni Island. Information gathered at the national level is presented here, along with highlights from the analyses from these two scales.

Stakeholder profiles began with the government – national and provincial representatives, especially from Macuata Province (a PEBACC focus area) – to introduce the PEBACC project and solicit direction from different natural resource departments within the government. Individual meetings and small workshops were held in central settings in the capital of Suva to assess how government departments and ministries operated with regard to natural resource management at the national level, and how natural resource goals and objectives were conveyed across the management spectrum (national, divisional, provincial, district, community). Interviews with government, non-government, university and industry stakeholders provided valuable contextual information for this report.

Data sources include published and non-published reports, as well as available spatial (GIS) and tabular data. In general, data sharing and consolidation of data among government administrations proved to be difficult in many instances–protocols for sharing information were different for each department, and many required long request times before granting access and in many cases raw data were not provided. For this reason, many of the datasets presented here may not be the most current, and may not represent the most accurate representation of the current condition. As such this ESRAM document, like many of its kind, may require updating as new information is gathered.

It is important to note regarding the analysis of spatial datasets that there are some inconsistencies with total reported areas. This is due in large part to the construction of the original datasets, where spatial areas are not necessarily consistent among datasets and legacies associated with GIS spatial analysis for derived products. While efforts were made to rectify these data to best reflect the spatial extent for each focus area, summaries should be viewed as representing the 'best approximate' areas and not counted as detailed survey-grade summaries of areas.

This document focuses on a broad, national scale analysis. Much of the information in this report is useful in providing background context for the two focal areas of Macuata Province and Taveuni Island; additional details regarding the provincial and island-level analyses can be found in the associated PEBACC ESRAM reports for Macuata Province and Taveuni Island.

Yaqaga Island, Bua Province, Fiji. © Stuart Chape.

2. CURRENT CONTEXT AND OVERVIEW

2.1 GEOGRAPHY AND POPULATION

Fiji lies within the Archipelagic Deep Basins Province and has more than 332 islands, a third of which are inhabited (Figure 1). Fiji's vast marine EEZ (exclusive economic zone) is 1.3 million km^2 in size. Approximately 40 percent of the EEZ borders international waters and the rest borders five Pacific Island nations: Vanuatu to the west, Solomon Islands to the northwest, Tuvalu to the north, Wallis and Futuna to the northeast, and the Kingdom of Tonga to the southeast.

Land area in the Fijian islands group totals 18,300 km^2. The three largest islands are Viti Levu (10,391 km^2; 57 per cent of total land mass), Vanua Levu (5,575 km^2; 30 per cent of total), and Taveuni (436 km^2; 2 percent of total). The topography of the larger islands is generally mountainous with wide coastal plains in some areas, particularly on the leeward (northwest facing) slopes of Vanua Levu, and in the larger river valleys. Maximum elevations are 1,300 m on Viti Levu, 1,000 m on Vanua Levu, and 1,200 m on Taveuni. The south eastern (windward) sides of the larger islands are generally wetter than the leeward north western island aspects.

Fiji is located close to the boundary of the Australian and Pacific tectonic plates (Neall and Trewick 2008). The oldest rocks are of volcanic origin and are mapped as the Wainimala Group (Phillips 1965), dating from the late Eocene (~40 million years ago). These are in the central-southern area of Viti Levu, and in the Yasawa and Mamanuca Islands formed by the subduction of the Pacific plate beneath the Australian plate (Neall and Trewick 2008). Uplift of these areas has led to deposition and the creation of surrounding areas of limestone. Approximately 12 million years ago, plutonic intrusions led to uplift events (primarily on Viti Levu), coinciding with changes in the plate boundary configuration, resulting in a spreading of the Fiji fracture zone that led to the creation of Vanua Levu approximately 7 MYA (Neall and Trewick 2008). Taveuni was formed from basaltic volcanic island flows from approximately 5 MYA to the present era (Neall and Trewick 2008), with over 100 eruption events having occurred during the Holocene (past 11,700 years) (Cronin and Neall 2001).

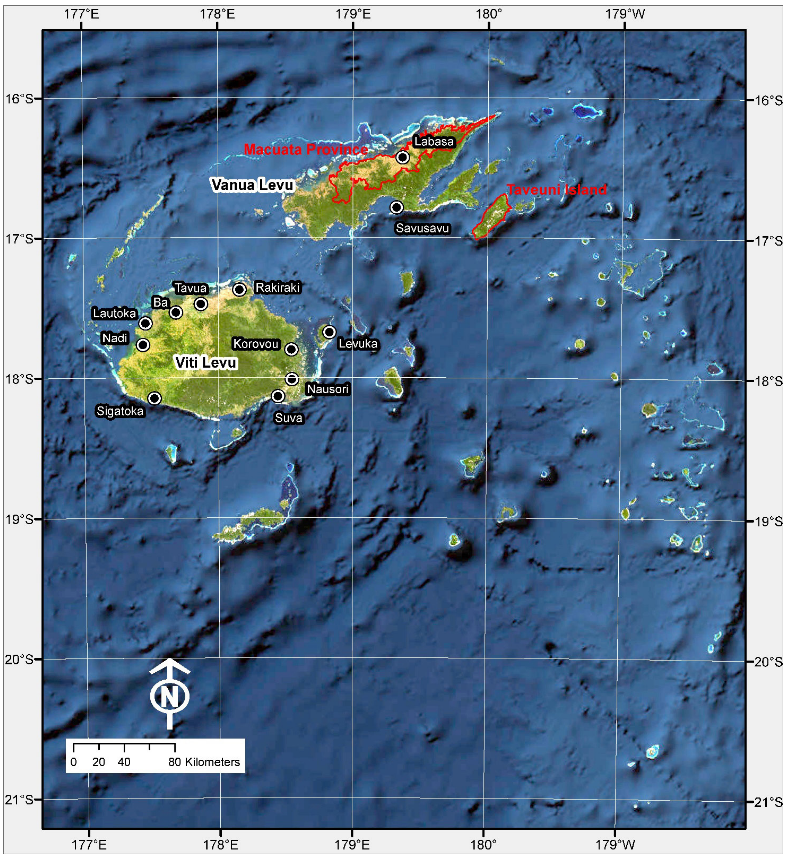

FIGURE 1. Map of Fiji with Macuata Province and Taveuni Island focus areas highlighted.

Comprehensive mapping of the soils of Fiji was conducted in the 1980s (Seru and Leslie 1986), with additional supporting taxonomic information by Leslie and Seru (1998). In 2012, SPC published Reference Manual for Utilising and Managing the Soil Resources of Fiji (Leslie 2012). According to this manual, 89 per cent of all soils are classified as clay or having a clay surface area. An additional 5 per cent of soils are of a loam soil type, and 6 per cent are classified as sand types.

Fiji, like most of the world, is urbanising. Fiji's population is growing overall, with population estimated at 400,000 in 1960 to nearly 900,000 people in 2016 (annual growth rate ~2.2 per cent). Over the past 25 years, the rural population has been relatively stable; virtually all growth is within the urban zones (Figure 2). Higher portions of youth and the elderly reside in rural areas, while working age populations are concentrated in urban areas (Figure 3). Overall age distribution is skewed towards youth, suggesting population decline is unlikely to be a challenge, but may cause increased workforce issues. Nationally in 2014, the unemployment rate was 6.2 per cent, but over 18 per cent for ages 15–24 years. GDP per capita in 2013 was FJD 8,950 (in 2013 US Dollars) (FBS, unpublished data).

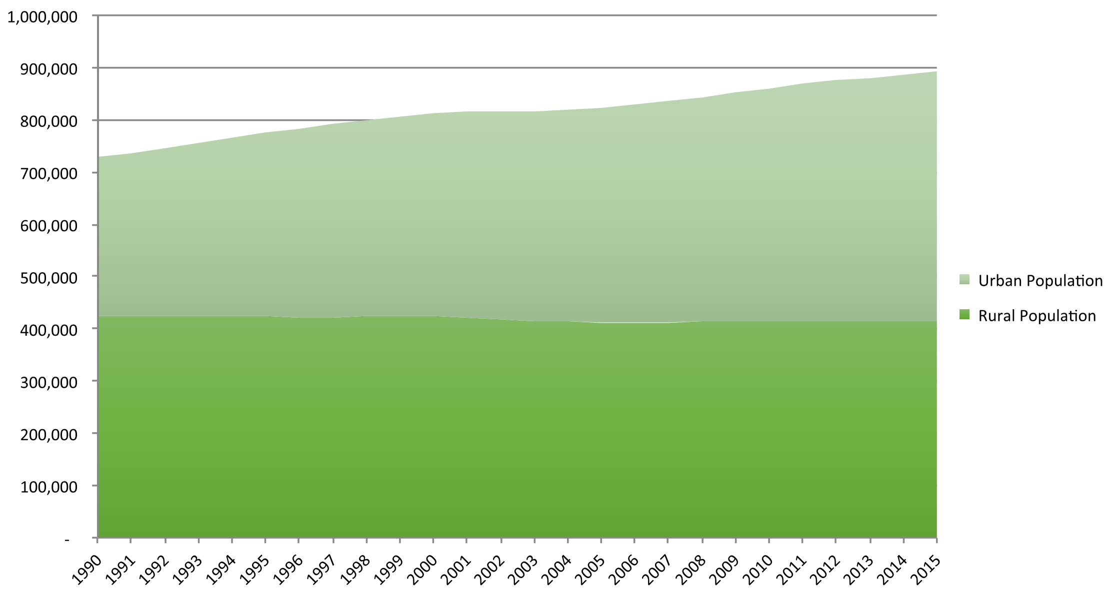

FIGURE 2. Fiji population, urban and rural, 1990–2015. Source: FAOSTAT 2016.

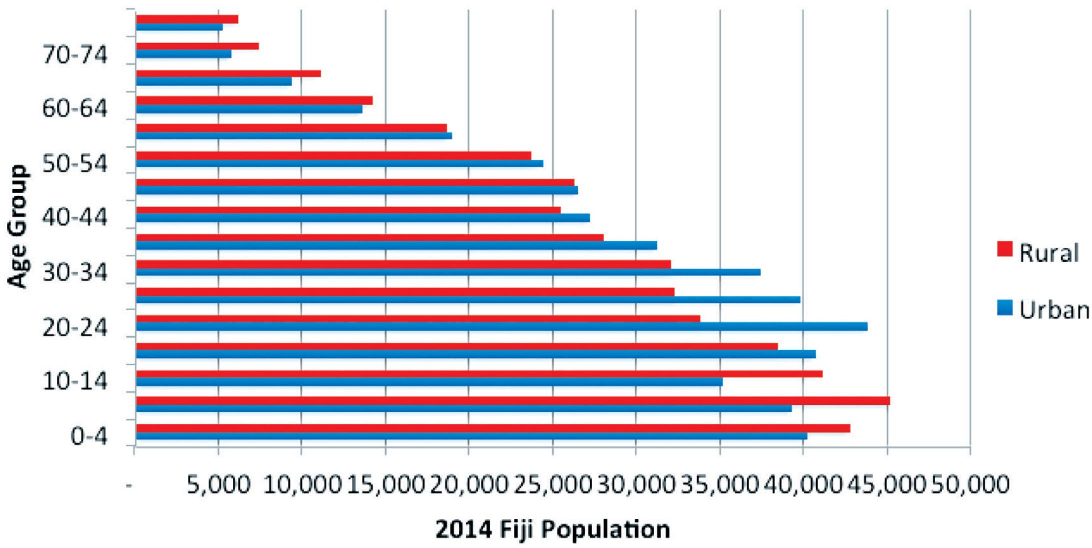

FIGURE 3. Fiji population by age group. 2014. Source: Fiji Bureau of Statistics

2.2 GOVERNANCE, POLICY AND INTEGRATING NATURAL RESOURCE MANAGEMENT

Various international, Pacific regional, and national policies influence the management of natural resources within Fiji. Fiji is particularly vulnerable to natural resource availability and quality due to its modest wealth, geography, size, and relationships across the region and globally. Fiji faces challenges in implementing national policy goals, often needing to rely on outside efforts to fund internal policy objectives. The Framework for Resilient Development in the Pacific (FRDP) is one regional effort focused on development of strategies individual nations in the region can take to develop resilience to climate change. The FRDP was the product of coordinated effort across numerous countries, territories, SPREP, the Pacific Island Forum Secretariat, the United Nations Office of Disaster Risk Reduction, the United Nations Development Programme, and the University of the South Pacific.

2.2.1 National measures

The primary national instruments for conservation and environment within Fiji are the National Environment Strategy and the National Biodiversity Strategy and Action Plan, in support of the Convention on Biological Diversity. These strategies primarily target terrestrial resources, focusing on conservation of ecosystems and biological diversity, protection of native flora and fauna, establishment of forest reserves and support of local community management. The main legislation is the 2005 Environment Management Act (EMA), which set up the National Environment Council (NEC). However, until recently, the NEC has not been fully operational, and requires momentum to engage in effective environmental management. Goals of the NEC are to:

- coordinate environmental policies and plans;
- require environmental impact assessments (EIAs);
- require permits for discharge of waste and pollutants into the environment; and
- create resource inventories, natural resource management plans, a national state of the environment report, and a national environment strategy.

Upland forest reserve, Taveuni.

The NEC appoints committees to address specific environmental issues. The Department of Environment (DoE) implements the recommendations from the NEC. The DoE formulates, reviews and implements the National State of Environment Report, the National Environment Strategy, the National Resource Management Plan and the National Biodiversity Strategy and Action Plan.

The Rural Land Use Policy (2005) is the umbrella for land-use planning and sustainable forest resource use for the Ministry of Agriculture, and is intended to protect, rehabilitate and manage natural forests. A national Forest Policy Statement with 26 accompanying pieces of legislation was adopted in 2007. A national REDD+ (reducing emissions from deforestation and forest degradation) programme was initiated in 2009, and is viewed as a success in protecting forest carbon stocks – pilot sites are located on Vanua Levu near the Macuata-Cakaudrove provincial boundary, and support growth and persistence of forests (limiting sediment delivery to reefs) (The REDD Desk[1]). Relevant legislative measures include the Endangered and Protected Species Act (2003), in addition to the Fisheries Act (1992) and the Environmental Management Act (EMA, discussed above). The EMA is the legislative framework for integrated coastal management in Fiji, and calls for the development of a coastal management plan. The EMA has two primary responsibilities: conducting EIAs and regulating waste disposal and recycling. The EIA is the main screening process that provides a check (and potential mitigations) to threats from land-use activities, including reclamation, construction, pollution, coastal erosion, upland logging, mining and agriculture. EIA implementation can be costly and data-intensive, which can severely limit its effectiveness towards public welfare objectives (Turnbull 2003). Staffing and expertise are often insufficient to identify alternative strategies and land management practices that will reduce environmental impacts.

Management of small projects, such as construction or maintenance of roads in local areas, generally does not go through a consultation process to evaluate or mitigate environmental effects. Management of 'cumulative effects', or the additive effects associated with many small projects that may cause localised environmental disturbances, are often overlooked in natural resource strategies.

2.2.2 Marine-specific policies

A number of policy and legislative actions are directed at marine resource use in Fiji. The Department of Fisheries is the lead agency responsible for fisheries management with a vision 'to have fisheries become and continue as one of the leading sectors in Fiji's socioeconomic development and generate economic growth and ensure that resources owners are equitably remunerated'.

Over the past few years, the Fisheries Department has been increasingly focused on aquaculture. Aquaculture is viewed as another way of strengthening food security in the country to improve livelihoods. The Department of Fisheries provides tilapia and post larvae at no cost to farmers for the stocking of their fish and prawn ponds annually, and several small coastal villages are pilots for pearl farming, algae, clams, prawns and fishes. Seaweed farming and other small-scale operations have occurred throughout the country in recent years with mixed success.

A new Aquaculture Bill of 2016 announced in the 2017–2018 budget was introduced as in incentive to support Fiji's fishing industry. The fiscal import and import excise duties on items imported for use in the aquaculture industry has been eliminated. Supporters argue that it will enhance economic prosperity of local operators, and reduce foreign investment, but opponents suggest that conservation of natural stocks will also need to be strengthened to address declines in coastal species. Human capital, technical expertise, funding, capacity and secure tenure rights remain obstacles to wide-scale success of aquaculture in Fiji.

Rather than addressing marine resource management broadly, and the health of coastal and marine resources in the country, the Fisheries Department focuses attention on production of fisheries. The effectiveness of the department is hindered by a variety of factors. Principal gaps include the inability to strategically focus multiple agencies on 'big picture' needs and to adopt and implement management plans; a lack of technical, financial and social capital; and the absence of a national policy or plan that sets a clear pathway to implement high level directives or focus actions on improving coastal management and sustainable fisheries (Gillett *et al.* 2014; Teh *et al.* 2007).

[1] https://theredddesk.org/

In May 2017, the Governments of Fiji and Sweden partnered to host the United Nations Ocean Conference (UNOC)[2] in New York, USA. At the conference, world governments identified commitments they are taking to implement UN Sustainable Development Goal 14[3], which seeks to 'Conserve and sustainably use the oceans, seas and marine resources for sustainable development'. The Fiji Government developed a series of voluntary commitments designed to protect and manage oceans sustainably (Table 1). These commitments cover a wide range of marine areas and species, as well as policy and management tools that would, if implemented, significantly increase Fiji's commitment to protecting its marine resources. Overall, the commitments increase the recognition of the interconnectivity of ridge-to-reef resources, address gaps in the current management structure, and galvanise the government's commitment to marine conservation on the world stage.

A villager displays her catch of the day at Lavena, Taveuni Island. Many communities depend on inshore fisheries for their livelihoods.

[2] https://medium.com/wcs-marine-conservation-program/fiji-makes-16-major-commitments-to-the-ocean-c6f8efce02cd

[3] https://sustainabledevelopment.un.org/sdg14

TABLE 1. Commitments identified by the Government of Fiji at the May 2017 United Nations Oceans Conference[4]

Commitment	Responsible Government Entity(ies)
Expansion of large scale marine managed areas in Fiji	Ministry of Fisheries, Department of Environment
Integrated Coastal Management to Preserve Ecosystems Services, Improve Climate Resilience and Sustain Livelihoods in Fiji	Department of Environment
Delivering improved coastal fisheries management services in Fiji	Ministry of Fisheries
The conservation and management of sea turtles within Fijian waters	Ministry of Fisheries
Conservation and management of all species of sharks and rays and their critical habitats within Fijian water	Ministry of Fisheries and Department of Environment
Protection and management of all marine mammal species in Fiji	Ministry of Fisheries and Department of Environment
Protecting spawning groupers: safeguarding food security and livelihoods for Fijians	Ministry of Fisheries
Introduction of a plastic shopping bag reduction	Department of Environment
Pacific voices for a global ocean challenge	Embassy of France and Fiji Government
Prohibition of destructive offshore fishing practices	Ministry of Fisheries
The Fiji pearl development plan - creating a blue industry	Ministry of Fisheries, Fiji Pearl Farmers Association, Ministry of Industry, Trade and Tourism,
Finalisation of Fiji's maritime boundaries and ECS claims	Ministry of Foreign Affairs
Sustainable tourism development framework	Ministry of Industry Trade and Tourism
The incorporation of ocean information into the *Vanua* GIS Platform	Ministry of Land and Mineral Resources

2.2.3 Climate change policy

A National Climate Change Country Team (NCCCT) was established in 1997 to develop the 2005 Fiji Initial National Communication to the UN Framework Convention on Climate Change. The NCCCT was represented by government agencies, non-governmental organisations (NGOs) and academic institutions. The NCCCT is tasked with information sharing, project reporting, and providing direction and guidance to the Climate Change Unit (see below).

The 2007 National Climate Change Policy Framework defined the broad policy position of the government and stakeholders to climate change issues. The framework was updated in 2011, leading to the development of the National Climate Change Policy (Government of Fiji 2012). The Climate Change Unit was established in 2009 as part of the Department of Environment, and tasked with coordinating climate change programmes and projects in Fiji. The Climate Change Unit was moved in 2011 to the Ministry of Foreign Affairs and International Cooperation and later to the Ministry of Economy. Fiji is developing a national action plan for climate change adaptation that will support the implementation of the National Climate Change Policy.

The Cabinet of Fiji created the Carbon Trading Technical Team in 2008 to work with the Department of Environment to identify carbon trading projects that could be included in voluntary and compulsory global carbon trading markets. The Department of Forestry has developed a national policy to interface with the Reducing Emissions from Deforestation and Forest Degradation + forest conservation (REDD+) programme. The policy guides the development and implementation of REDD+ activities in Fiji.

[4] https://oceanconference.un.org/commitments/#

2.3 TENURE, CONSERVATION AND STEWARDSHIP

2.3.1 Ownership

As elsewhere in the Pacific region, Fiji has had a long history of indigenous, or customary, land ownership (iTaukei), where land areas and traditional fishing grounds (qoliqoli) are retained by rights to a clan-based system (mataqali) as the core unit, and is further divided to families and individuals within the clan. As a legacy of the colonial period, approximately 80 per cent of the land area of Fiji was retained by the iTaukei, with some allocated to the state (~7–10 per cent), and the remainder as legacy freehold lands (~8–10 per cent) that were largely used for logging, copra and sugarcane production. Freehold lands have shifted in ownership over time to include iTaukei owners as well as non-indigenous Fijians, foreign residents and corporations. The national distribution of land ownership and traditional fishing grounds is presented in Figure 4.

Land ownership distribution varies across Fiji, with some islands under single ownership status (e.g. private islands) as well as mixed ownerships. The PEBACC focus areas illustrate these differences, with Macuata Province exceeding the national average at 91 per cent iTaukei ownership, while Taveuni Island has over one-third of its lands in freehold ownership (Table 2).

Complicating matters of land ownership and land-use change is the practice of land leasing, where leases can be established lasting for brief periods (such as for annual sugarcane lots) and extending up to 99 years, depending on the type of lease and primary use. Most leases are registered with the government (as per regulation) and provide for limited intervention by landowners during the lease period; some leases are not registered and are operating under direct agreements. ITaukei holdings are administered by the iTaukei Land Trust Board and the Native Land and Fisheries Commission under the Ministry of iTaukei Affairs, following the Native Land Act (1995). The Department of Lands and Surveys, under the Ministry of Land and Mineral Resources, administers state lands. Freehold lands can be owned by any legal entity (person or business) and are administered under the State Lands Act.

Most agricultural leases in many parts of rural Fiji do not have explicit environmental safeguards in place to limit what activities can be done on the land, nor do they provide regulations regarding the condition of the land upon return. This is especially true for land leases on iTaukei lands established decades to a century ago through agreements with corporations. This is a common practice across Fiji, and has largely contributed to a fragmented and degraded landscape, as former plantations were abandoned and are only recently being reverted to the landowners. In recent times, however, there has been some specificity regarding the activities allowed for the land leases; these extend to environmental safeguards (e.g. land clearing rules, planting objectives, adherence to natural resource management plans, etc.), although this is not known to be a national, institutional development.

TABLE 2. Terrestrial land tenure (km² and percentage of focus area) by the major categories. Unmapped areas have no designation in the available dataset and are limited to an area on Viti Levu. Source: Department of Lands.

	National Level		Macuata Province		Taveuni Island	
Land tenure	**km²**	**% Area**	**km²**	**% Area**	**km²**	**% Area**
ITaukei land	14,610	81%	1,771	91%	232	52%
Private freehold	1,448	8%	128	7%	155	35%
State land	1,325	7%	54	3%	60	14%
Unmapped	678	4%	-	-	-	-
Totals	**18,061**	**100%**	**1,953**	**100%**	**447**	**100%**

Incorporating conservation tactics and environmental safeguards for leases (both land and fishing grounds) is an important and workable mechanism to improve degraded landscapes and seascapes while also diversifying incomes from extraction-based activities (e.g. farming, forestry and fishing). Similarly, business investment requires security in land leases to ensure there is a reasonable expectation for return on investment; this has been especially identified by aquaculture industry representatives with regard to pearl farming, requiring streamlined and straightforward lease arrangements that are enforceable by lessees as well as lessors. Encouraging local management and adaptation through development of natural resource strategies that identify safeguards is an important step in ensuring ecosystem resilience for future uses.

2.3.2 Traditional vanua structure

Indigenous Fijian communities represent over 50 per cent of the population and own >80 per cent of the land resources with water rights on the 410 qoliqoli in Fiji. The Ministry of iTaukei Affairs represents central government to the village level (and vice versa) where traditional leadership is based on pre-European contact principles (a 'sector-based' hierarchy) of the vanua. The term vanua can be defined in two ways:

- a collection of families, clans and tribes living together under the leadership of a chief, and
- the land, people, ecosystems and the connection with land and sea.

The vanua structure has followed a decisively non-European approach for centuries, and is dictated by customary obligations toward the vanua (as a whole, or an entity) and toward one another (i.e. shared roles and responsibilities). Traditional authorities and churches often play the role of mobilising communities in collective action.

In each province, the current vanua structure is tied with the central government body through the provincial councils under the Ministry of iTaukei Affairs. This office is established in all 14 provinces of Fiji and includes a government representative (*roko tui*) with assistants serving smaller districts. Each district has a representative (*matanitikina*) to represent district needs; a village representative (*turaga ni koro*) in turn serves as the village representative to the provincial council under the Ministry of iTaukei Affairs, interacting (or assuming a role with) the bose vakoro, or village council. Land ownership within the vanua is registered under the iTaukei Land and Fisheries Commission (TLFC) and land is allocated to each clan (*mataqali*) within a tribe (and further subdivided to sub-clans and families), and also (where applicable) to tribes within a larger vanua.

The clan divisions (*mataqali*) are represented by families through generations, and assume one of seven responsibilities of the vanua as one of seven groups (*tutuvakavanua*), each having responsibility for aspects of society (including resource management), and are the basic unit of ownership[5] (Figure 5). These include the chiefly clan (*turaga*), the nobles (*sauturaga*), the heralds or messengers (*matanivanua*), the warriors or guardians (*bati*), traditional priests (*bete*), craftsmen (*mataisau*), and fishermen (*gonedau*) (Ravuvu 1983).

[5] In some cases, past disputes have ended in partition of clans from one tribe to another, which can leave a *vanua* without a particular *mataqali* representation, and victorious tribes with abundance in patriated clans. Granting of land ownership to the patriated clans is at the discretion of the *vanua*. This form of tribal migration may have occurred centuries before and *vanua* decisions remain in effect today.

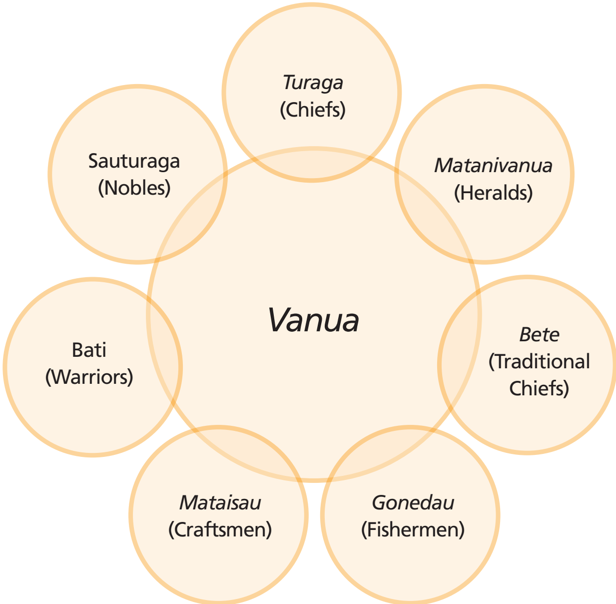

FIGURE 5. Traditional structure (*tutuvakavanua*) of the vanua involving *tutu*, or responsibilities, represented by clans (*mataqali*). This scale exists for a single tribe, multiple tribes, and increasing hierarchy to the high chiefs.

Each tutuvakavanua holds a responsibility and knowledge-base for management of resources that includes both land- and marine-based natural resources, as well as cultural and social wellbeing for the society. Acting in these traditional roles, each representative serves as an expert or 'chief' of that responsibility for the tribe, as well as a custodian or landowner for the clan (mataqali) they represent. For example, in matters concerning fishing and management of the qoliqoli resources, the traditional fishermen (gonedau) will be respected for their knowledge and guidance, as they are the people most versed and familiar with the status and trends of the qoliqoli resource, and are often the traditional owners of that resource. For this reason, the traditional chief (tauraga) would consult the representatives of the gonedau traditional role to make the decision workable for the vanua as a whole.

Metaphorically, the chiefs act as the chair of the vanua where he or she serves as the focal point for power deliberation within the vanua, though the decision must come only after consultation with the entire vanua (or representatives of the tutuvakavanua thereof). Similarly, traditional owners within the vanua must consult the chief prior to any activities on anything owned in the vanua; there are generally no rights for anyone in the vanua to do anything without proper consultation with the whole. This holds true for single tribes to the high chiefs (ratu) of many tribes, where chiefs do not unilaterally dictate terms without appropriate consultation.

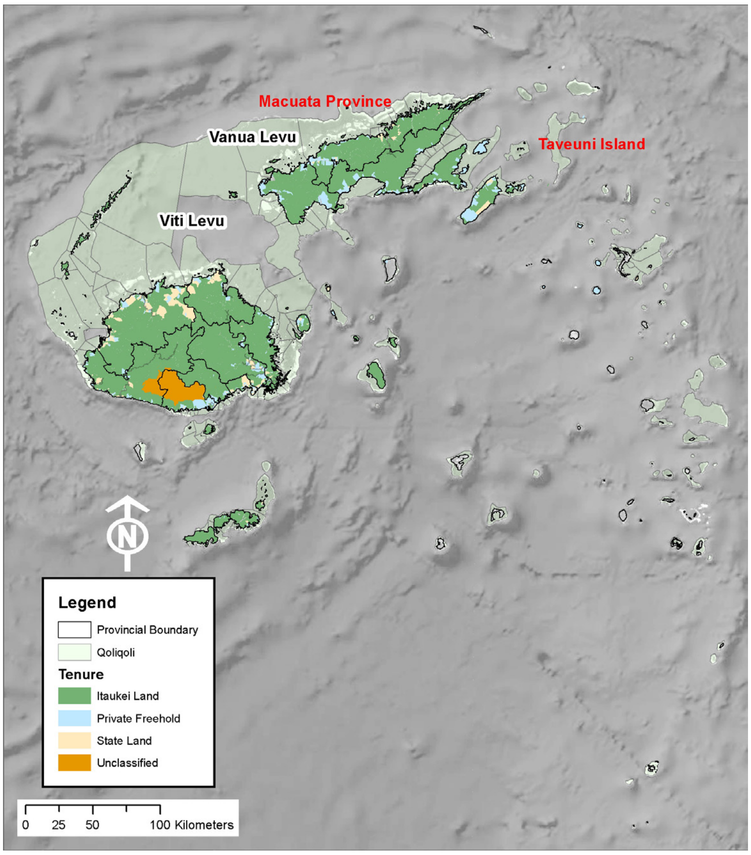

FIGURE 4. National distribution of land tenure, including qoliqoli. The PEBACC focus areas of Macuata Province and Taveuni Island are highlighted. Source: Department of Lands and Department of Fisheries.

While this system has been in place for centuries, it is recognised that it has not always provided for the best and most forward-thinking decision making. In addition, the socio-political landscape has fundamentally changed in recent centuries to contain a mix of cultures and governance structures that largely operate in parallel – western derived political government co-exists with vanua. However, there is opportunity to evaluate the positive characteristics of the responsibility structures of the vanua (e.g. tutuvakavanua) along with Fiji's administrative governance to help to shape and define natural resource management in meaningful ways in the 21st century. This is especially true for developing stakeholder groups and localised management, as well as means for integrating sector-based governance (e.g. ministries and departments such as agriculture, forestry, fisheries, etc.) toward common goals.

2.3.3 Protected areas

Protected areas across Fiji were summarised using data from the World Database on Protected Areas (WDPA).[6] The WDPA identifies marine and terrestrial protected areas and was jointly developed by the UN Environment Programme and the International Union for Conservation of Nature. A total of 11,952 km^2 are marine protected areas (MPAs), and 1,035 km^2 (5.4 per cent of the total land area) are in some form of terrestrial protected status (Figure 6). Terrestrial protected areas include conservation reserves (1 feature; 205 km^2), forest reserve (5 features; 81 km^2), nature reserves (6 features; 64 km^2), a recreational reserve (1 feature; 38 km^2), a heritage park (1 feature; 24 km^2), a Ramsar Convention Wetland of International Importance (1 feature; 8 km^2), and other reserves, parks and sanctuaries, etc. (7 features; 22 km^2).

The Fiji Locally Managed Marine Area Network (FLMMA) was established to provide support for management of qoliqoli marine resources using a community-based adaptive management approach. A LMMA in Fiji is:

> *An area of nearshore waters and its associated coastal and marine resources that are largely or wholly managed at a local level by the coastal communities, land-owning groups, partner organizations, and/or collaborative government representatives who reside or are based in the immediate area.'* (Govan *et al.* 2008)

FLMMA promotes the development of a natural resource management plan to identify specific recommendations for communities. Fiji has a long history of marine conservation. There are nationally recognised MPAs (Figure 6), gazetted by the Fiji Government. The Great Sea Reef Marine Protected Area was gazetted in November 2005 and covers an area of 380,000 km². In 2006, prohibition zones were established to protect the most vulnerable habitats and species, and include Namenalala, multiple sites off the coast of Macuata Province, and the Yasawas (Figure 6).

Marine resources in reef and lagoon areas in Fiji are largely contained within 410 legally-defined customary fishing rights zones (qoliqoli) over 30,000 km^2 (Figure 6), and are 'registered and demarcated to reflect user rights under the Fisheries Act' with the TLFC (Fa'asili *et al.*, 2002). The delineations are based on historically recognised customary fishing grounds, which follow reef geomorphology and extent and are under the ownership of adjacent communities.

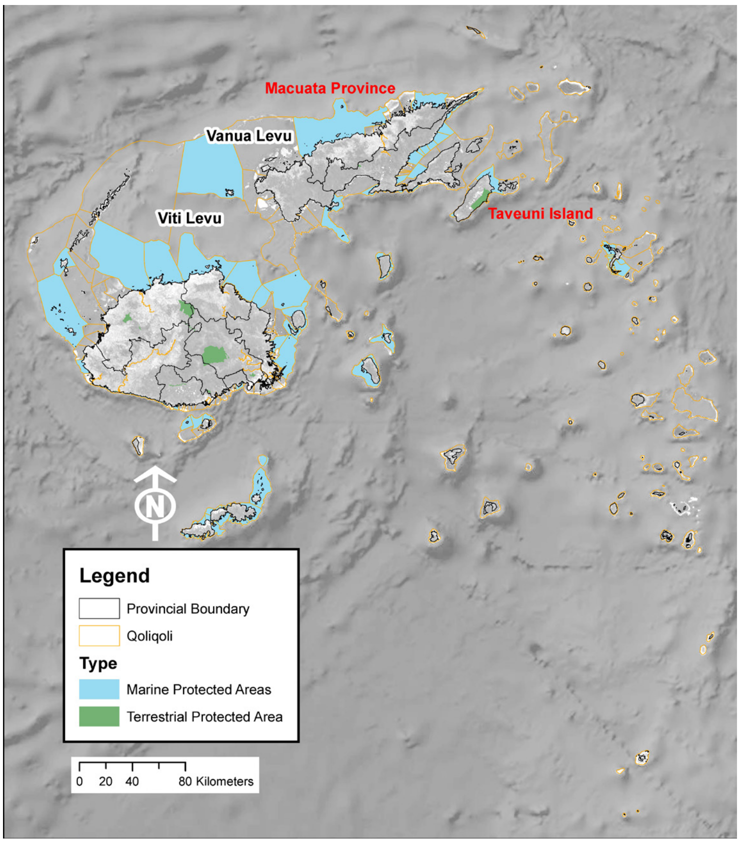

FIGURE 6. Protected areas in Fiji. Source: World Database on Protected Areas.

[6] https://www.protectedplanet.net/

The Fisheries Act recognises the protection of customary fishing rights beyond the qoliqoli, but there are few legal applications to regulate (Sloan and Chand 2016). Fishing within traditionally demarcated qoliqoli needs written permission of the registered owner(s) of the area (usually by way of the chief of the relevant coastal village) and registration via the divisional commissioner before the government will issue a formal fishing license.

Despite gaps of clear laws, policies and enforcement regulating qoliqoli management, traditional governance is accepted in practice and integrated into a dual governance system for inshore waters (Sloan and Chand 2016). While there are gaps in the understanding of legislation acknowledging qoliqoli and traditional management rights, and with some conflicts among traditional owners, the traditional owners play a vital role in the managing Fiji's inshore waters. These customary rights are held on a communal basis and honoured by all interested parties including the Department of Fisheries, fishers, and external participants (e.g. NGOs, international governmental organisations, etc.).

2.3.4 Governance of water use and supply

The four principal agencies responsible for regulating water use/supply in Fiji are: (i) the Department of Drainage and Irrigation (Ministry of Agriculture) that regulates irrigation water; (ii) the Department of Lands (Ministry of Lands and Mineral Resources) that manages utilisation of water resources in river basins; (iii) the Department of Mineral Resources (Ministry of Lands and Mineral Resources) that licenses groundwater use; and (iv) the Water and Sewerage Section of the Public Works Department (Ministry of Infrastructure and Transport) that manages public drinking water, primarily in urban areas. Given this dispersed arrangement of oversight agencies, there is no single entity regulating, managing, or delivering water in Fiji, which can lead to complications and significant confusion in supply and demand and end-user delivery.

2.4 INDUSTRY AND ECONOMY

Fiji's economy is a mix of resource-based industries, as well as modernising technical and manufacturing sectors. In 2016, manufacturing was the largest sector of Fiji's gross domestic product (GDP), shown in Table 3 (over page), followed by the wholesale and retail sector. Agriculture was the sixth largest sector. All sectors saw growth from 2011 to 2016 except mining. Overall, the economy is not intensively reliant on natural resources for market-generated value, although the GDP does not capture all informal household economic activity and value of goods and services generated. Fishing and aquaculture are of more importance in terms of GDP than forestry, although subsistence agriculture and fishing are disproportionately important in most rural communities.

Tourism-related industries are represented across major GDP categories, including accommodation and food services, as well as arts, entertainment and recreation. Fiji is a major tourism destination, with over 650,000 annual visits, over 90 per cent of which are for personal travel (as opposed to business). The average stay is roughly ten days and total visitor days are over six million annually (FBS 2012). Annual direct earnings from tourism are FJD 1.3 billion.

GDP data suggest that Fiji's market sectors, as defined by market output and transaction revenue, are diversified across numerous sectors, and those sectors most reliant on natural resources are not responsible for the majority of market activity. Therefore, the market-based economy as a whole does not seem particularly vulnerable to climate change, while individual sectors such as agriculture and fishing would be. These vulnerable sectors are, however, of central importance to household livelihood and subsistence.

TABLE 3. GDP by Industry in millions of Fiji dollars (FJD), 2011 and 2016. Source: Fiji Bureau of Statistics.

Industry	GDP (FJD in millions)	
	2011	2016*
Total GDP	5,739	6,710
Manufacturing	807	855
Wholesale and retail and repair of motor vehicles and motor cycles	669	790
Financial and insurance activities	529	630
Public administration and defence; compulsory social security	437	608
Transport and storage	359	593
Agriculture	473	501
Education	410	471
Information and communication	341	407
Accommodation and food service activities	370	392
Real estate activities	288	281
Construction	154	207
Professional, scientific and technical activities	128	165
Administrative and support services	133	155
Human health and social work activities	138	151
Electricity, gas, steam and air conditioning supply	109	130
Fishing and aquaculture	119	119
Other service activities	114	119
Mining and quarrying	90	58
Forestry and logging	33	35
Arts, entertainment and recreation activities	22	24
Water supply, sewerage, waste management and remediation activities	19	21

*Note: 2016 data are provisional. Constant 2016 dollars.

Vatuki & Nadogo Islands_Vanua Levu © Stuart Chape

2.4.1 Subsistence agriculture

Approximately 285,000 hectares in Fiji are devoted to agriculture production, the majority of which is operated by small farmers. 44 per cent of farms are below 1 ha in size, while only 0.2 per cent are over 100 ha, and most of the remaining farms range from 1 to 5 ha (Bacolod *et al.* 2012). There has been a downward trend in the number of farmers, with a 32 per cent decline from 1991–2009. This trend suggests fewer households are reliant on agriculture for income and livelihood, but it also suggests less capacity for self-reliance in the face of food shortages. The small farm sizes do suggest capacity for a wide range of adaptive approaches to challenges facing agriculture in Fiji, including crop diversification and varied irrigation practices.

The availability of food in Fiji has recently increased over time, as the FAO-measured food deficit is declining. Food deficit identifies the per capita shortfall on calories for the population. In 2015 Fiji was ranked 87th globally, better than Costa Rica and Mexico (FAO 2016). Food availability is not currently a crucial and acute issue at the national level. Food prices are slightly increasing, which can make household level investment and adaptation more difficult, as well as increase the pressure on local agriculture production. However, anecdotal accounts suggest that more traditional foods like dalo and fish have seen steep increases in price, leading to changes in diet.

Despite land lease agreements that are decades in duration, there appears to be an aversion to investment in soil resources and other infrastructure on leased lands. For example, orchard crops and coconut plantations rely on trees that take years to bear fruit and so are not widely grown outside long-term freehold landowners or as designated communal areas around villages. Much of the locally consumed fruits and vegetables are imported because of low supply and reliability of local crops – this is especially true for restaurants and hotels, who must ensure adequate and high-quality food supplies for the tourist industry. Irrigation and tenure improvements could improve this situation.

Goats graze on farmland in the Yarra valley, Viti Levu. The majority of Fiji's agricultural production is operated by small scale farmers.

2.4.2 Challenges and the need for investment: The dalo example of Taveuni

Dalo (taro), an economically and culturally important crop, serves as an example of the challenges associated with long-term investment in crops and soils for subsistence and semi-commercial farmers. On Taveuni, the total area under dalo cultivation has consistently increased over recent decades due to high demand for export and encouragement from the Ministry of Agriculture, but production saw a dramatic decline, beginning in 2014. Data provided by the Taveuni Ministry of Agriculture office show that overall dalo production rates have dropped from 30 to less than 7 tonnes per hectare (a four-fold decrease from peak production) over the last 20 years (Figure 7). To meet the high demand for export, cultivated lands increased from less than 100 ha in 1994 to 1,150 ha in 2013 (more than an 11-fold increase). Meanwhile dalo production on Taveuni peaked in 2007 at 8,200 tonnes, and declined to 3,700 tonnes in 2015 (Figure 8). At the average price of FJD 2.60 per kg in 2015, this equates to a drop from FJD 21.3 million in value to FJD 9.6 million, less than half of the peak output, with 11 times the land area being cultivated.

Expansion of dalo on Taveuni was mostly observed through incremental and progressive movement upslope by small-scale farmers through land leases or trespass into intact forest lands to reap short term (3–5 year) nutrient pulses from forest soils before witnessing further decline, causing eventual abandonment and a repeat of the cycle. Land areas in Taveuni' s restrictive 'Blue Line' forest conservation area have been converted to agriculture in recent years, with the cause given as 'poor soil fertility' in existing agricultural plots. This cycle of deforestation, agricultural conversion and abandonment by subsistence farmers is a leading cause of deforestation and land degradation worldwide.

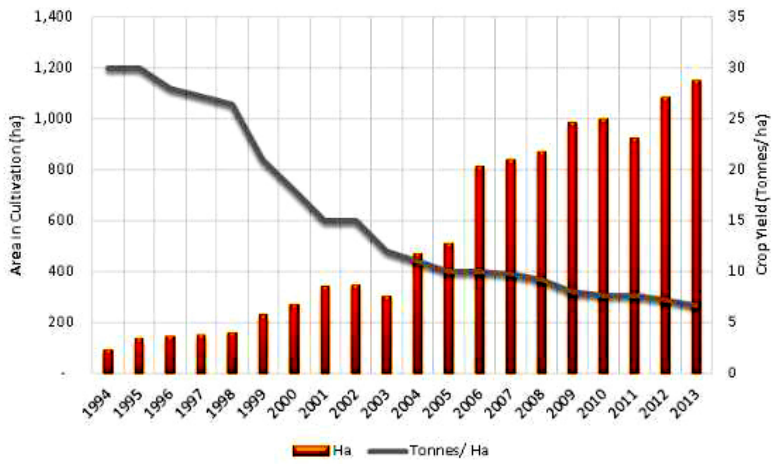

FIGURE 7. Dalo production area and productivity for a 20-year period for Taveuni. Source: Ministry of Agriculture.

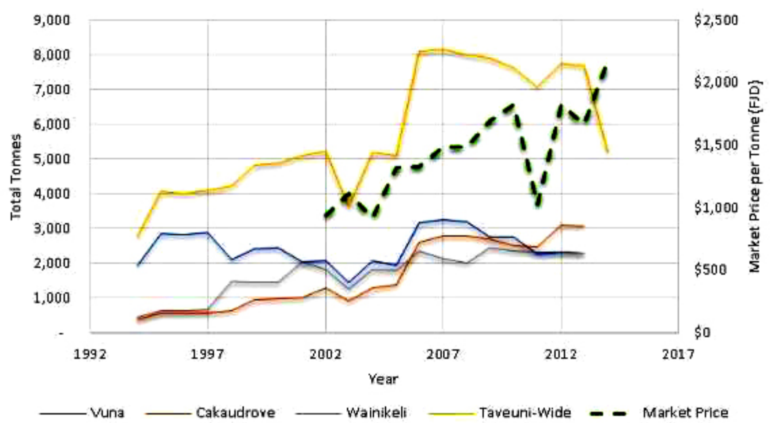

FIGURE 8. Total dalo (taro) production and market price trends. Not all years are populated. Source: Ministry of Agriculture.

2.4.3 Sugarcane industry

Sugarcane has been the leading production and export industry in Fiji since the decline of Fiji's initial focus on cotton. Fiji's focus shifted from cotton to sugarcane in the late 1800s due to its inability to compete with United States cotton after the U.S. Civil War ended in the late 1860s. Currently, sugarcane is grown in Viti Levu and Vanua Levu, with three mills on Viti Levu and one in Labasa on Vanua Levu. In 2016, the total national crush (harvest and processing) was 1.4 million tonnes, down from a ten-year high of 2.5 tonnes in 2007 (Figure 9). As of 2016, there were approximately 12,000 active sugarcane growers in all of Fiji, down from approximately 15,000 in 2007 (Figure 10). These statistics may be explained by an estimated 14 per cent loss to sugarcane by TC Winston (Government of Fiji 2016). Sugarcane growers are supported by the Sugar Research Institute of Fiji (SRIF[7]), an independent organisation closely associated with the Fiji Sugar Corporation (FSC) and focused on research to improve sugarcane production, including breeding, agronomy, and pest and disease control. There have been extensive fair-trade investments in the region, targeted at improving the quality of life for growers. Sugar provides approximately 51,000 jobs and indirectly supports more than 200,000 people, nearly one-quarter of the Fijian population (Government of Fiji 2016).

From 2007 to 2016, total sugar production fluxed with an overall decline from 237,000 to 140,000 tonnes (Figure 9). Nearly all of this sugar was exported to Europe through a preferential import agreement (expiring in 2017, see below), with the balance divided among the United States and Japan (FSC 2017). Production per hectare has fluctuated over the past ten years, but was overall stable for the 2007–2016 time period (Figure 10).

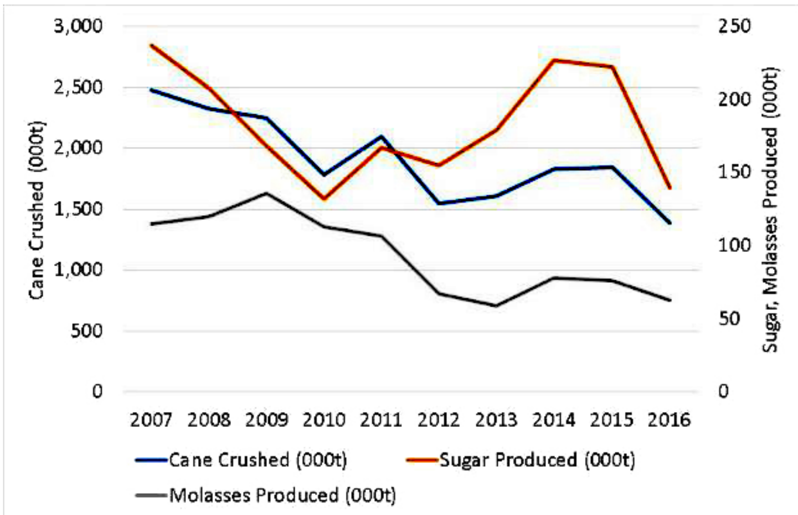

FIGURE 9. Sugarcane crushed and sugar and molasses produced nationally (thousands of metric tonnes). Source: Fiji Sugar Corporation 2017.

[7] www.SRIF.net.fj

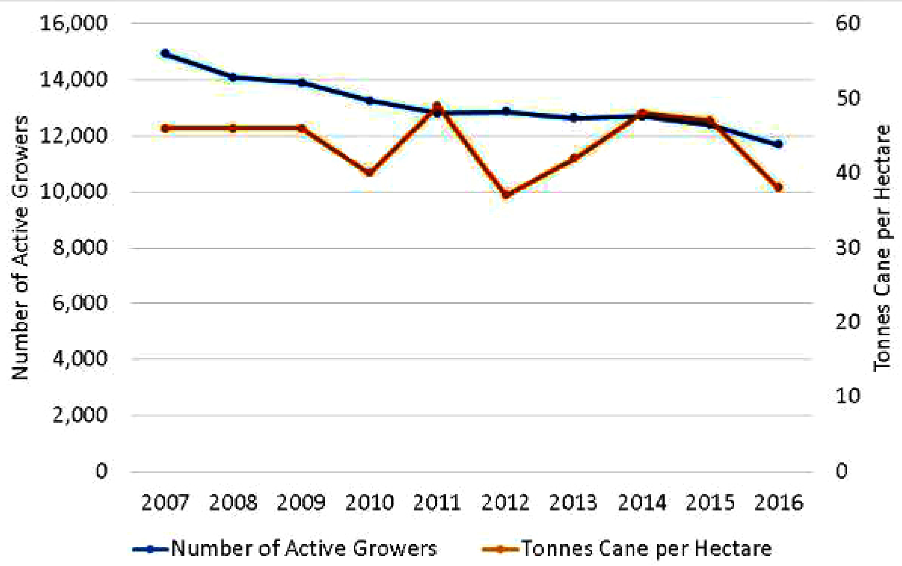

FIGURE 10. Number of active sugarcane growers and tonnes of cane produced nationally. Source: Fiji Sugar Corporation 2017.

While sugar production has been stable over the most recent available ten-year timeframe, there are reported declines in efficiency at the scale of the grower and the transportation system. Growers and grower representatives report decline in production with loss of soil fertility and reduced rainfall, with irrigation investments showing returns of increased production. In the Macuata Province, FSC owns a train that is available for transport of sugarcane to the mill in Labasa, but degradation of the tracks has slowed the pace of transport and the train's reliability. Consequently, the train transports only approximately 25 per cent of the total harvest, when at its peak the train transported 75 per cent of total harvest (FSC 2017). The farthest sugarcane fields from the mill are a four-hour drive, and while they were once a one-day train trip, the train now takes three days to cover this distance. As a result, roads into and through Labasa experience a constant flow of trucks and tractors loaded with sugarcane during harvest seasons, creating excessive traffic and noise from convoys, as well as road damage from excessive use.

Interviews with the Labasa Sugar Mill indicate that the mill could accommodate higher harvest capacity than it currently processes. Sugar industry leaders in Macuata Province believe that production volumes could greatly increase with irrigation, but there is little irrigation currently available, limited to a few small and pilot operations. Sugar-growing operations are sensitive to water availability, waiting for seasonal rains to begin before planting. Using different varieties to allow staggered harvest timing also decreases risk of loss to drought.

A cane truck with harvested cane, Kings Road, Viti Levu.

Waste material from the Labasa Sugar Mill is now being used for energy cogeneration as biomass fuel. During the first six-month period of operation and sale in 2015, it generated an additional FJD 3 million revenue in energy production. The sugar mill plans to begin to use additional material from a timber mill close by to increase total energy production. In addition, E10 ethanol is under production as a by-product of molasses and cane juice production.

A European Union study focused on fair-trade practices of the sugarcane industry on Vanua Levu found the following challenges facing the industry (Bower 2012):

- cane yields (tonnes per acre) are in danger of being too low to be viable for many farmers in terms of revenue generation and cost recovery;
- there is decreasing availability of land due to expiration and non-renewal of land leases;
- long-term land degradation in terms of soil fertility;
- migration of the work force to urban centres;
- insufficient capital investment to maintain essential infrastructure such as railways and mill equipment;
- natural disasters, including the 1999 drought, flood damage in 2009 and 2012, and Tropical Cyclone Winston (Category 5) in 2016, damaged Fiji's cane growing areas; and
- a cane payment system that does not align the incentives of grower and miller and that has resulted in a decline in the quality of sugarcane transported to the mill in the last decade.

The industry is also at risk due to expiry of preferential access to the European Union's sugar markets (October 2017), although there have been recent assurances that the market will be extended until 2023.

Land tenure issues are reported by grower representatives to be central to challenges facing sugarcane growers in Macuata Province, and probably to Fiji as a whole, as unpredictable year-on-year leasing precludes the necessary conservation of resources and investment in capital assets, including irrigation infrastructure and soil fertility. The leasing system also restricts the ability to afford such investments without the collateral of land title.

There is some informal consensus that sugarcane and agricultural production in Fiji can be more productive and profitable now, and more resilient to future effects of climate change, with more secure long-term ownership or use-right security. Secure long-term ownership or use rights are necessary to justify capital investments, either natural or built. For example, water storage and irrigation systems, fences, orchard crops, riparian buffers, shade trees and other structural or system investments that will have benefits for multiple years will be under-invested when potential investors cannot be confident that they will be able to experience the full benefits over time.

Similarly, natural resources are not always used in a way to provide long-term function when the user cannot be sure they will benefit from some conservation and restraint. For example, management of long-term soil fertility may not be a concern for a farmer with no long-term tenure security. As a result, they farm as intensively as possible to maximise profits and minimise inputs. This leads to negative issues associated with soil tilth and assurances of long-term productivity.

Long term tenure or access security is necessary to allow maximum private, local investment in productive capital assets that will both support economic productivity and resilience. Otherwise, government will need to bear a greater share of the financial and resource burden for long-term economic security. The entity with greatest control over a resource, and most likely to dictate its use, will be the only viable entity for long-term investment.

Sugar cane field, Labasa, Vanua Levu. © Stuart Chape

3. CLIMATE AND CLIMATE CHANGE

3.1 CLIMATE OVERVIEW

Fiji is characterised as having a tropical maritime climate with relatively small within-year variability in temperatures (Fiji Meteorological Service, 2006). The influence of the surrounding ocean limits the change in average monthly temperatures to only about 2–4°C between the coolest months (July and August) and the warmest months (January to February) (Hijmans *et al.* 2005). Near the coasts, the average night-time temperatures can be as low as 18°C and the average daytime temperatures can be as high as 32°C. Past records show extreme temperatures as low as 8°C and as high as 39°C.

Rainfall is highly variable in Fiji, with strong orographic control (Fiji Meteorological Service 2006) and ranges from 1,800 to over 3,500 mm per year (Figure 11). The prevailing southeast trade winds result in the main islands having pronounced dry leeward zones in the north west and wet windward zones in the south east (Hijmans *et al.* 2005). Tropical cyclones and depressions can cause high winds, especially from November to April. The wet season in Fiji coincides with the period of cyclonic activity (November to April), with dry conditions for the remainder of the year. Rainfall patterns are controlled primarily by the north and south movements of the South Pacific Convergence Zone, the main rainfall producing system for the region, with much of the rain falling in locally heavy but short-term periods (i.e. periodic intensive rain vs. time-distributed rainfall), which have direct implications for short-term flooding events and periodic drought periods.

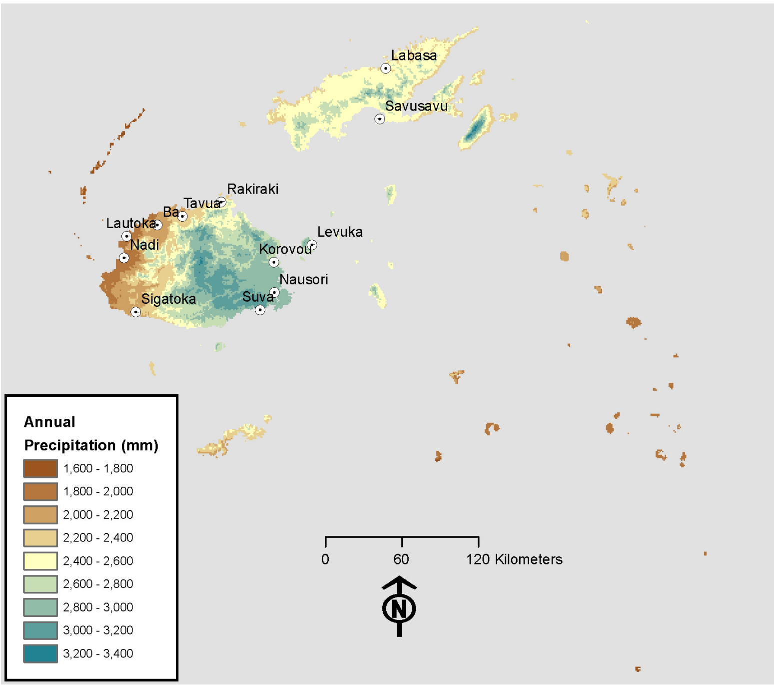

FIGURE 11. Mean annual precipitation.

Flooding is common in low lying areas during most years (Govt. of Fiji and United Nations Development Programme 2014). Severe flooding is usually associated with periods of prolonged heavy rainfall from the passage of a tropical cyclone or depression. Most cities and large population centres are located in flood-prone areas on floodplains and near the confluence of large rivers with marine areas. Flash flooding is common during the wet season and storm tides and swells often flood low-lying coastal areas during severe cyclones. Droughts are common, and even in average years, the drought impacts are felt in dry zones during extended dry periods. Droughts worsen during El Niño/ Southern Oscillation (ENSO) events such as occurred during 1982/83, 1997/98, and 2015/16.

Tropical Cyclone Winston (TC Winston) greatly affected Fiji with category 5 wind forces, causing serious damage to housing and infrastructure, crops and forest resources. Overall damage was estimated to be ~FJD 1.99 billion, including FJD 1.29 billion in damage to physical assets and FJD 0.71 billion in losses, excluding the environmental sector (Figure 12, Table 4; also see Section 4.6.2., Table 15 for estimates to quantify losses of ecosystem services values, with caveats, to native forests, mangroves and coral reefs) (Government of Fiji, 2016). Damage and production losses were greatest in Ba, Ra and Cakaudrove Provinces, comprising 68 per cent of the total losses.

TABLE 4. Total damage and production losses caused by TC Winston by province (FJD million). Source: Modified from Fiji Post-Disaster Needs Assessment May 2016.

Province	Damage (FJD million)	Production Losses (FJD million)	Total Losses (FJD million)	% Total for Fiji
Ba	526	142	668.1	35%
Ra	230.8	86.1	316.9	17%
Cakaudrove	183.2	131.5	314.7	16%
Bua	57.4	94	151.3	8%
Lomaiviti	102.3	45.5	147.8	8%
Tailevu	53.9	66.8	120.7	6%
Naitasiri	43.3	29.2	72.5	4%
Macuata	15.5	28.1	43.5	2%
Lau	23.5	13.3	36.8	2%
Nadroga/Navasa	16.4	18.5	34.9	2%
Rewa	5.6	2.5	8.1	<1%
Serua	1.3	1.1	2.3	<1%
Namosi	1.2	0.9	2.1	<1%
Total	**1,260.4**	**659.5**	**1,919.7**	

3.2 CLIMATE CHANGE PROJECTIONS

The Pacific Climate Futures[8] web-based decision-support tool was used to characterise possible future climate conditions for Fiji. Pacific Climate Futures (PCF) was developed by the Australian Government through the Pacific Climate Change Science Program[9] and the Pacific-Australia Climate Change Science and Adaptation Planning[10] (PACCSAP) programme. PCF provides summaries of climate projections for 15 countries including Fiji. The framework for PCF was developed by the Australian Government's Commonwealth Scientific and Industrial Research Organization. The technical underpinning of the project is described in Whetton *et al.* (2012), and an example application approach is demonstrated in Clarke *et al.* (2011).

Pacific Climate Futures summarises projections from a suite of global climate models (GCMs) that were used in the Intergovernmental Panel on Climate Change[11] Fourth Assessment Report (CMIP3 models) and Fifth Assessment Report (CMIP5 models). For the purposes of this ESRAM, we confined the scenarios to the more recent CMIP5 results. The CMIP5 results are available for up to 43 GCMs (depending on location and parameters of interest). Summary results are available for 13 time periods from 2030–2090 at five-year

8 https://www.pacificclimatefutures.net/en/

9 https://www.pacificclimatechangescience.org/

10 https://www.environment.gov.au/climate-change/adaptation/international-climate-change-adaptation-initiative/paccsap

11 http://www.ipcc.ch/

intervals. The CMIP5 results are available for four emissions scenarios, each of which is based on assumptions about likely trajectories of future greenhouse-gas and aerosol concentrations. These four Representative Concentration Pathways (rcps) are very-low (rcp2.6), low (rcp4.5), medium (rcp6.0) and very-high (rcp8.5).

As noted above, there are up to 43 GCMs that may inform the possible future climate conditions in Fiji. Although all these models observe the basic laws of physics, there are variations in how models treat various physical processes and components of the global climate system. Output values for all variables from a given model are have an internal consistency with each other that is they are all physically plausible (Clarke *et al.* 2011). Using a measure of central tendency (mean, median) for all or a subset of all models would not be valid because it would not produce internally consistent results. One of the goals of the Pacific Climate Futures web tool is to identify, for given climate parameters of interest, what the consensus is among the various models, how strong that consensus is, and what the outliers (least change, greatest change) might be. Given that the GCMs project out over a ~75-year time period, we would expect that the level of agreement and the magnitude of the difference among models would change for different future periods.

Figure 13 displays a plot of the projected mean annual change in rainfall (y-axis, expressed as a percentage) against the projected mean annual temperature change (x-axis, °C) for all 43 models for the period centred around the year 2070. The maximum consensus climate future based on these models for this time period is that the future will be 'Hotter and Little Change in Rainfall'. Nineteen of the 45 models predict this future, suggesting that there is only moderate consensus among the models. The maximum consensus models indicate a likely increase in temperature, over baseline conditions, of from 1.7–2.4 °C, and little if any change in rainfall on an annual basis.

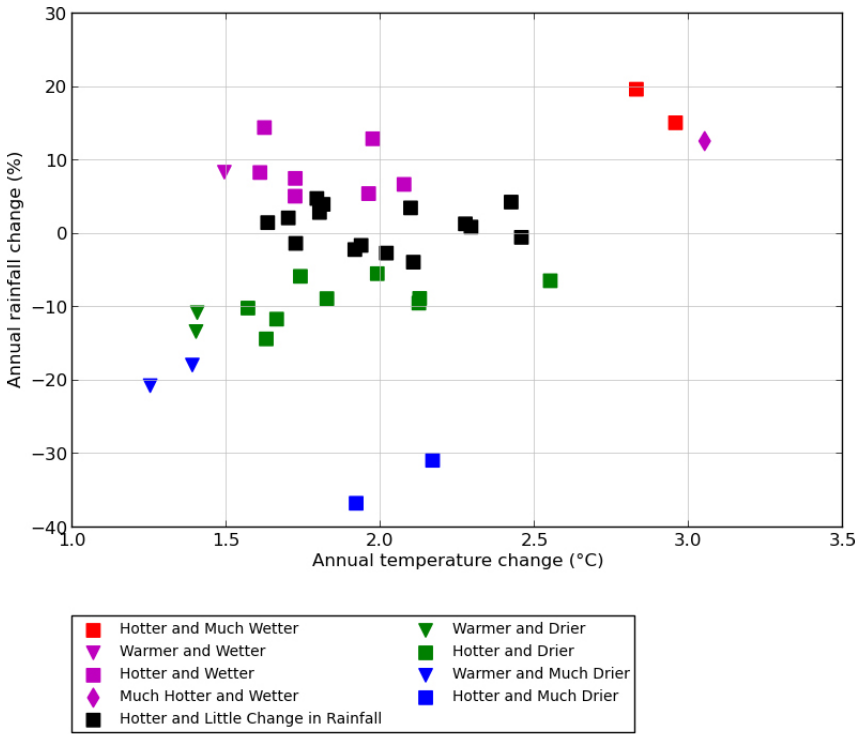

FIGURE 13. Projected mean annual change in rainfall (y-axis; expressed as a percentage) plotted against projected mean annual temperature change (x-axis; °C) for all 43 models for the period centred around the year 2070. Reproduced from Pacific Climate Futures web-based tool: (https://www.pacificclimatefutures.net/en/climate-futures/future-climate/).

Graphs of historical and simulated mean annual surface air temperature and precipitation for Fiji were produced using the above approach and are available on the Pacific Climate Futures website. Historic mean annual air temperature is shown as the departure from the mean 1986–2005 observed values for the Fiji area; both as raw values (GISS[12]) and smoothed values (smoothed GISS; Figure 14, top). Historic mean annual precipitation values are also shown as the departure from the mean 1986–2005 observed values for the Fiji area; both as raw values (GPCP[13]) and smoothed values (smoothed GPCP; Figure 14, bottom).

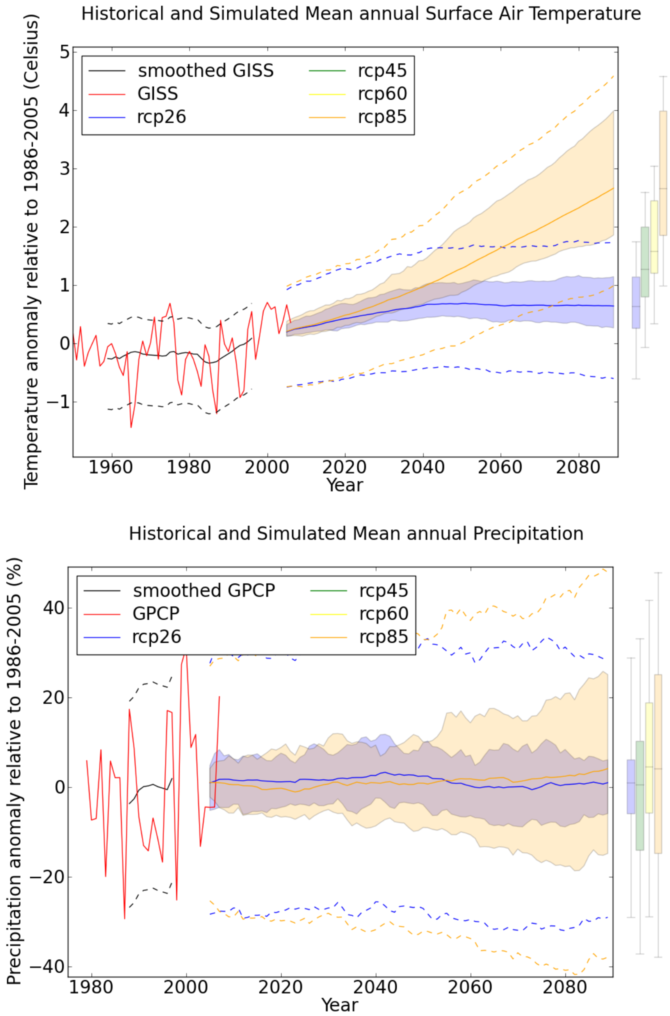

FIGURE 14. Historical and simulated mean annual surface air temperature (top) and precipitation (bottom) for Fiji. Reproduced from Pacific Climate Futures web site (https://www.pacificclimatefutures.net/en/climate-futures/future-climate/).

The future time series plots shown in Figure 14 are for the lowest future emissions scenario (rcp26) and the highest emissions scenario (rcp85). These plots show the central tendency, the 5th to 95th percentile spread of modelled values (shaded areas) and the 5th to 95th percentile of the observed (dashed black lines) and modelled (other dashed lines) inter-annual variability (PACCSAP 2014). The range of projected values for the 20-year period that centres on 2090 are shown for the four projections to the right of the graphs.

[12] GISS (Goddard Institute for Space Studies) estimates of monthly global surface temperature

[13] GPCP (Global Precipitation Climatology Project) estimates of monthly rainfall

3.3 SUMMARY OF CLIMATE TRENDS AND PROJECTIONS FOR FIJI

The Pacific-Australia Climate Change Science and Adaptation Planning (PACCSAP) programme summarised global climate change processes, trends, and projections for countries in the Pacific region. These projections are considered by the Fiji Meteorological Office to be the best available science. Projections for the 21st century were CMIP5 projections for individual countries. Results taken directly from PACCSAP (CSIRO, *et al.* 2015) are reproduced here.

3.3.1 Current climate

- Annual and half-year maximum and minimum temperatures have been increasing at both Suva and Nadi Airport since 1942 with trends significant at the 5 per cent level in all cases except the Nadi Airport November–April maximum temperature. Minimum air temperature trends are greater than maximum air temperature trends.
- The annual numbers of Cool Days and Cool Nights have decreased, and Warm Nights have increased at both sites. Warm Days have increased at Suva. These temperature trends are consistent with global warming.
- Annual, half-year and extreme daily rainfall trends show little change at Suva and Nadi Airport since 1942.
- Tropical cyclones affect Fiji mainly between November and April, and occasionally in October and May during El Niño years. An average of 28 cyclones per decade developed within or crossed Fiji's Exclusive Economic Zone (EEZ) between the 1969/70 and 2010/11 seasons. Twenty-five out of 78 (32 per cent) tropical cyclones between the 1981/82 and 2010/11 seasons became severe events (Category 3 or stronger) in Fiji's EEZ. Available data are not suitable for assessing long-term trends.
- Wind-waves around Fiji are typically not large, with wave heights around 1.3 m year-round. Seasonally, waves are influenced by the trade winds, location of the South Pacific Convergence Zone, southern storms, and cyclones, and display little variability on interannual time scales with the El Niño–Southern Oscillation (ENSO) and Southern Annular Mode. Available data are not suitable for assessing long-term trends.

3.3.2 Climate projections

For the period to 2100, the latest global climate model projections and climate science findings indicate:

- El Niño and La Niña events will continue to occur in the future (very high confidence), but there is little consensus on whether these events will change in intensity or frequency.
- Annual mean temperatures and extremely high daily temperatures will continue to rise (very high confidence).
- There is a range in model projections in mean rainfall, with the model average indicating little change in annual rainfall but an increase in the November– April season (low confidence), with more extreme rain events (high confidence).
- The proportion of time in drought is projected to decrease slightly (low confidence).
- Ocean acidification is expected to continue (very high confidence).
- The risk of coral bleaching will increase in the future (very high confidence).
- Sea level will continue to rise (very high confidence).
- Wave height is projected to decrease across the Fiji area in the wet season, with a possible small increase in dry season wave heights (low confidence).

A healthy mangrove forest along the coast, Taveuni. Climate change can be expected to amplify existing local threats to coral reefs, mangroves, seagrasses and intertidal flats in Fiji.

4. VULNERABLE ECOSYSTEM SERVICES

This section summarises vulnerabilities imposed by climate change, or extreme climate events, as well as those circumstances that frame natural resource conditions by current and past activities or events (additive forces). Specifically, vulnerable conditions represent the condition, state or trajectory of a resource to provide fewer ecosystem services. This is different to a threat to resources, in that the vulnerability becomes the outcome to specifically address through ecosystem-based intervention or adaptation.

Vulnerable conditions to ecosystem services are summarized by thematic groupings:

- marine ecosystem vulnerabilities;
- freshwater vulnerabilities;
- coastal erosion, flooding and transportation infrastructure;
- agricultural systems;
- terrestrial ecosystems; and
- Fiji's ecosystem service values.

4.1 MARINE ECOSYSTEM VULNERABILITIES

The marine resources of Fiji are increasingly threatened by human-causes, notably commercial and household subsistence fishing. Overfishing, in combination with the additive stressors of climate change and extreme climate events, and increasing pollutants (sediment, wastewater, chemical leaching) from terrestrial land practices, is resulting in degradation of Fiji's marine ecosystems and a decline in marine populations (Bell *et al.* 2011; Gillett *et al.* 2016). Table 5 provides an overview of the additive and climatic forces that contribute to vulnerabilities of marine ecosystems in Fiji. In the broad view at the national scale, climate change issues are difficult to mitigate. Focus on the human-based disturbances, such as curbing fishing pressures and managing terrestrial run-off and pollution, are priorities to improve conditions and prevent further degradation of the marine ecosystem.

TABLE 5. Climate and non-climate forces contributing to marine resources vulnerability.

Climate Forces	Additive Forces	Vulnerable Conditions
Storm frequency and intensity	Overfishing	Coral reef health and extent
Sea surface temperature	Terrestrial run-off pollution	Seagrass health and extent
Sea level flux	Mangrove and marsh degradation and loss	Mangrove health and extent
Ocean acidification	Material extraction (sand, rock, coral)	Inadequate reef and pelagic fish populations
	Channel dredging	Eroded coasts
	Oceanographic patterns	Community use and livelihood
	Use-related damage	

4.1.1 Coral reef health and extent

Coral reefs (Figure 15) are vulnerable to local conditions in Fiji, primarily due to terrestrial run-off from agricultural practices on land, and from commercial level overfishing and intense local exploitation, as demand for seafood exports increases within the region. Ocean warming and acidification from rising dissolved carbon dioxide (CO_2) are widely considered the greatest threat to coral reefs globally, and the expansive reefs of Fiji are at risk, with a 26 per cent rise in ocean acidification since the industrial revolution. Coral reefs of Fiji are comparatively resilient to intermittent disturbances, as evidenced by the ability to recover from major mass bleaching events following extended periods of water temperature elevations above 29°C and recovery following intense cyclones, although effects of ocean acidification generally degrade conditions and amplify human-caused pressures.

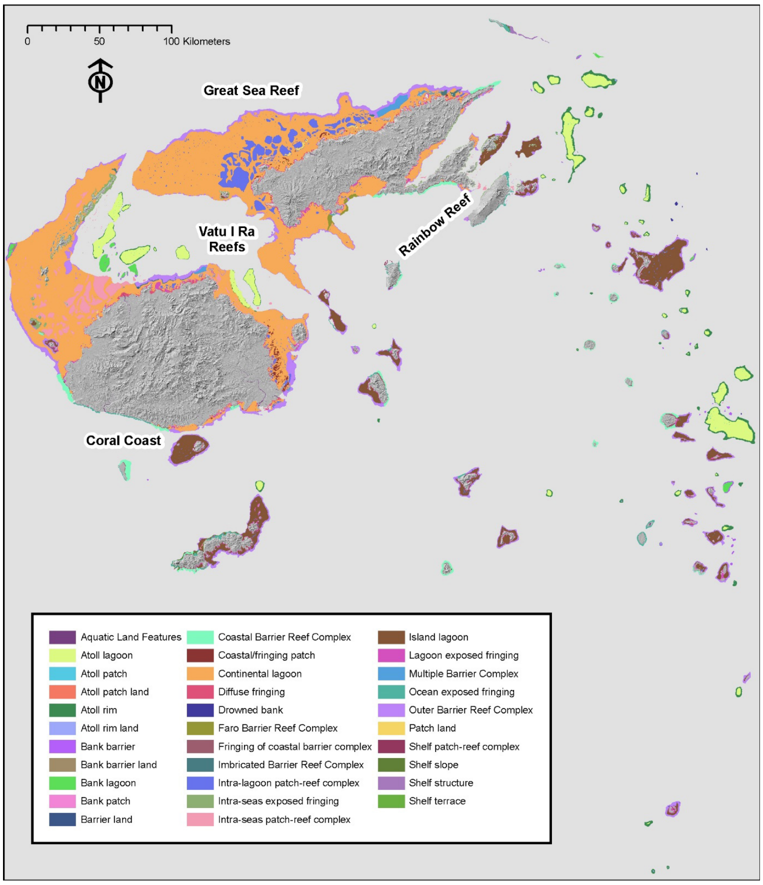

FIGURE 15. Marine habitats at the national scale. Source: Department of Fisheries.

Fiji's qoliqoli (Figure 4) are exposed to increasing fishing pressures, including commercial fishing vessels originating from within and from outside of the country, mangrove and coastal ecosystem degradation, and declines in water quality due to upland land-use practices and cumulative effects of development. Coral reef habitats located offshore around the coral/mangrove islets are generally in better condition than those closer to the mainland (Cumming *et al.* 2002).

Fiji's coastal resources face a number of natural and anthropogenic threats that include tropical cyclones, crown-of-thorns starfish outbreaks, pollution, overharvest, coastal development, destructive fishing practices including dynamiting and poisoning, and declining water quality associated with land management activities. Overfishing, water quality degradation and global climate change are considered the greatest immediate threats. Generally, more populated areas of Fiji on the main high islands (Viti Levu and Vanua Levu) are subjected to more frequent and intense stressors, with reefs around Suva Harbour and Laucala Bay being heavily affected by pollution, eutrophication and loss of habitat (Chin *et al.* 2011). Reefs on more remote low-lying offshore areas (including the Yasawas, the Lau group, and Kadavu) are subjected to fewer human disturbances. However, coastal fringing reefs, particularly those close to urban centres and settlements, exhibit signs of degradation (Chin *et al.* 2011). Coastal pollution from terrestrial activities is a significant stressor to Fiji's coral reef ecosystems, leading to degrading reef health.

Coastal pollution from terrestrial activities is a significant stressor to Fiji's coral reef ecosystems, leading to degrading reef health.

Conservation tactics, including prioritising reef and fisheries conservation and sustainable management as part of Sustainable Development Goal 14 (UNOC, see Section 2.2.2) are important moves in mitigating human-caused impacts to address pollution and ocean acidification pressures on the reef environment. Local establishment of no-catch or no-entry tabu areas and marine protected areas (Figure 6) are likewise, progress towards conservation and diminished pressures on the reef environment, assuming proper design, monitoring and enforcement follow these designations.

One such area of importance is the Qoliqoli Cokovata section of the GSR (Macuata Province), which was nominated by the Government of Fiji as a Ramsar site designation. The Fiji National Wetlands Steering Committee has agreed to designate the 1,349 km^2 qoliqoli as the first protected site under the Ramsar Conventions on Wetlands of International Importance, with local traditional management to also include fishing bans, better regulation and monitoring. These important steps are critical in staying the decline in fisheries and marine health and adapting to climate extremes and population pressures.

To be effective in meeting marine management goals, inclusion of land-based activities should be considered to identify stressors generated by land-use activities, or other supportive ecosystem features on land that can be enhanced or mitigated through restoration means. For the Qoliqoli Cokovata, this involves the inclusion of a 1,878 km^2 direct impact area (Figure 16), consisting of catchments draining directly into the marine area. This effectively doubles the area for integrated ridge-to-reef management, and crosses provincial and administrative boundaries (24 per cent is in Cakaudrove Province, 2 per cent in Bua Province[14]).

Ridge-to-reef management to minimise habitat degradation via pollution, along with sustainable reef management, are key aspects that can mitigate the imminent climate-related pressures on coral reefs, especially ocean acidification.

[14] See Ecosystem and socio-economic resilience analysis and mapping: Macuata Province, Fiji. SPREP, 2020. .

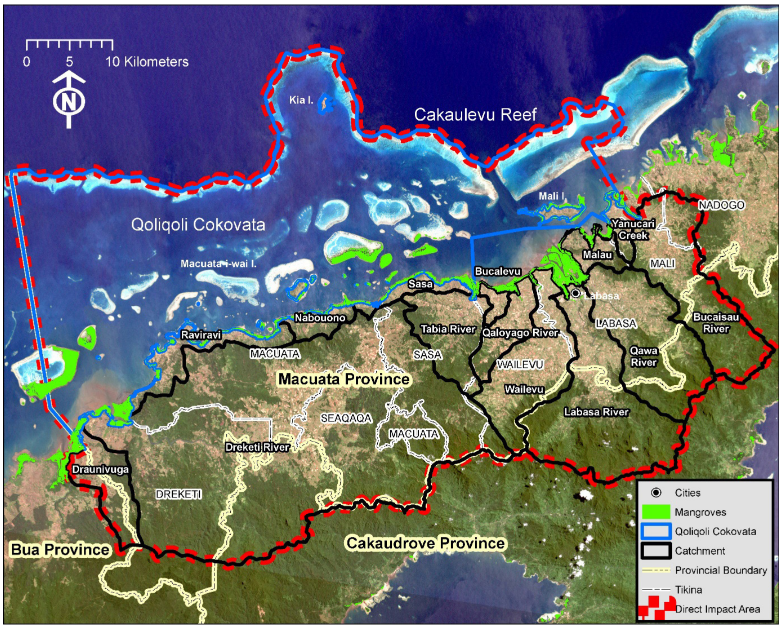

FIGURE 16. Map of the Qoliqoli Cokovata, including the terrestrial direct impact area.
Source: Ecosystem and socio-economic resilience analysis and mapping for Macuata Province, Fiji. 2020.

4.1.2 Factors affecting fish and reef populations

Climate change can be expected to amplify existing local threats to coral reefs, mangroves, seagrasses and intertidal flats in Fiji, resulting in declines in the quality and area of all habitats of important food resources. Nearshore coral reef habitats experience heavy fishing pressures, reducing abundance of reef fish, sea cucumbers, giant clams and other high value species.

Customary marine resource owners rely heavily on reefs for subsistence, livelihoods and sources of income. Fishing is the main source of protein for rural communities, with finfish and macro-invertebrates actively harvested. A recent study by the MACBIO project (Gonzalez *et al.* 2015) estimated the consumption rates derived from subsistence sources as 13.16 kg/person/year for rural populations and 1.05 kg/person/year in urban environments. These estimates yield a total subsistence fishery catch of 6,050 tonnes for 2014, with approximately 68 per cent as subsistence finfish and 32 per cent invertebrates from the nearshore reef environments based on earlier estimates (Starkhouse 2009). Inshore commercial fisheries catch, which are mostly intended for urban consumption and export, were reported as 7,370 tonnes (64 per cent finfish and 36 per cent non-finfish) (Gonzalez *et al.* 2015). An estimated 5,994 tonnes of fish and invertebrates were recorded from market outlets in 2005 (Department of Fisheries 2005); commercial catch available at the Bailey Bridge Market in Suva originates from long distances, including Macuata Province. Overall, estimated catch from reported sources extends to between 10,000 and 15,000 tonnes per year, or between ~27 and 40 tonnes per day, from Fiji's national resources. Of the 410 qoliqoli in Fiji, 70 were considered overexploited, 250 fully developed at maximum yield capacity, and the remaining 90 qoliqoli under a sustainable management regime (Gonzalez *et al.* 2015).

Terrestrial run-off is another major human-caused contributor to the decline in marine health. There are no known data sources or monitoring for sediment and nutrient delivery to the near-shore environments, although even normal rainfall events can show substantial sediment plumes generating from most rivers, which also carry additional pollutants from urban and agricultural areas (nutrients, chemicals, wastewater). The coastal flat areas are particularly capable of attenuating terrestrially-based run-off with increases in mangrove populations and protection of estuarian zones and stream banks. Estimated increases in rainfall intensity (i.e. 'pulses') will likely increase large-scale plume releases from terrestrial sources, causing concentrations that can cause additional short-term stress or damage.

Land clearing (and subsequent burning), farming, and poorly drained or fortified road networks are all contributors to sediment and nutrients that can be delivered to the reef environments. Attenuation of sediment delivery and transport can be made through uses of riparian buffering (e.g. tree planting in ~30 m buffer along streams) and mangrove establishment and protection in both riverine and estuarine areas (see below and Section 4.2.3).

4.1.3 Mangroves, coastal marshes and seagrass ecosystems

Fiji has the third largest mangrove area in the Pacific Island region, with eight true mangrove species, and one hybrid, encompassing 48,745 ha (2.7 per cent of Fiji's land area, Figure 17) (Atkinson *et al.* 2016). More than 95 per cent of Fiji's mangroves (tiri or dogo) occur on the islands of Viti Levu, Vanua Levu and Kadavu, although smaller fringes exist across the nation. On higher islands, deltaic and estuarine mangroves dominate, whereas embayment, lagoon and reef flat mangroves exist on low-lying outer islands. Amongst the most productive ecosystems on the planet, they act as critical nursery sites for marine food organisms (crabs, prawns, mangrove lobsters, molluscs and fish) and as breeding grounds and nurseries for pelagic and other fish and prawns (Mumby *et al.* 2004).

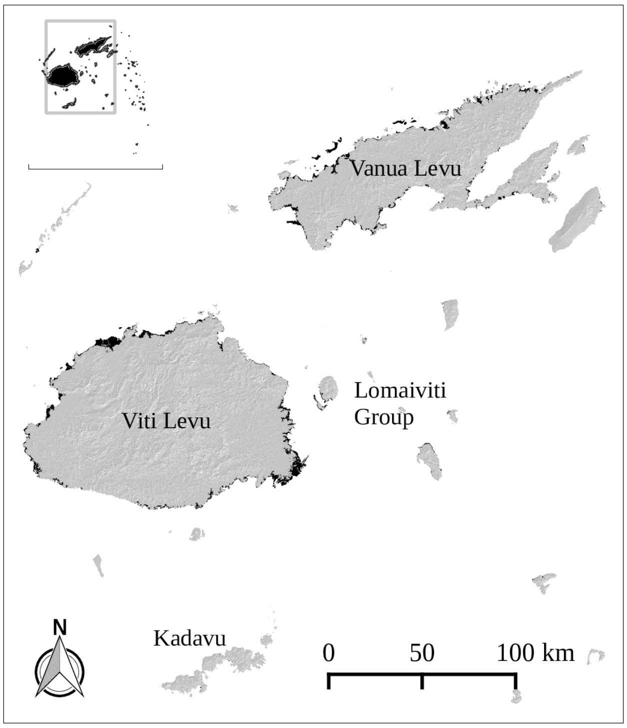

FIGURE 17. Fiji's mangrove systems. Source: Atkinson *et al.* 2016.

Conversion of mangroves to agricultural lands along the coastal flats is evident in populated areas across Fiji, including in the Rewa River Delta (Viti Levu) and around Labasa on Vanua Levu. Figure 18 shows one example near Labasa with land conversion of mangroves to sugarcane on state lands. In this example, the soil structures and suitability indices, as well as the proximity to the existing mangrove (e.g. 'hard edge' seen along the orange farm boundary), suggest conversion from historic mangrove or coastal marsh ecosystems.

FIGURE 18. Aerial image of Labasa area and associated mangroves (white arrows), low-lying areas of possible converted mangroves to sugarcane on state land parcels (orange border areas), and potential areas of road bed blocking expansion of mangroves inland (red line). See also Figure 23. Image Source: DigitalGlobe 2017, Google 2017.

Complicating the conversion process is the development of road networks in lowland areas. These can be farm access roads, fill, or fully developed road networks. Mangrove and coastal marshes require regular access to tidal fluxes and mixing with freshwater from streams. Roadbeds of even 30 cm in height above the floodplain can effectively block the free flow of tidal and stream water and cause harm or death to mangrove patches. This can limit the extent of mangroves and coastal marshes along the landward edge, thereby restricting the natural growth and expansion of the mangroves to attenuate pollution and provide nursery habitat and other ecosystem services. The red line in Figure 18 is one example area that has limited inland expansion of a mangrove system, although even minor furrows in the sugarcane fields can alter the hydrology. Over the past few decades, Fiji has experienced an average rise in relative sea level of 2 mm per year. Mangroves and coastal marshes are important communities to mitigate the effects of sea-level rise in ideal circumstances where mangrove extent can migrate inland, where terrain allows.

While mangroves serve as a filter for sediment and pollutants from terrestrial sources, mangroves can also be degraded by poor water quality. Degraded mangrove forests have consequences for coastal fisheries, since fisheries values can be reduced by as much as 50 per cent in catchments where run-off pollution is high (Atkinson *et al.* 2016). Fish kills have been documented in the lower reaches of the Ba, Labasa and Qawa rivers, often near sugar mills, reducing the abundance and diversity in lower mangrove fringed reaches of highly-altered river catchments (Jenkins and Jupiter 2011; Jenkins *et al.* 2010). Degraded mangroves also have implications for storm protection and coastal erosion; clearing of mangroves allows waves to reach inland areas, increasing erosion potential and exposing shores and community infrastructure to direct storm surge effects, even from minor storm events. Large volumes of unconsolidated sediments are stored in mangrove forests and held by living root mass – in the Rewa Delta of Viti Levu, sediments average 1.2–1.8 m in depth (Heider *et al.* 2013). Releasing this sediment has severe 'pulse' effects on nearby reefs, blocking stream/river outlets and greatly increasing riverine flooding of low-lying areas. Removing mangroves entirely via direct conversion or through road construction (e.g. blocking tidal flows) results in a loss of attenuation of pollution and sediment effluent to nearby reefs.

Waterfall, Ravilevu nature reserve, Taveuni.

Mangroves in Fiji are threatened by conversion from planned coastal development (settlement expansion, tourism, industrial sites, flood management, water storage, aquaculture, solid waste disposal, etc.), sedimentation (including from the spoils of dredging operations), magnetite sand mining, and climate change impacts. Mangrove harvest for poles, charcoal and firewood was estimated at 1.5 to 4.5 thousand cubic metres in 1992 (Jaffar 1992). Generally, firewood uses are more common in rural rather than urban environments, or opportunistic if an area is to be developed (see Figure 19). Other pressures increasingly threaten mangrove health. On larger islands, much of the upper elevation extent of the mangrove/wetland ('back forest') has been cleared to the high tide mark for agriculture (particularly in the Rewa River Delta of Viti Levu), and coastal development now threatens much of the remaining tidal and estuarine stands through clearance and reclamation. Tourism development, harbour and marina construction and settlement expansions often claim mangrove forests through removal and infilling (e.g. Denarau near Nadi, although awareness and restoration are under way).

Mangroves are also important for storage of atmospheric carbon, with most of the storage in the marine sediments. Figure 19 shows a simulated 'time series' of mangrove degradation from land conversion to a development near Suva, as part of a mangrove carbon assessment conducted by IUCN (Heider *et al.* 2013). The standing stock losses associated with complete conversion to development was estimated to be 1,518 tonnes per ha of CO_2 equivalents, similar to the annual tailpipe emissions of ~325 passenger vehicles[15] for a single hectare of converted mangrove forest. This equates to the total 2016 annual emissions from the 110,763 registered vehicles in Fiji (Bureau of Statistics 2016) stored in less than 350 ha of Fiji's mangroves. Deforestation and degradation of mangroves can be a significant source of carbon dioxide emissions with only moderate coastal developments within Fiji.

FIGURE 19. Mangrove degradation from firewood collecting and ultimately conversion to development near Nadonomai village, outside Suva (2013). The area includes fill for new development, areas cut and abandoned for 3 years, a 1-year-old cut section and intact mangroves. Views are seaward (left) and landward (right).

Seagrass meadows are found in the intertidal and shallow subtidal waters of protected and softbottom shores throughout Fiji, with large seagrass meadows occurring south of Viti Levu along the Coral Coast, in the backreef areas of Suva, the Lomaiviti group, and surrounding Denarau. Dense seagrass meadows occur on the northern shore of Vanua Levu around the coral/mangrove islets (Skelton and South 2006) as well as the north western lagoons of Taveuni (pers. obs.). The intertidal and shallow subtidal seagrass communities of Fiji have high biological productivity; are efficient in nutrient recycling; help maintain coastal water quality; and support a large biomass of consumers, especially those of fisheries importance; and sustain diverse floral and faunal communities. They are a critically important nursery habitat for many species. Fiji's seagrass meadows also provide foraging habitat for over half of the adult green turtles in the central South Pacific (Chelonia mydas) (Craig *et al.* 2004), and are thought to be regionally important habitat for sea turtles across the region (Figure 20).

Seagrass meadows in Fiji provide diverse food resources of major subsistence and commercial importance) providing or enhancing protein needs for low-income, subsistence residents and coastal communities. This

[15] https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

underlines the need to secure the survival of the remaining seagrass meadows to protect community food security. During low tide, it is common for people to glean available food sources, finding uses for species of all sizes, including echinoderms, crustaceans, molluscs, anemones and many other invertebrate species. They are often collected by women and children for family consumption or sold in local markets. Physical damage from 'raking' for harvest, footpaths and boat motor damage leave lingering effects on local areas.

Seagrass meadows downstream of agricultural plots without erosion controls and those that experience poor water quality from human habitation and development are at greatest risk of degradation. Further, there is a reliance of near-shore seagrass meadows on sediment attenuation by coastal ecosystems (mangroves, marshes); intensive and excessive sediment plumes are direct threats to seagrass communities and habitats, although attenuation, or slow delivery of sediment over time, aides in the accretion of coastal flats that provide habitat for seagrass meadows to establish. Links between riparian vegetation, floodplain meadows, mangroves and seagrass communities are vital to maintain in order to provide attenuated sediment and nutrient delivery to the lagoon and reef environments. Currently, conversion to urban and agricultural lands is making these links highly vulnerable.

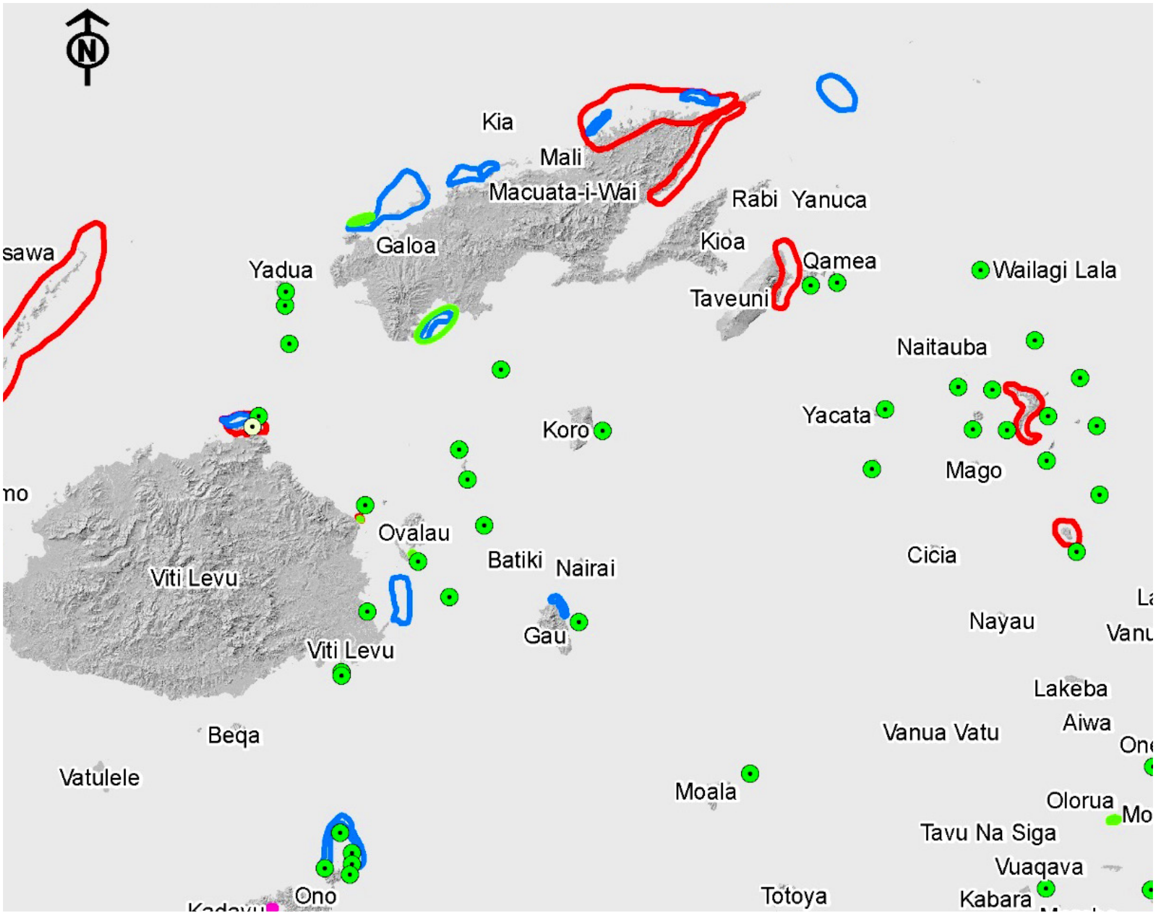

FIGURE 20. Sea turtles sites of importance in Fiji.

4.1.4 Key drivers of change

The key drivers of change affecting marine resources in Fiji are summarised from the materials above and from Gillett and Cartwright (2010). They are briefly described below.

Pollutant run-off from terrestrial sources. Coastal and near-shore marine areas and ecosystems are experiencing significant run-off-related pollution from terrestrial activities. Sediment, wastewater, chemical leaching from terrestrial land practices are degrading Fiji's marine ecosystems, exacerbating the decline in marine populations.

Overfishing (commercial and subsistence). Demand from coastal fisheries will increase, but as over-harvesting and habitat degradation continue unchecked, production will not be able to meet demand. Over half of the qoliqoli in Fiji are fully developed at maximum yield capacity. Global markets for reef fisheries are increasing, and as populations and demand grow and marine resources continue to decline in Southeast Asia and China, coastal marine resources in the Pacific Islands will likely become increasingly attractive and highly valued. Qoliqoli Macuata has experienced this with the beche-de-mer fishery, where exports are largely going to Hong Kong.[16]

Extreme climate events. Extreme climate events, such as TC Winston in 2016, directly affect coastal marine resources (mangroves, seagrass, coral reefs, etc.), as well as increase terrestrial run-off pollutants. Effects on marine resources will increase as extreme climate events increase in frequency and magnitude.

Ocean warming and acidification. Coral reefs are expected to degrade in response to projected effects of coral bleaching and acidification (in combination with other stressors described here). Coral reef fisheries are consequently likely to become less productive, although the rate is not yet known.

Loss of mangrove ecosystems. Mangroves act as critical nursery sites for many marine organisms and are also important for storage of atmospheric carbon. Conversion of mangroves to agricultural lands, loss of connectivity from roads, degraded water quality from terrestrial run-off threaten these important features.

Degradation and loss of seagrass meadows. Seagrass meadows, found in intertidal and shallow subtidal waters, have high biological productivity, are efficient in nutrient recycling help maintain coastal water quality, and support fisheries and other floral and faunal communities, including sea turtles. Seagrass meadows are also being degraded by terrestrial run-off (as described above). Mangrove loss (and associated loss of sediment attenuation) further degrades seagrass communities.

Governance. There is a lack of capacity, funding, and priority directed at marine resource management in Fiji. Challenges exist in all levels of government (national, divisional, provincial, district) and traditional ownership (mataqali). The Department of Fisheries is limited in revenue and ability to provide basic fisheries-related management services and infrastructure. Lack of ridge-to-reef management exacerbates habitat degradation via pollution and lack of mitigation.

Inadequate protected areas. Local establishment of no-catch or no-entry tabu areas and marine protected areas have made progress toward conservation and protection of reef and other marine environments. However, design, monitoring and enforcement have been largely insufficient to realise the intended goals. On the other hand, activities such as Qoliqoli Cokovata as a designated Ramsar site and implementing the UNOC commitments of 2017 (see Section 2.2.2), will further these goals.

Other factors. Shifts in focus for markets, fuel costs, technology and innovation, and implementing foreign aid are drivers of change, largely for the short-term.

[16] At the time of this writing, there is consideration of an export ban for sea cucumber.

4.2 FRESHWATER VULNERABILITIES

Fiji has a diversity of freshwater systems including large rivers such as the Rewa and Dreketi Rivers, smaller perennial and seasonal streams and creeks, lakes, estuaries and mangrove lagoons. Most rivers in Fiji are small, narrow catchments draining to the coast. The largest rivers transport large quantities of sediment and have low flow deltas at their mouth. There are over 17,000 km of mapped streams in Fiji. Additive (human-caused or circumstantial) forces affecting freshwater resources are shown in Table 6, particularly agricultural production, forestry, and mining. These probably have a greater influence on freshwater resources than do predicted effects of climate change.

TABLE 6. Climate and non-climate forces contributing to freshwater resources vulnerability

Climate Forces	Additive Forces	Vulnerable Conditions
Storm frequency and intensity	Existing ground/surface water trends in use	Groundwater supply
Sea-level flux	Population trends	Surface water supply
Rainfall magnitude	Terrestrial run-off pollution (erosion, mines, sanitation)	Pollution attenuation capacity
Air temperature regime	Wetland and riparian degradation and loss	Floodplain vulnerability
Drought frequency, duration, intensity	Gravel extraction	Aquatic habitat and species
	Delivery infrastructure	Community use/livelihood of aquatic use
	Irrigation use and trends	Recreation and tourism
	River/stream re-engineering	

Water services in Fiji include urban water supply and sanitation (Public Works Departments, Fiji Water Authority), irrigation (Ministry of Agriculture), hydropower (major projects are the responsibility of the Fiji Electricity Authority), rural water supply and sanitation (Fiji Water Authority, managed locally), urban drainage (municipalities), and flood control (Ministry of Agriculture) (SOPAC 2007).

Landslide, Qamea Island.

4.2.1 Groundwater supply

Groundwater resources exist on nearly all islands in Fiji, but the availability and sensitivity of the risk to depletion varies (SOPAC 2007). High yield aquifers are found in the alluvial deposits of unconsolidated sand and gravel in the valleys of Fiji's largest rivers. Groundwater on smaller islands, however, may exist as thin lens on top of salt water and are subject to salt water intrusion with over-pumping (and in some cases, minimal pumping) by groundwater wells (SOPAC 2007). Little is known about the rate or sustainability of groundwater extraction; current withdrawal rates are, however, likely sustainable (though unknown) over the medium term. Part of the reason for this is that, up to the present time, the relatively abundant and well-distributed rainfall patterns have favoured surface water use. If surface water becomes less reliable, there may be increasing demand for groundwater.

Annual rainfall levels are predicted to remain largely unchanged into the future (Figure 13). Given the long subsurface pathways, it is unlikely that groundwater recharge will be significantly changed by predicted climate change. One exception might be from higher evapotranspiration rates associated with predicted increases in annual air temperatures and extended drought periods over several seasons. This, coupled with losses of forests, may contribute to lower rates of groundwater infiltration due to soil heating, evaporative loss, and run-off.

4.2.2 Surface water supply

Surface water sources supply most domestic, agricultural, and industrial water in and around the largest population centres. In rural areas and outlying islands, water is supplied by a combination of surface and groundwater sources. Rainwater harvesting systems are often used on smaller islands but the relatively abundant and constant rainfall has resulted in systems that may be inadequately sized for drought events. Conflicts over water availability among competing uses have occurred in some locations and there is a lack of a single regulatory authority to adjudicate water disputes. The majority of surface water use is for agriculture.

Drought in Fiji is associated with El Niño climate conditions (SOPAC 2007). Drought is intensified in many parts of Fiji by the lack or inadequacy of water supply storage (reservoirs, tanks) and supply infrastructure. Under present practices, long periods without rainfall (months) result in inadequate water supplies. This has cascading effects on communities, agriculture, tourism and the economy. Rainfall amounts are generally frequent enough to fill small catchment tanks; extended periods of drought typically deplete catchment reserves in a short period of time and most water systems cannot withstand long periods with little or no rainfall. Drought has affected the sugar industry and this has had direct implications for the national economy. The drought in 1997–1998 caused FJD 104 million revenue loss to the sugarcane industry. The greatest drought occurred on the western sides of Viti Levu and Vanua Levu and in the Yasawas[17] (SOPAC 2007).

[17] https://www.go-fiji.com/naturaldisasters.html

4.2.3 Pollution attenuation capacity

Freshwater pollution in Fiji occurs primarily from land management practices. The ability of terrestrial, riverine, and marine systems to absorb and attenuate pollution limits the overall functional potential of Fiji's downstream ecosystems.

As land is converted to agriculture, forest is cleared from wood harvesting, often by biomass burning and land clearing. The resulting (denuded) landscape is highly prone to erosion and transfer of sediments to stream systems. Sedimentation obstructs passages and changes the stream channel configuration to limit habitat types for aquatic species. Logging operations, ground-disturbing agricultural practices (especially in riparian zones), gravel mining and poor road surfaces often result in erosion of soil and increased turbidity, which may disrupt feeding success of fishes (Gratwicke *et al.* 2002). Jupiter *et al.* (2012) surveyed fisheries communities in 32 catchments in Macuata and Bua provinces. Fish presence/absence and abundance were found to be lower in catchments having less than 50 per cent intact forest cover at the basin scale. The authors attributed this in part to higher levels of conductivity of sediment downstream that was probably caused by higher erosion rates in catchments with more fragmented forest cover.

Agricultural and forestry pollutants pose a major threat by significantly altering the chemical and biophysical characteristics of the water, making the habitat non-conducive to aquatic life. Sediment and mineral pollution from agriculture and mining, including herbicides and pesticides from subsistence farming, enter the stream system and contaminate habitats. Some chemicals also bind with sediment to form toxic concentrations harmful to aquatic species. Some rivers are being degraded by gravel and bauxite mining (UNDP 2018). Waste material can result in a rise of river bed level, clogging of the stream channel, increased siltation and downstream flooding. Run-off from pesticides, herbicides, and mining effluent have degraded some rivers in Fiji's high islands. Discharges of untreated human wastewater–common but not well mapped–with associated pathogens is occurring in many rivers and streams, particularly in the vicinity of rapidly urbanising areas, as well as dispersed rural villages that deposit human waste directly into the stream channel (UNCCD 2017). Direct faecal contamination from cattle and pigs and run-off from animal feedlots is another direct source of freshwater contamination, as is solid waste disposal from villages and municipalities. The extent to which groundwater sources are being contaminated is largely unknown, but the threat is likely greatest in shallow lens aquifers in coastal areas and on smaller islands (SOPAC 2007).

Klein *et al.* (2012) evaluated the connection between forest conservation and coral reef protection for Fiji using a process that linked pollutants generated from watershed sources to pollution effects on reef areas. They found rapidly diminishing returns on the amount of forest protected, and wide variations in the effectiveness of protected areas. For example, protecting 2 per cent of forest in one area resulted in a 500 times more beneficial effect on reef condition than a similar-size area elsewhere. Later, Klein *et al.* (2014) evaluated approaches for maximising the combined benefits of upland protected areas, developed to protect terrestrial ecosystems and further biodiversity goals, with ongoing efforts to protect and enhance marine areas and, in particular, the coral reef systems surrounding Fiji. As demonstrated by Klein *et al.* (2012) and other studies, the links are strong between upland protection, river transport and freshwater ecology, and marine impacts. Local results must, however, consider watershed-level scarcities and vulnerabilities.

Depending on site characteristics and with diligent planning and evaluation, gravel extraction can occur at sustainable levels with little or no effects. However, excessive or poorly planned removal can result in major impacts, which have been seen in many of Fiji's rivers, particularly in proximity to urban centres (NatureFiji-MareqetiViti 2010); gravel mining produced 300,000 m^3 in 2004 (although locations are not known) (Shi, L 2014, cited in Gonzalez *et al.* 2015). Extraction of gravels and modification to the streambed composition changes the hydraulic characteristics and responses. Most of Fiji's rivers are a mixture of pools and stretches of slow-moving water, interspersed with rapids, with Fiji's native species adapted to these conditions and habitats (NatureFiji-MareqetiViti 2010). This habitat differentiation (pools and rapids) is lost with excessive streamside disruption and gravel extraction.

4.2.4 Floodplain vulnerability

Floodplains in Fiji occur along the major river systems (Figure 22). These areas contain a large proportion of the urban areas, much of the economic infrastructure (e.g. sugar plantations, mills, manufacturing), and a significant amount of agricultural lands. In addition, most large floodplain areas are in close proximity (longitudinally and elevationally) to marine areas (Figure 22). Flooding is common and will be exacerbated by projected increases in more extreme rainfall events and sea-level rise. Increased sediment loads and run-off efficiency will amplify flooding problems. Options for wetland attenuation are slight, other than in mangrove systems. The effects of gravel mining on flooding are unknown and unmapped, but may alleviate short-term flooding, depending on location, although with potentials for other environmental consequences (increased transport, erosion, lower water tables, and stream bank downcutting). Short-term increases in channel capacity may attenuate flooding, but lack of channel complexity and increased run-off rates may amplify flooding frequency and intensity.

Logging and other land management actions in headwater areas that increase run-off efficiency, coupled with increases in impervious areas and a lack of adequate drainage infrastructure in downstream urban areas, increase the magnitude of flood events (SOPAC 2007). McGree *et al.* (2010) reviewed flooding in Fiji between 1840 and 2009, summarising the meteorological causes and consequences of the major events. Flooding in Fiji occurs primarily, although not exclusively, during the November to April wet season (Figure 21). Dry season flood events are most prevalent during La Niña years (McGree *et al.* 2010). Most events are noted to occur in response to rapid run-off from cyclone events, although other causes include south-westward displacement of the South Pacific Convergence Zone, frontal systems, and combinations of some or all of these factors. Slow moving frontal systems may set the stage by saturating soils, followed by cyclonic systems where most or all of the rainfall is quickly conveyed to stream systems. The authors note that the record is likely skewed towards river systems with large population centres (particularly the town of Ba). The designation of a flood as 'notable' is subjective and based on the severity of the consequences. Prolonged wet seasons may result in a series of events, or the exacerbation of flood effects from landslides and other debris.

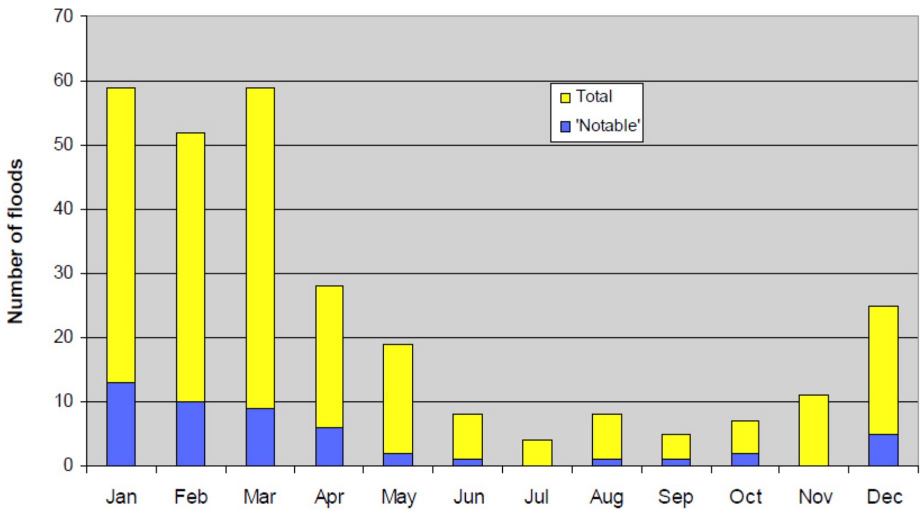

FIGURE 21. Monthly mean distribution of flood events in Fiji, 1840–2009. Source: McGree *et al.* (2010).

4.2.5 Aquatic habitat and species risk

The primarily sandstone, marl and andesitic volcanic geology of Fiji dates back seven million years. Erosion has created relatively low gradient valleys extending landward, with steep headwater areas rising to elevations of up to 1,300 metres elevation. Streams are relatively low gradient for most of their length, with steep mountainous sections in the headwaters. Larger rivers and principal streams have perennial flow (Fiji Mineral Resources Department 2015).

Riparian landscapes in Fiji are generally degraded and have not been well considered as an important managed resource to stream systems; riparian zones mostly exhibit sparse canopies adjacent to a large proportion of the forested and grazing lands.

Strong seasonality in flow of tropical streams and steep topography are dominant features of the high islands in Fiji. These specialised adaptations may have contributed to some of the highest global endemism density in freshwater fish fauna when Pacific Island species richness is adjusted for land area (Abell *et al.* 2008). Generally, aquatic species inhabit areas with high water quality and intact riparian vegetation. Declines in diversity and abundance are often reliable early indications that water quality is deteriorating, and/or riparian vegetation is being removed. The main freshwater and estuarine species caught in Fiji are freshwater clams (kai), freshwater prawns (Macobrachium and Palaemon), flagtails, eels, tilapia, gobies and carp. These species are taken from Fiji's rivers, lakes and estuaries for subsistence and commercial fisheries.

The principal effects on freshwater habitats and species in Fiji caused by climate change include potential increases in flood-related disturbances, increased frequencies of low stream flow, and warmer overall water temperatures. Saltwater intrusion and inland extension of brackish waters is likely to be a significant factor in coastal areas of low relief. These impacts will favour some species at the expense of others, with a likely shift in community composition and possible vectors for non-native species establishment. Additive human-caused forces will, however, probably continue to pose the greatest risks; increased sedimentation and other pollutants, physical habitat destruction (loss of riparian buffers and channel complexity), and continued barriers to upstream migration are all disturbance vectors that cause harm to aquatic species and habitat.

4.2.6 Livelihoods

The rivers and streams of Fiji are important to local communities. While aquatic harvest quantities are largely unknown, freshwater and estuarine habitats provide areas for reproduction, feeding, recruitment, growth, and migration that are important to livelihoods and also provide a consistent source of local protein. Since freshwater ecosystems are at risk due to climate change, the cultural traditions and food security of local communities may also be at risk. There may also be an increased frequency of epidemics associated with water-borne diseases, resulting in loss of freshwater fish and invertebrate populations, as well as diseases that affect people (mosquito borne and acquired bacteria, parasites and viruses from infected food and water).

4.2.7 Recreation and tourism

Freshwater resources play a minor role as key destinations for tourists in Fiji, the majority of tourist destinations being associated with the marine environment. Threats to healthy river systems and the associated freshwater amenities will likely increase vulnerabilities and have unintended negative consequences on the quality of resources valuable to the tourism industry. Renowned freshwater ecotourism opportunities, including rafting in the Upper Navua River on Viti Levu as well as coastal walks and waterfall adventures on Taveuni, are associated with conservation areas with lowered threats.

4.2.8 Key drivers of change

The key drivers of change affecting freshwater resources include the following:

- lack of a single regulatory authority to adjudicate water disputes – while conflicts over water availability are currently limited to certain local areas, government capacity may become needed in times of extended drought or disaster responses;
- freshwater pollutants – most surface water use is for agriculture, and freshwater pollutants are primarily water-borne sediments from agricultural and forest land management practices, run-off of agricultural chemicals, mining run-off, and untreated human waste in localised areas;
- attenuation capacity is compromised by lack of riparian buffers, floodplain degradation, and loss of channel complexity due to gravel extraction (common within large rivers, such as the Labasa River);
- erodibility is the primary soil limitation, particularly associated with deforested landscapes at high slopes;
- high vulnerability to inundation – urban areas, transportation, and other infrastructure are located on floodplains and/or in sea-level rise areas;
- increased storm intensity is likely to exacerbate flooding and coastal erosion; and
- strong seasonality in flow and steep topography increase susceptibility to climate change (increased storm severity, increased drought periods) and land management practices (soil disturbance, erosion).

4.3 COASTAL EROSION, FLOODING AND TRANSPORTATION INFRASTRUCTURE

This section augments the marine and freshwater vulnerability sections above, with the addition of transportation infrastructure to integrate potential coastal erosion and flooding issues. Transportation and energy infrastructure are vulnerable to storm events, particularly as sea level rises (Table 7). The principal roads are close to the ocean and many are already experiencing erosion and flooding and are vulnerable to climatic and additive forces. The dispersed and disconnected nature of Fiji's communities due to separation by the sea is a vulnerability during disaster response and recovery periods. It also can exacerbate effects and lengthen the time of recovery from energy and fuel supply shortages or infrastructure failures. This was witnessed after TC Winston with delays in responses that lasted months for rural areas.

TABLE 7. Climate and non-climate forces contributing to transportation and energy infrastructure vulnerability

Climate Forces	Additive Forces	Vulnerable Conditions
Storm frequency and intensity	Population growth	Transportation infrastructure
Air temperature	Fuel prices	Disaster response capability
Sea-level flux	Land-use patterns and trends	Community connectivity/ geographic separation
	Market trends	Power grids
	Geography and accessibility	

4.3.1 Coastal erosion and flooding

The effects of sea-level rise are likely to be considerable along coastal areas of Fiji, with some communities already experiencing impacts. Sections of low-lying coastline are faced with increased inundation, flooding, and salt water intrusion (Figure 22). Exceptions across Fiji appear to be rare, often occurring where costly land reclamation activities protect villages. Beach erosion and encroachment have brought about loss of land and coastal vegetation, and forced the relocation of buildings and infrastructure. In some areas, years of coastal erosion and flooding have made homes uninhabitable. Communities on the northwest coasts of both Viti Levu and Vanua Levu experience the highest storm surges because they face the most common direction of approach for tropical cyclones (McInnes and Hoeke 2014). Residents in Vanua Levu have begun planting grasses on the island's shoreline to address coastal erosion.

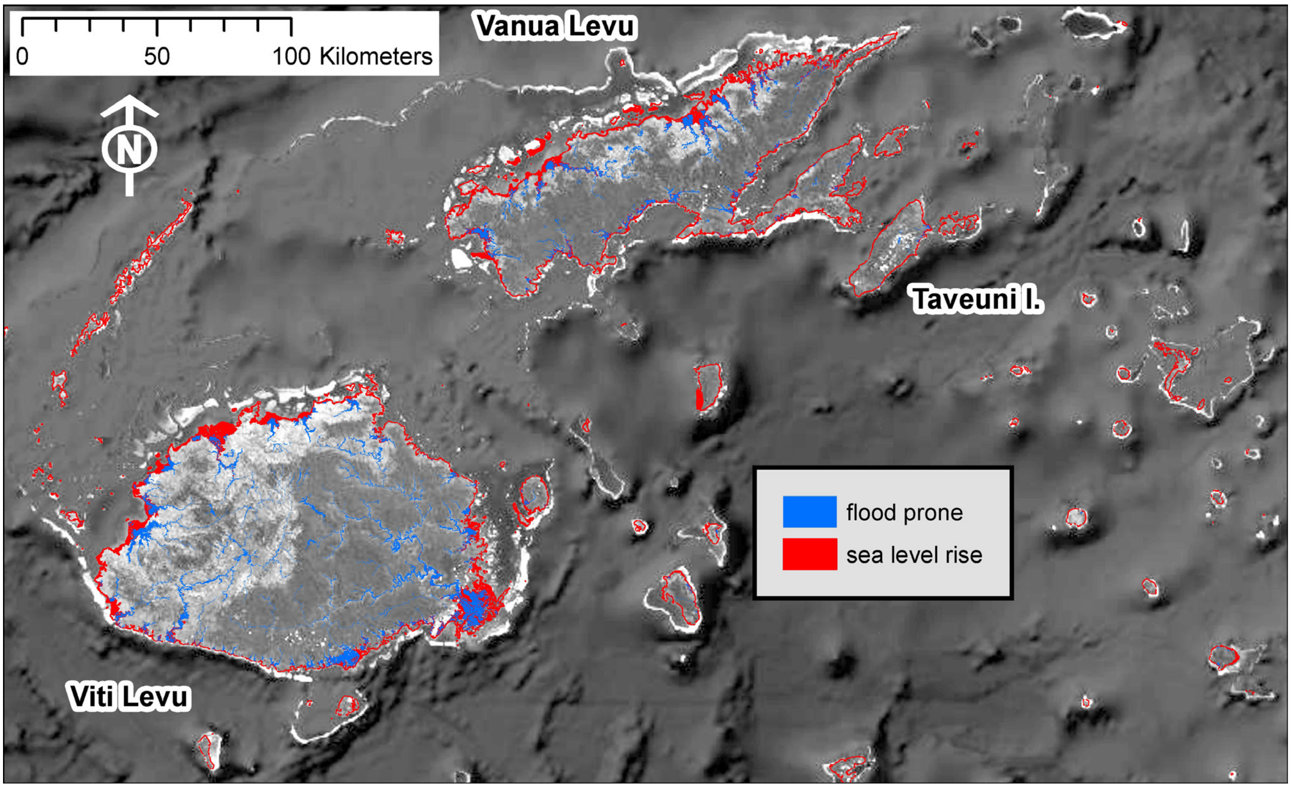

FIGURE 22. Areas prone to flooding and susceptible to sea-level rise.

Examples from Labasa City in Macuata Province show potentials for widespread inundation from riverine flooding and sea level increases/storm surges. Figure 23 shows scenarios of a 1 m rise in sea level and a corresponding 1 m rise from the relative stream elevation. This results in threats to infrastructure from flooding that affect most of the urban area and associated agricultural lands.

Farmer cleaning his cassava plantation.

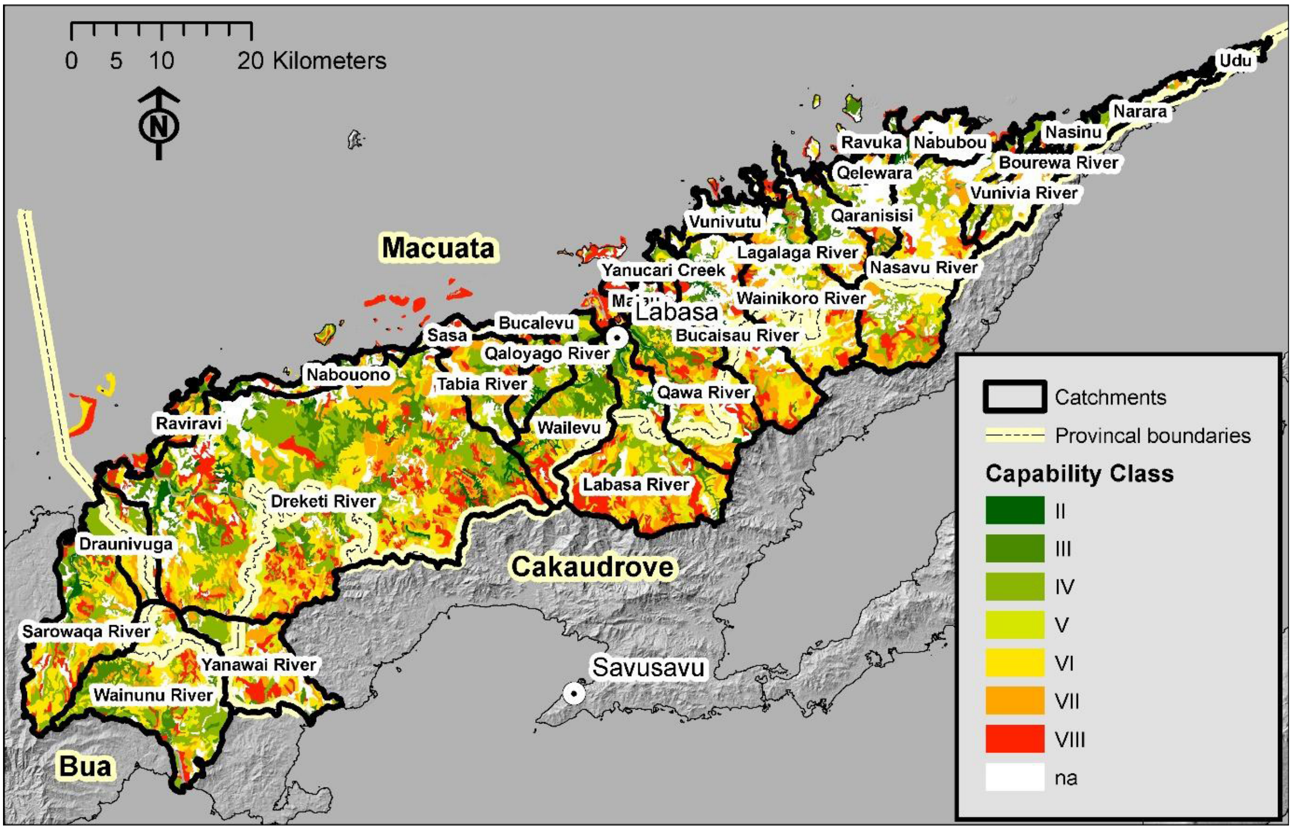

FIGURE 23. Inundation potential from riverine flooding and sea-level rise, and flood-prone portions of major roads and tramlines with a focus area on the Labasa River Delta, Macuata Province.

4.3.2 Transportation infrastructure

The road networks are vulnerable to storm events, including flooding and erosion. Roads and train tracks in Fiji vary in condition and general maintenance. Interior access is limited, and roads are steep and often impassable during storm periods. Storm effects are amplified in coastal areas by sea-level rise.

Key issues with transportation infrastructure are found in the low-lying areas. Flood risk and sea level/ inundation risks are displayed at the national scale in Figure 22 with a closer view of Labasa in Figure 23 (1 m rise); potential inundation from river systems was calculated as the 'relative elevation' to the stream surface; likewise, ocean inundation is relative to sea level. Both capture potential high rainfall events, storm surges, and other potential issues at varying depths; lengths of each transportation infrastructure at risk are shown in Figure 24.

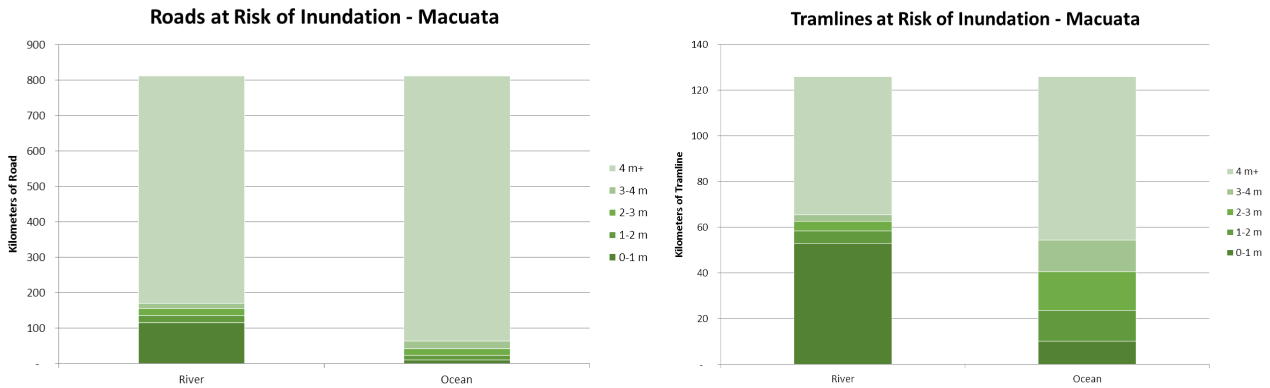

FIGURE 24. Roads (left) and tramlines (right) at risk from inundation due to flooding. Elevations are relative to stream elevation (river) and sea level (ocean) up to 4 m.

Overall for Fiji, the total lengths of potential road inundation from sea-level rise is quite low, with only 4 per cent of the mapped road networks country-wide less than 4 m above sea level. With respect to streams and river systems, 18 per cent of roads are within 4 m of river systems. For tramlines, risk of flood inundation is much greater than with roads, reflected by lower elevations for tramlines in general than for roads. Overall for Fiji, 44 per cent of tramline rails are less than 4 m above adjacent river levels and 26 per cent are less than 4 m above sea level.

Although national risk is low in terms of length of transportation arteries at risk, localised areas dependent on road and tram use are typically in urban environments; the Labasa City surroundings (Figure 23), for example, are greatly dependent upon low-lying bridges, and road networks that are projected to be inundated within 1 m rise in sea levels or stream flooding. While the length of roads may be insignificant at the national level, the damage to infrastructure and disruption in services are substantial to the provincial economic and political centre. Likewise for the Suva Peninsula; here high risk inundation areas are along the major peninsular ring road (Queen Elizabeth Drive). Infrastructure along this road includes the country's capital and largest and most significant business district, and has weakened bridges on the major road connection between the capital and the international hub of Nadi to the west. Similar conditions exist for Nadi, where much of the low elevation areas are subjected to ten-year storm event risks of surges (Gravelle and Mimura 2008).

4.3.3 Key drivers of change

The key drivers of change for coastal erosion, flooding, and transportation and systems include:

- changing demand with urbanisation and urban population growth;
- associated increasing demand for transportation and connectivity between rural and urban areas, Vanua Levu and Viti Levu;
- aging infrastructure that declines in functionality if not updated or replaced, or causes abrupt disruptions in travel (e.g. broken bridges, washed-away roads, etc.);
- vulnerable infrastructure to flooding and key transportation routes due to low-lying locations, especially in urban environments;
- import of vehicles in recent years have put pressures on existing infrastructure and routes;
- road and transportation planning to adjust for disaster management, and to build to capacity of current and future needs within a secured transportation network; and
- review of lowland land-use practices and adjust them (e.g. sugarcane in lowland areas near Labasa, Figure 23) to increase capacity of ecosystem-derived services (e.g. mangrove attenuation of flooding and sediment capture in this instance), and identify zoning rules to minimise impacts for future developments.

4.4 AGRICULTURAL SYSTEMS

Agricultural resources are critical to Fiji's food security and economy. Agriculture in Fiji is vulnerable to climate change in several ways (Table 8). Storms can damage infrastructure and crops, erode soils, and damage transportation systems necessary to transport produce to market. Changes in climate patterns can affect crop suitability and disease or pest vulnerability. Changes in precipitation patterns, including timing, extremes, and severity and frequency of droughts will affect not only crop choice but also viability. At the same time, climate change is shifting the underlying natural conditions that farmers and processors must operate within, market forces and other socio-economic dynamics influence the demand for agricultural produce. This includes prices both for their products and their required inputs, both of which are affected by other producers and supply chains.

TABLE 8. Climate and non-climate forces contributing to agricultural vulnerability

Climate Forces	Additive Forces	Vulnerable Conditions
Storm frequency and intensity	Imports	Household revenue dependence
Higher mean annual and daily extreme air temperatures	Land tenure	Household food dependence
Changes in rainfall distribution (temporal and spatial)	Land use history and practices/ intensities	Eroding soils
	Market demand	Soil infertility
	Operating costs	Agricultural land base
	Disease vectors	

4.4.1 Household revenue and food dependence

Production losses associated with large storm events, particularly TC Winston in 2016, have direct impacts on Fiji's agricultural economy and household responses. The total value of damage and production assets losses attributed to TC Winston in the agricultural sector was FJD 542 million, of which FJD 80 million is attributable to damage and FJD 461 million attributed to losses (Government of Fiji 2016). The agriculture sector accounts for 45 per cent of total employment in the country, with a wide distribution of informal and subsistence agriculture. Overall crop production was the most affected by TC Winston, with a 40 per cent loss, largely associated with dalo, cassava, yam, banana, plantain and leafy vegetables. Export crops supplying income to rural households were also affected: ginger, taro and copra. Permanent crops (yaqona, coconut and plantation trees) that require longer-term investments were also affected, limiting dividends for future harvests. Infrastructural losses included nurseries, copra driers, roads, machinery, buildings, and inventory stores. Sugarcane and livestock accounted for 14 per cent of losses, affecting infrastructure, local jobs and revenue associated with many rural households raising semi-commercial goods.

While TC Winston was an uncharacteristically large and destructive event, pathways to resilient revenue and food dependence require immediate post-disaster responses to include small community gardens, 'storm proofing' for seedling stock, storm protection for inventory and infrastructure, and other fortification methods. In the absence of these responses, increases in climate extreme events will continue to take a toll, or further complicate recovery efforts of past events. Distribution of local food production is important to build resilience to natural disaster events, as communities are isolated due to infrastructure failure (short term). A well-distributed food production system builds resilience to often localised storm damage.

Land tenure issues are central to challenges facing farmers in Fiji as unpredictable year-on-year leasing precludes the necessary conservation of resources and investment in capital assets. Productivity and profitability would be more resilient to future effects of climate change with more secure long-term ownership or user-right security, as would be the incentives to invest in fences, riparian buffers, and other best management practices that would protect freshwater and marine resources. Longer-term leases (>25 years) are also enacted, although interviews support the view that, regardless of time, there is a reluctance to allocate any funds into infrastructure as the perception is it may never be recovered.

4.4.2 Eroding soils, soil infertility and agricultural land base

Soil erosion is a central issue for Fiji, due to steep slopes, high rainfall, and soil characteristics that combine to create a naturally erosive condition. Agricultural production that encroaches on steep slopes and results from conversion from forested areas is at the highest risk for degradation and erosion. Other factors influencing surface water flow, including deforestation and stream degradation, are additives to erosion hazards to the agricultural land base.

The same climate and additive forces of change affecting eroding soils are also affecting soil fertility. Soil fertility limitations are magnified by weak land tenure security for growers, who cannot (or will not) make long-term investments, either in terms of direct improvements to soil, nor in their use of soil in a conservative way that maintains fertility. This is mostly because farmers cannot be certain they will maintain tenure to benefit from scarce resource investments. As is typical throughout the tropics, forest conversion to agriculture leads to a decline in available nutrients, and eventually leads to abandonment for subsistence farmers to seek additional lands to farm. This cycle leads to expansion in additional forest lands (via lease or trespass), leading to higher deforestation and fragmentation for short-term crop cycles. Addressing the need directly requires a focused effort by government to encourage investment in diversification of crops, agricultural extension, and land-use laws.

Short-term or insecure land tenure also inhibits farmers that cannot afford to invest in adaptive approaches, such as irrigation or soil fertility management, nor undertake actions that require multi-year timeframes, such as increased use of perennial or permanent crops or value-added processing. Use of irrigation and crop rotations requires investment. Without direct investment and security of investment, choices narrow for small commercial or subsistence farmers. Working more efficiently with the land currently under agriculture, rather than converting new lands for short-term gains, requires (in part) land stewardship and security of investment.

4.4.3 Key drivers of change

The key drivers of change affecting agricultural systems include the following:

- disaster or climate extreme responses and fortification – repeated impacts on infrastructure, lost crops and revenue, and associated damage to market delivery due to extreme climate events will test the ability of subsistence, semi-commercial and commercial agricultural entities to persist;
- well-distributed food production system needed to build resilience to localised storm damage and disaster response;
- market forces affecting agricultural commodities – export markets and efficiencies determine demand for land uses to favour farming, at least at the commercial scales, and booms in crop demand through scarcity can increase demand for agricultural lands, promoting deforestation and land-use changes affecting other resources;
- coastal erosion affecting infrastructure – coastal erosion and sea-level rise are factors that put transportation systems at risk;
- lack of irrigation makes cane and other crops susceptible to drought; intensive rainfall predicted by climate change can damage crops; and
- lack of land tenure stability from short-term leases (e.g. <25 years) discourages diversification and infrastructure improvements and encourages extraction of resources without building buffers.

4.5 TERRESTRIAL ECOSYSTEMS

Many of the threats of terrestrial land-use change have been identified in previous sections, with lenses of vulnerability of resources ranging from fisheries, freshwater uses, agriculture, and landscape continuity and attenuation during large-scale disturbance events. This section summarises forces that come together to form conditions that create large- and long-term disturbances on terrestrial ecosystem-level processes (Table 9).

TABLE 9. Climate and non-climate forces contributing to terrestrial ecosystems vulnerability

Climate Forces	Additive Forces	Vulnerable Conditions
Rainfall frequency and intensity	Deforestation	Fragmented/degraded forests
Drought	Large flood events	Invasive species expansion
Windstorms	Land-use change	Erosion/soil degradation
Air temperature	Imbalanced soil nutrients	Unstable supply of land products
Storm surge	Invasive species	
	Subsistence harvest	

4.5.1 Land use / land cover

Land use/land cover (LULC) estimations were made in 2010 (SOPAC/SPC-GSD, 2010) using aerial imagery based on Landsat imagery and ground-truth analysis for all of Fiji. The mapping classifications were designed to capture different forest and non-forest types, with emphasis on mixed-use lands (e.g. crops, coconut) and little differentiation of forest types at the national scale. Forest type differentiation requires more ground truth analysis and typically first-hand background of forest conditions to accurately delineate subtle differences (e.g. species types) as well as overall condition (e.g. degradation). For this reason, large-scale LULC inventories often do not over-stratify forest types unless it is within a priority interest, such as the National Forest Inventory that is used for greenhouse gas or biodiversity reporting.

For interpretive uses for this ESRAM, the 2010 LULC types were consolidated into basic descriptors to describe the different classes of land uses. These include agriculture, agroforest (including coconut plantations), forest, grassland/shrubland non-forest types, and other features (wetlands, inland water features and settlements).

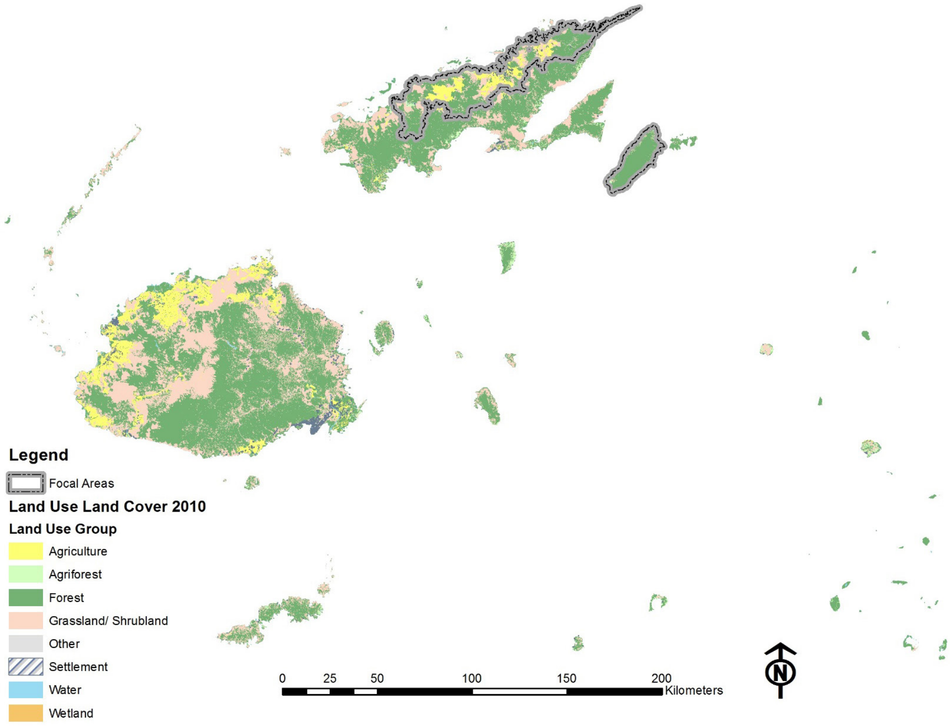

FIGURE 25. National Land Use-Land Cover map for Fiji. LULC categories are aggregated for general interpretation. PEBACC focus areas of Taveuni Island and Macuata Province are highlighted. Source: SPC-GSD unpublished.

TABLE 10. Aggregated land use/ land cover types for the ~18,500 km2 of Fiji. Source: SPC-GSD unpublished.

Land Use/Land Cover Group	Area (km^2)	% Area
Agriculture	1,576	9%
Agroforest	272	1%
Forest	10,609	57%
Grassland/ Shrubland	5,777	31%
Other	7	<1%
Settlement	108	1%
Water	181	1%
Wetland	2	<1%
Total	**18,532**	**100%**

Three LULC groups comprised 97 per cent of the land area for Fiji (Table 10): Forest cover (57 per cent), grassland/shrubland (31 per cent) and agricultural classifications (9 per cent). The remainder were in settlements, inland waterbodies and other features. Within these groups (Table 11), forest classifications were not differentiated as to plantations, native or degraded forests. Similarly, the open lands/grasslands classification is also likely in areas with subsistence agricultural and dispersed settlements. Agricultural lands were mostly accounted as large sugarcane farms (7 per cent of the land area).

TABLE 11. National land use/ land cover as mapped and defined by SPC-GSD (unpublished).

LULC Group	LULC Category	Area (km²)	% of Group	% of Area
Agriculture	Cassava	3	<1%	<1%
	Coconut Crops	20	1%	<1%
	Cultivated Land	146	9%	1%
	Mixed Crops	18	1%	<1%
	Orchards	19	1%	<1%
	Rice	11	1%	<1%
	Sugarcane	1,359	86%	7%
Agroforest	Coconut Forest	62	23%	<1%
	Coconut Plantation	203	74%	1%
	Oil Palm	<1	<1%	<1%
	Scattered Coconut Plantation	7	3%	<1%
Forest	Forest	10,608	100%	57%
	Scattered Forest	<1	<1%	<1%
Grassland/ Shrubland	Grazing Land	<1	<1%	<1%
	Open Land/ Grassland	5,772	100%	31%
	Shrubs	5	<1%	<1%
Other	Barren Land	7	100%	<1%
Settlement	Settlement	108	100%	1%
Water	Water	181	100%	1%
Wetland	Wetland	2	100%	<1%
Total		**18,532**		

Generally, LULC coverages provide a good basis for determining the overall land cover types and track land cover changes using systematic and repeatable methodology. Currently there are no direct comparisons as to LULC change known and verified for Fiji. Data for exacting trends in conversion to agriculture are problematic, as deforestation is often at small scales (<5 ha) for conversion to subsistence farming. No data are known to exist, although there is clear evidence of recent activity (e.g. Forestry REDD+). Repeated measurement and ongoing monitoring are needed to capture changes in LULC.

TABLE 12. LULC aggregate classes intersected with land tenure classifications at the national level. See also Figure 4. Source: 2010 LULC (SPC-GSD) and Department of Lands.

	iTaukei Land		Private Freehold		State Land		Unmapped	
LULC Group	Ha	%	Ha	%	Ha	%	Ha	%
Agriculture	108,765	7%	16,785	13%	45,110	34%	2	<1%
Agriforest	12,837	1%	4,968	4%	851	1%		
Forest	839,528	58%	58,494	46%	50,557	38%	60,896	90%
Grassland / Shrubland	485,594	33%	44,391	35%	30,334	23%	6,714	10%
Other	504	<1%	112	<1%	85	<1%		
Settlement	4,652	<1%	2,569	2%	4,700	4%		
Water	3,498	<1%	723	1%	663	1%	191	<1%
Wetland	159	<1%	53	<1%				
Totals	**1,455,537**	**100%**	**128,096**	**100%**	**132,299**	**100%**	**67,803**	**100%**

The LULC database was intersected with the land tenure database with breakdowns shown earlier to assess the ownership distribution across LULC sectors (Table 12). Overall, iTaukei lands had the highest forest cover among ownerships (58 per cent) and lowest agricultural land base by percentage (7 per cent), and highest by area. Private freehold lands had a higher proportion of agricultural lands (13 per cent) while state lands were evenly distributed among agriculture and forestlands (34 and 38 per cent respectively) with slightly lower grassland/shrubland areas than did iTaukei and private lands (33 and 35 per cent respectively).

Data for exacting trends of conversion to agriculture are problematic, as deforestation is often at small scales (<5 ha) and can occur over time to support subsistence farming. For example, yaqona is farmed in the shade and overstory trees are then thinned to 'release' the crops and promote more growth over a period of three to six years. Followed by dalo farming or similar crop, these changes can be small scale and incremental and difficult to detect using remote sensing, requiring frequent high quality images and diligent throughput through available mapping services or donor-funded projects.

4.5.2 Fragmented forests

Forest fragmentation, or creating patch or edges of existing forests, results from several factors, including infrastructural development, population growth, expansion of subsistence agriculture, timber harvest, or slash-and-burn activities associated with land clearing. One major factor affecting large forested environments of Fiji has been recently found on Taveuni.[18] Extreme weather events in 2016 (record-setting rainfall for three months and record high temperatures for two months) coupled with the size and destructive force of TC Winston, subjected the windward forests of Taveuni to large-scale stressors.

In July 2016, aerial imagery was acquired by Landsat (8-band image) of Taveuni, which produced high quality multispectral images for remote sensing that could be used to assess the vegetative conditions during the post-cyclone period and the height of the drought period of 2016 – capturing a snapshot of ecosystem responses to these extreme climate events.

A normalised difference vegetation index (NDVI) value was calculated from the multispectral Landsat imagery to assess an index of vegetation health. The NDVI is a ratio of signal of the red spectrum and the near-infrared light that is calculated from the image, and is expressed on a scale of –1 to +1. In general terms, this yields a marker of vegetation health, measured as wavelengths of light absorbed and reflected by green and growing plants (e.g. photosynthetically active). High NDVI values (>0.6) correspond to dense vegetation at

[18] See Ecosystem and socio-economic resilience analysis and mapping: Taveuni Island, Fiji. SPREP 2020.

peak growth, while moderate values (0.2-0.5) may indicate sparse vegetation or senescing or damaged plants (nutrient poor crops, insect/disease damage, physical damage, etc.). Low NDVI values (<0.1) generally indicate little to no vegetation.

The imagery analysis (Figure 26) revealed large-scale disruption and fragmentation of native forests and the potential for invasion by non-native grasses and vines.

The weed *Merremia peltata* creeps across the land, Taveuni Island.

Figure 27 displays close-up views of the upper reaches within the Taveuni 'blue line' and forest reserve areas through a photo image (left) and GIS image analysis (right). The white arrows indicate the same locations and, noted from the photo, show broad areas of windthrow and forest fragmentation with low stem density and a prevalence of ground cover vegetation. This would appear to be a significant change to the structure of cloud forest types to a more degraded or open type of structure, vulnerable to colonisation. Coupled with the island-wide assessment (Figure 26), large swathes of the upper reaches of the Taveuni Forest Reserve area on the windward side are at risk.

Notwithstanding the dramatic changes from TC Winston, chronic forest fragmentation from human-caused changes are largely associated with timber harvest or slash-and-burn activities for land clearing and conversion to agriculture. Typically small plot areas (~5 ha) are farmed for a number of years, followed by fallow and abandonment. This leads to a chain of fragmented forests, where forest edges are encroached upon, increasing the susceptibility of forest changes due to human-induced grass fires (for land clearing) that kill native forest edges. The cycle continues with repeated burns and conversion of forest lands, causing a cycle of deforestation and fragmentation. While not quantified, forest fragmentation is high in the upper reaches of nearly all watersheds in Fiji. This is especially evident in the leeward side of Fiji, with dispersed farming and settlements, and frequent use of fire that leaves forest fragments in the steep valleys with grasslands that surround them.

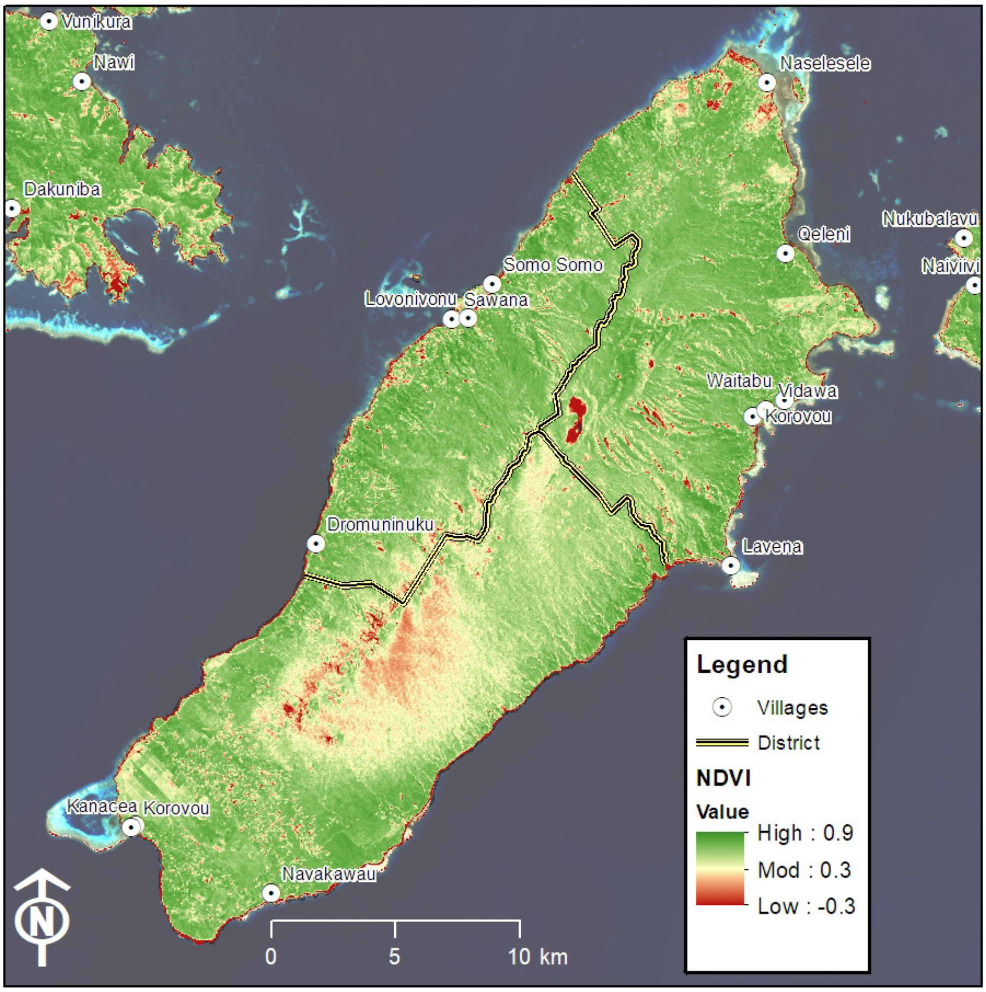

FIGURE 26. A normalised difference vegetation index (NDVI) image calculated from July 2016 following TC Winston and at the height of a drought period. Green values indicate healthy vegetation. Yellow is more sparse or senescing vegetation. Red values are bare soil or very sparse vegetation

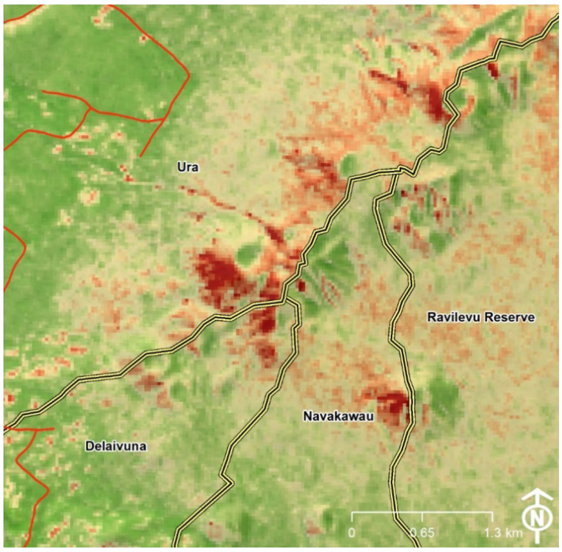

FIGURE 27. Left: Aerial view of forest degradation on high peaks of the central ridge of Taveuni (western side). Right: a normalised difference vegetation index (NDVI) map derived from 2016 Landsat 8-band imagery, indicating vegetation health (red = degraded or poor health, yellow = intermediate, green = high productivity). Arrows indicate reference locations surveyed. Note fragmented stands in left area corresponding with low NDVI values.

Climate and human-derived disturbances are well attenuated with large, contiguous forest cover. With fragmentation, there is more edge and generally smaller patches, which results in more edge-effect disturbances, including wind damage, invasive species, and other disturbances (e.g. fire) around the given patch. In general, the more landowners or lessees in a given area, the more fragmented a landscape becomes due to individual management decisions at small scales. So, as settlements increase in size, so does the level of fragmentation around that settlement.

Drinking water from a natural spring – an important ecosystem service, Taveuni Island.

4.5.3 Invasive species expansion

Current biosecurity programmes affecting international air travellers appear to be adequate, and there are inspections of goods entering by cargo shipment into Fiji. However, there does not appear to be any inter-island security, especially related to agricultural products and acquisition of seed and rootstock within Fiji. This was particularly observed for both Macuata Province and Taveuni, both important agricultural producers for Fiji. There does not appear to be a systematic method of controlling soil movement from other islands (e.g. washing stations for transport vehicles, soil removal), or the transfer of pests that affect food security, or for inspection of potential soils distribution. Invasive species are widely considered to have an advantage over native species under climate change, especially with severe storm events that weaken standing forests and plantations, as well as increase incident light for fast-growing species. Forest fragmentation and land cover changes favouring expanded settlements are also key vectors in the spread of invasive plant species.

4.5.4 Erosion/soil degradation

Similar to the vulnerabilities listed in the previous sections, increasing the overall cover to higher complexity has a direct effect on the soil profile and the fate and transport of eroded or degraded soils. Increases in vegetative cover complexity; using multi-tiered agricultural designs to minimise erosion; protection, enhancement and expansion of forests; limiting disturbances; and strengthening land tenure are key strategies that can limit these vulnerabilities on the landscape.

4.5.5 Key drivers of change

The key drivers of change affecting terrestrial ecosystems include the following:

- **Economic stability.** A key driver in deforestation and conversion of lands is having economic stability that moves away from extractive, subsistence uses to more efficient and higher-value uses. Primary example is conversion of forestlands to short-term agricultural plots or increased and dispersed settlements.
- **Economic boom cycles.** Short-term economic booms, such as dalo and yagona as seen in recent years, can result in sudden pulses in deforestation and land conversion to meet short-term market demand. This has been a documented driver in the deforestation of Taveuni.[19] Oftentimes this involves the exchange of short-term leases that result in a degraded landscape for the lessor after the fact.
- **Climate events.** Extreme climate events can have large-scale effects on vegetation structure and functioning, such as cyclones and other destructive forces. Increases in rainfall intensity increase flooding and scouring events that damage soils or reduce opportunity for native species, especially in riparian zones. Prolonged drought events likewise cause mortality and stress to native ecosystems, allowing for invasive species expansion, losses in hydrologic functioning, and other services. Monitoring and responsiveness are key to characterising and addressing new challenges.
- **Road networks.** Increases in road networks make new areas of the landscape open to settlements, resulting in land conversion to settlements and agriculture, as well as increases in opportunity for invasive species introductions.

4.6 FIJI'S ECOSYSTEM SERVICE VALUES

4.6.1 Context of valuing ecosystem services

Fiji's functional ecosystems and natural resources provide a multitude of essential goods and services to residents and visitors. While a complete list is impractical to fully compile, important examples of ecosystem goods and services include provision of clean water, clean air, consumable fish, fertile soils, building materials, storm and flood protection, and wildlife. Numerous studies and reports exist, identifying and detailing these services, several of which are referenced throughout this document (e.g. Atkinson *et al.* 2016; Gonzalez *et al.* 2015; O'Garra 2012). The complexity and diversity of ecological and other biophysical processes in Fiji makes full identification and understanding of all such ecosystem services infeasible. As scientific knowledge progresses, new ecosystem services are revealed.

Just as full identification of all ecosystem services in Fiji is a challenging and probably endless endeavour, so too is full valuation of these services. Valuation in a qualitative sense can entail describing how people and communities benefit from the types, qualities, and quantities of Fiji's ecosystem services. Economic methods do exist for providing monetary estimates of ecosystem services, but such monetary valuation techniques are generally most appropriate for considering marginal or incremental changes in the overall quantity or quality of a particular ecosystem service. For example, a village might be able to consider how it would need to behaviourally adapt or the purchases it would need to make, if it were to lose one per cent of its available surface water supply. If it were to lose its entire water supply, however, a community's members might need to fully relocate, and collectively, total loss of all ecosystem services would make an area uninhabitable. Furthermore, economic valuation is rooted in the value of money to individuals, communities and institutions. An underlying principle of the value of money is its scarcity. If a community had access to unlimited reserves of financial wealth, prices and monetary values would likely be meaningless. Therefore, budget constraints and limits on available financial resources, are an essential characteristic of monetary valuation. While Fijian communities might be particularly wealthy in terms of natural, human, social and cultural resources, financial wealth can be an important constraint.

[19] See Ecosystem and socio-economic resilience analysis and mapping (ESRAM): Taveuni island, Fiji

Therefore, the ability of Fijian communities to pay for ecosystem services, even in a hypothetical scenario, is limited. Analyses seeking to assess the financial value of resources via market or non-market techniques generally rely upon estimation of the willingness-to-pay amount by a group of beneficiaries. The question might also be framed as the amount a community is willing-to-accept to lose a resource, but these approaches, while maybe more practical in this context, face analytical problems. For example, asking a community in Fiji how much it would be willing to accept to give up its entire water supply similarly might mean that the community must disband or relocate. All of these caveats are to say that consideration of monetary values for ecosystem services in Fiji make economic sense for small and temporary changes, but should be given less credence for major long-term changes.

4.6.2 Ecosystem service valuation

When considering trade-offs and various options for investment of scarce resources, it can be useful to use representative monetary values for ecosystem services, particularly when the trade-offs involve financial investments, or comparison to more traditional market goods and services (bought and sold in functioning markets) like food imports or water treatment facilities. One useful source for representative monetary values for ecosystem services in Fiji is a global meta-analysis that reviewed hundreds of studies and provides monetary values per hectare for many of the ecosystem services found in Fiji (de Groot *et al.* 2012). Such global valuations do not perfectly account for the site-specific scarcities in terms of the current supply, demand, substitutes and complements. So these values should be considered representative rather than precisely accurate. This compilation of values represents a wide range of valuation techniques, including: (i) survey-based stated preference techniques, whereby people are asked how much they would be willing-to-pay; (ii) revealed preference techniques that use observable behaviours; (iii) indirect market expenditures (such as travel costs or real estate prices); and (iv) avoided costs, which represent the market cost of replacing an ecosystem service via a conventional good or service, such as paying for a water filtration plant to replace a forest's filtration services.

de Groot *et al.* bundle several identifiable and monetisable ecosystem services by each habitat type category they use. They use a breakdown of ecosystem services into the four categories developed by the United Nations Environment Programme's Millennium Ecosystem Assessment (2005). These four categories are: provisioning services, regulating services, habitat services, and cultural services (Table 13).

TABLE 13. Examples of the four categories of ecosystem services considered

Category	Example Ecosystem services
Provisioning Services	Food Water Raw materials Genetic resources Medicinal resources Ornamental resources
Regulating Services	Air quality regulation Climate regulation Disturbance moderation Regulation of water flows Waste treatment Erosion prevention Nutrient cycling Pollination Biological control

Category	Example Ecosystem services
Habitat Services	Nursery services Breeding grounds Genetic diversity Species diversity Functional diversity
Cultural Services	Aesthetic and wellbeing Recreation Inspiration Spiritual experience and development Cognitive development Traditional uses

Given the caveats and utility of describing ecosystem service values by habitat type to those habitat types for Fiji, applying the de Groot values per hectare yields hundreds of billions of dollars (FJ) per year for the country (Table 14), as compared with the FJD 6.7 billion in reported GDP (see Table 3). The coral reef values dominate these values, and are not allocated at the national scale. Coastal wetlands in this table represent areas of mangrove. These values and area estimates do not include land area in development or agriculture, including forestry, as income-producing values. To the extent that these developed land uses also supply some ecosystem services, these areas and values are underestimates.

TABLE 14. Annual economic value of Fiji's ecosystem services by habitat type (identified from sources above). Source of values: de Groot *et al.* 2012.

Habitat Type	Median value per ha (FJD 2016)	Area (ha)	Value (FJD 2016)
Coral Reefs	$472,902	670,000	316,844,232,800
Coastal systems	$63,946	NA	NA
Coastal wetlands	$29,065	38,000	1,104,458,782
Inland wetlands	$39,510	200	7,901,929
Fresh water rivers and lakes	$9,410	18,100	170,325,431
Tropical forests	$5,628	1,060,900	5,970,223,237
Grasslands	$6,447	577,700	3,724,513,240
Total	**NA**	**2,364,900**	**327,821,655,420**

A similar summary pertaining to the marine and coastal ecosystems was conducted in more detail and depth by MACBIO (Gonzalez *et al.* 2015) across Fiji's qoliqoli. This analysis focused on seven specific environmental services provided by the marine environment (Table 15).

Overall, data such as these for ecosystem service valuation may assist decision-makers in evaluating trade-offs to support sustainable resource management practices, as well as improve the understanding of the effects of resource degradation on human benefits derived from ecosystem-based assets.

TABLE 15. Summary of environmental services values from marine and coastal ecosystems in Fiji (2014 dollars). Source: Gonzalez *et al.* 2015.

Service	Ecosystem	Area	Unit value[a]		Total value	
			FJD/ha/yr	USD/ha/yr	FJDm/yr	USDm/yr
Subsistence fisheries	Inshore	6,704 km^2	88.07	44.09	59.04	29.56
Commercial fisheries	Small-scale inshore artisanal fishing	6,704 km^2	21.74–80.08	10.88–40.09	14.57–53.69	7.30–26.88
	Bêche-de-mer				5.5–16.5 (gross)	2.9–8.7 (gross)
	Offshore tuna	1.29m km^2	0.16	0.08	20.11	10.07
Mineral and aggregate mining	Total				3.05	1.54
	Deep-sea mining				1.55	0.78
	Aggregate mining	300,000m^2	5/m^2	2.5m^2	1.5	0.76
Tourism	Total				1,145.82 (gross)	573.63 (gross)
	Coral reefs and lagoon	6,704 km^2	1,367.3	684.52	916.66	458.90
	Mangroves	38,500 ha	5,952.33	2,979.89	229.16	114.73
	Coast	1,130 km	202,800.8/km	101,527.3/km	—[c]	—[c]
	Coastal land	1,130 km^2	2,028.00	1,015.27	—[c]	—[c]
	Fiji land	18,274 km^2	627.02	313.90	—[c]	—[c]
Coastal protection		2615 km^2[d]			12.72–21.20	6.36–10.61
Carbon sequestration	Ocean[e]	1,290,000 km^2	6.77	3.39	873.33	437.31
	Seagrass	NA[b]	1,515.42	758.66	NA[b]	NA[b]
	Tidal marshes	NA[b]	2,759.94	1,381.70	NA[b]	NA[b]
	Mangroves	385 km^2	3,835.58	1,920.19	147.67	73.93
Research and education			NA[b]	NA[b]	NA[b]	NA[b]
Total					**2,281.81–2,487.41**	**1,142.60–1,172.23**

a Unless otherwise indicated;

b Not available;

c Total value for coasts is included in value for mangroves;

d Source: Fiji Lands Department;

e Only considers social cost of carbon

5. KEY FINDINGS AND THEMES

Overall this document seeks to identify pathways for developing adaptation options to increase resilience of critical ecosystem services and livelihoods at the national level. The following provide insight to reach this national goal, keeping in mind the focal areas and associated documents for the PEBACC project for both Macuata Province and Taveuni Island:

- There is a need to link ecosystem-based functions with the socio-economic and political landscape – managing for natural resources as an investment into the future requires time, resources and change in behaviours to create more choices.
- A need to track, monitor and link ongoing projects of all types with the context of resource use, potential community confusion, and conflicting missions.
- A need to identify, map, quantify, address, mitigate and geographically bind the cumulative effects of projects in an ecological and social context.
- A need to address the challenge of political boundaries in connected landscapes for successful ridge-to-reef ecosystem management.
- A need to cross ministerial mission boundaries to address environmental concerns across disciplines, especially for projects not requiring fully developed environmental impact assessments, through use of best management practices, such as maintaining stream buffers in road maintenance projects.
- A need for centralised planning resources, or a multidisciplinary task-force to increase awareness of actions to ecosystem services at local levels, and make these available during the planning and implementation process for all proposed projects or interventions. This also includes an autonomous operating budget for outreach.
- A need to organise outside donor-driven projects so that common mission goals are met in meaningful ways, and everyone works to increase durability of projects and build long-lasting environmental awareness and choices for communities: smart investment strategies to yield long-term dividends.
- A need to localise management and oversight obligations to increase capacity and ownership, while still managing cohesively for ecosystems.
- A need for community organisation to prioritise and address their own resource concerns, allowing for clear linkages to have community concerns emerge laterally and vertically through the political structure (inter-agency and community-district-provincial-divisional-national structures).
- A need to allow for appropriate investment or incentives for land users to ensure sustainability through improving soil fertility, diversifying crops or protecting forests.
- A need for a transparent and central data exchange, if Fiji is willing to accept outside partners to assist in natural resource management.

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