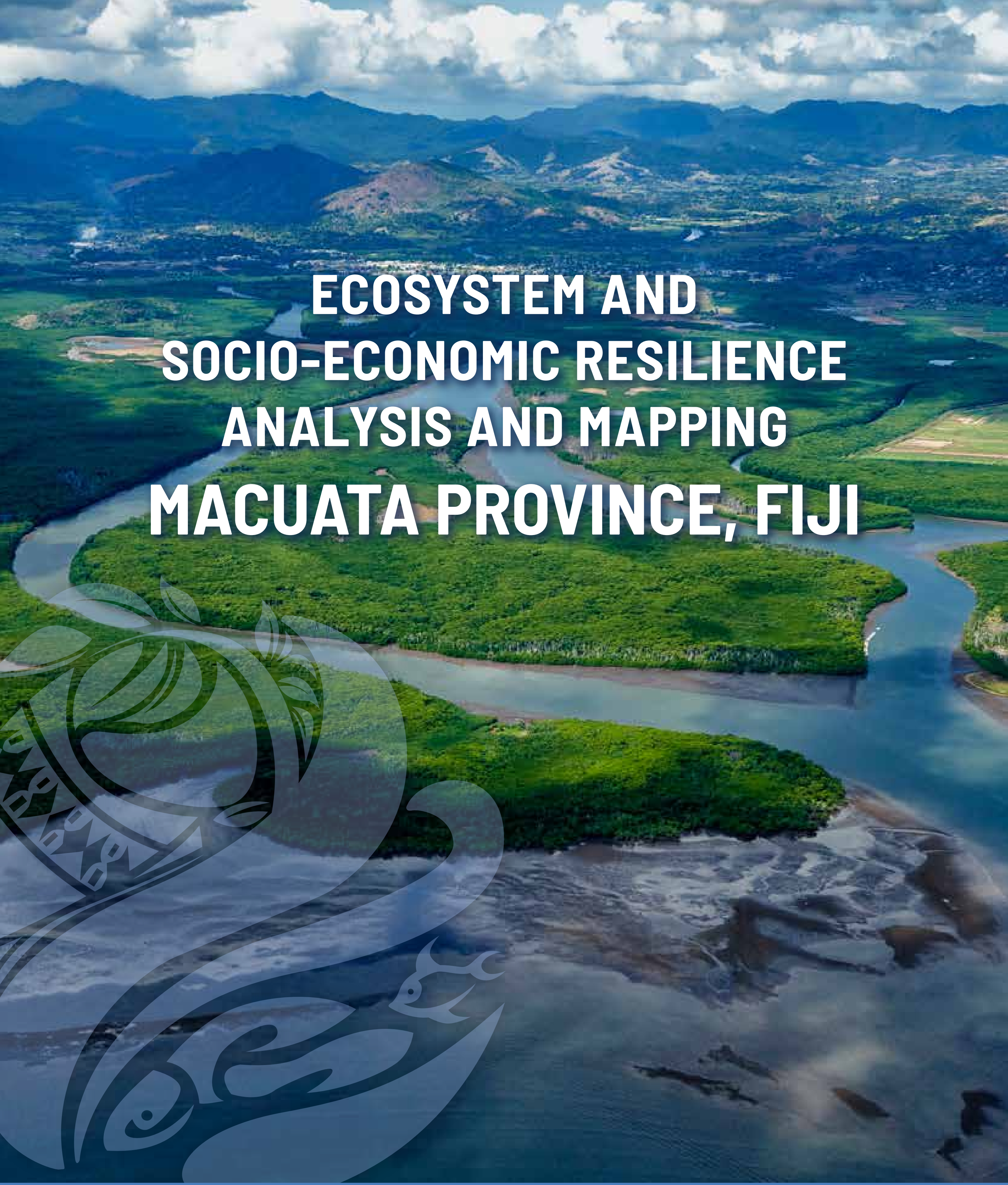

ECOSYSTEM AND SOCIO-ECONOMIC RESILIENCE ANALYSIS AND MAPPING

MACUATA PROVINCE, FIJI

SPREP
Secretariat of the Pacific Regional Environment Programme

Supported by:

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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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ECOSYSTEM AND SOCIO-ECONOMIC RESILIENCE ANALYSIS AND MAPPING

MACUATA PROVINCE, FIJI

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

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We would like to thank the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) through the International Climate Initiative (IKI) for their commitment to the Fijian people and the environment. Special thanks to contributors from the Wildlife Conservation Society; the Pacific Community's Geoscience, Energy and Maritime Division; Marine and Coastal Biodiversity Management in Pacific Island Countries (MACBIO); and a host of other projects and non-governmental organisations who shared knowledge and information.

We acknowledge the many people in the Government of Fiji who provided guidance and support for obtaining the latest information and policies and for supporting community involvement.

CONTENTS

ACRONYMS

BMU	German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
CMIP	Climate Model Intercomparison Project
EbA	Ecosystem-based Adaptation
ENSO	El Niño/ Southern Oscillation
EEZ	Exclusive Economic Zone
ESRAM	Ecosystem and Socio-economic Resilience Analysis and Mapping
FJD	Fiji dollar(s)
FSC	Fiji Sugar Corporation
GDP	Gross Domestic Product
GIS	Geographic Information Systems
GSR	Great Sea Reef
GCM	Global Climate Model
IKI	International Climate Initiative
LMMA	Locally Managed Marine Area
LULC	Land Use/Land Cover
MPA	Marine Protected Area
NGO	Non-Governmental Organisation
NRMS	Natural Resource Management Strategy
PACCSAP	Pacific-Australia Climate Change Science and Adaptation Planning programme
PCF	Pacific Climate Futures
PEBACC	Pacific Ecosystem-based Adaptation to Climate Change
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

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
Vanua	traditional community chiefly structure, also as it pertains to local community
Yaqona	a root crop also known as kava (*Piper methysticum*)

FOREWORD

With its high forested mountains, sweeping river valleys, fertile soils and spectacular coastline, Macuata Province is blessed with an abundance of high-quality natural resources. These resources form the base from which our people derive their sustenance and well-being; i.e. they are the base of our provincial economy. While we face a number of development challenges, we should never take for granted the importance of our natural environment in supporting us. This is particularly the case now that climate change is upon us, as changes in our climate are already placing, and will continue to place, additional pressure on our ecosystems and biodiversity thereby threatening their – and by extension our – well-being.

In this context the Macuata Ecosystem and Socio-economic Resilience Analysis and Mapping report is an important contribution to development planning in the province. It is the first provincial scale study that I am aware of that combines information on all our natural resources and ecosystems and explains how they contribute to our economy and our livelihoods. It further provides an overview of the ecological status of these resources, key drivers threatening them and projected climate change impacts. It highlights some of the administrative challenges we face in managing these resources sustainably - for example the challenge of managing 'connected landscapes' as discussed in chapter 5.

From this report we better understand that protection of the environment is a logical and effective way to strengthen our resilience to climate change and that development in our province needs to be based on principles of 'green growth' as outlined in Government's 'Green Growth Framework for Fiji: Restoring the Balance in Development that is Sustainable for Our Future'.

I wish to commend SPREP and all those that participated in this study.

Ratu Wiliame Katonivere

Tui Macuata (Paramount Chief of Macuata Province)

EXECUTIVE SUMMARY

The ecosystem and socio-economic resilience analysis and mapping (ESRAM) is a baseline study to identify vulnerabilities in ecosystem services at national, provincial and community scales in Fiji. It provides a basis for the design of ecosystem-based adaptation options for climate change adaptation planning to strengthen climate resilience in the country. This report is an analysis at the *provincial scale*, with Macuata Province as the focal area. The emphasis on seeking the drivers of change that create vulnerabilities from both climate- and non-climate related forces.

This report emphasises the following:

- Macuata Province is a complex area that covers many connected landscapes that transcend political boundaries into neighbouring provinces, and require true ridge-to-reef (watershed) management approaches and effective governance to do so.
- The Great Sea Reef is among the most important of the world and extends the length of Macuata Province, providing vital marine resources; serious challenges exist for sustainable management associated with harvest and mitigation of land-derived pollutants.
- Climate change is expected to increase air and sea temperatures, increase sea levels and increase levels of ocean acidification – rainfall is likely to be more intensive, followed by periods of drought.
- Industrial agriculture is a key economic driver for the Provincial economy and the country, supplying 35 per cent of Fiji's sugarcane industry. Climate change impacts affecting rainfall and temperature may directly affect productivity.
- Sugarcane plantations and development areas have displaced mangrove and coastal wetland areas, lowering the capacity for flood and storm water mitigation, and for attenuating land-derived pollutants to the marine environment.
- The Macuata Natural Resource Management Strategy requires updating and climate resilience components require strengthening.
- Significant opportunities exist for developing new, island-wide natural resource strategies that manage for ecosystem function in connected landscapes. It is proposed that this approach be piloted using the traditional Qoliqoli Cokovata fishing grounds, incorporating the watersheds draining into it and recognising the need for cross-border governance.

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 for the Environment, Nature Conservation and Nuclear Safety (BMU) through the International Climate Initiative (IKI) 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 project (PEBACC) is focused on identifying, prioritising and implementing EbA strategies to meet critical needs in three countries (Fiji, Vanuatu and Solomon Islands) at three different scales: national, provincial and a focused island scale.

The key objectives of the PEBACC project are 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 scale 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 successful approaches that should be considered for future policies in the host country and communities.

This report presents the provincial scale ESRAM synthesis for Macuata Province on Vanua Levu, Fiji. The goals of this provincial-scale synthesis are: (i) to capture the current condition, potential future conditions and ecosystem services that are important at large landscapes; (ii) identify the vulnerable resources and the stressors or additional factors (forces) – both climate change and local activities – that threaten ecosystem services; and (iii) identify an options development pathway that will potentially increase resilience to local and global trends that threaten critical ecosystem services and livelihoods in Macuata Province.

Although the focus is within the Macuata Provincial boundary, many of the watersheds extend upward beyond the provincial boundary into neighbouring Cakaudrove and Bua Provinces, and require a 'ridge-to-reef' approach to evaluate connectivity and potential sources contributing to vulnerability, regardless of the political or administrative boundary. In contrast, questions pertaining to infrastructure at risk, economic considerations, and other potential activities, may be limited to the area within the provincial boundary. In many cases, due to data availability and inconsistencies in area represented by different datasets, the Macuata analyses are largely relegated to areas on mainland Vanua Levu and do not necessarily include the off-shore islands. Due to the size and complexities of Macuata Province, the analyses are focused on how Macuata contributes to the whole of Fiji, as well as how this large land area, with its complex structures of communities and government, functions to support the larger population and economic concerns.

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 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 people 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. The population is growing slightly, with all growth occurring in the urban population.

Fiji lies within the Archipelagic Deep Basins Province and has more than 332 islands, a third of which are inhabited. Fiji's vast marine EEZ (exclusive economic zone) is 1.3 million km^2 in size. Approximately 40 per cent 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.

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.

1.3 ESRAM METHODS

As a consolidation document, efforts were made to gather existing spatial and quantitative data from a wide range of governmental and non-governmental organisations (NGOs) working in Fiji. This resulted in some summary information with spatial data associated for Macuata Province, but not across all sectors. Further, information gathered was evaluated as to completeness, versioning and other best available science. Interviews with natural resource professionals across sectors provided additional information and clarity, or helped to identify key gaps in understandings of trends, available data and capacity.

Locally-based information was obtained from government officials and NGOs based in Suva and Labasa that had focus areas in Macuata Province; emphasis of available capacity specifically provided information about marine populations and environments and, where available, trends in climate, infrastructure and land management activities.

In general, there are no central information clearinghouses that store natural resource information that cross sectors (e.g. agriculture, forestry, fisheries, water quality, etc.), although there are efforts under way with the office of the Commissioner Northern to consolidate across sectors in the Northern Division – a critical element in managing for connected landscapes that cross administrative boundaries. Efforts by NGOs have relied on close collaboration and have been particularly strong with spatial data, planning, reporting and collaboration within the province.

Local government officials are located mostly in Labasa. They cover a wide range of issues across Macuata Province, which is large and diverse. Visiting all areas on a regular basis is a challenge because of poor transportation. To investigate the capacity to manage across provincial boundaries, additional interviews and efforts were made to identify consolidating points within the Cakaudrove Provincial seat of Savusavu. Coordination was via the divisional office of the Commissioner Northern, which is a logical hub for consolidation of data resources – a recommended strategy that emerged from this ESRAM.

Stakeholder profiles began with the government at national, provincial and district scales to introduce the PEBACC project and solicit direction from different natural resource departments, including iTaukei affairs.

Workshops were held in a central setting (Labasa) and were attended by mostly NGOs and other project-level operators within the province. There are significant activities occurring in Macuata Province that extend into the upper watersheds of Cakaudrove Province. Efforts are under way to coordinate project-level activities, although significant challenges exist with coordination of efforts, goals and objectives, and an overall 'plan' that can be conducted to meet common objectives.

Data sources included published and non-published reports, as well as available spatial (GIS) and tabular data. While many of the datasets presented here include spatial (area) information by categories, 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, or through legacies of GIS analysis. 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.

While every effort was made to obtain the best available background data during the timespan of this phase of the PEBACC project (June 2016–July 2017), the data (and derived analysis products) may not represent the most recent or accurate representation of the current condition. As such, this ESRAM document, like many of its kind, is designed to be updated as new information is gathered.

This ESRAM report summarises key background information required for the subsequent development of EbA activities for Macuata Province, the second PEBACC milestone: the Macuata EbA Options Assessment Report.

Timber mill at Malau with Labasa town in the distance. © Stuart Chape

Aerial view of Labasa town, Macuata Province with Nasuva Creek in the foreground and the Labasa River behind. © Stuart Chape

2. OVERVIEW OF MACUATA PROVINCE

2.1 GEOGRAPHY AND SOCIO-POLITICAL OVERVIEW

Macuata Province (Figure 1) is located on the north-west coast of Vanua Levu, and includes adjacent near-shore islands, totalling an area of 2,000 km^2. Macuata Province is divided into eleven districts, or tikina. The topography is mountainous to the south with wide coastal plains and river valleys, ranging from sea level to 920 metres. The southern boundary with adjacent Cakaudrove Province generally follows the crest of the island, but there are several areas where the boundary crosses south of the crest, or where Cakaudrove Province extends northward into catchments (watersheds) that drain through Macuata Province, resulting in watersheds that cross provincial and administrative boundaries.

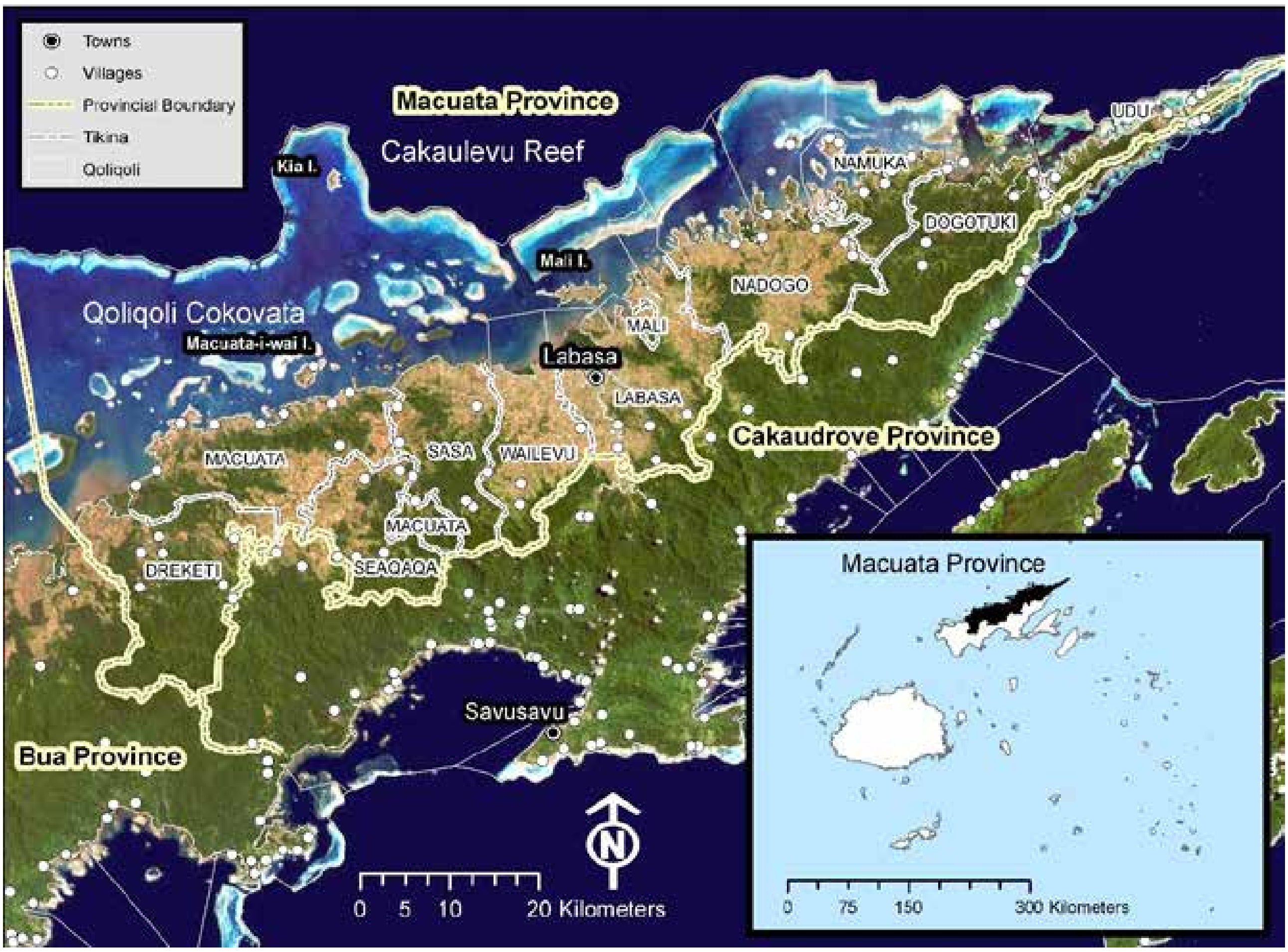


FIGURE 1. Map of Macuata Province with provincial and tikina (district) boundaries.

Vanua Levu is a much younger island than Fiji's main island of Viti Levu, approximately 7 million years old, consisting of sandstone, marl, and volcanic terrains (Neall and Trewick 2008; Phillips 1965). Soils are dominated by clays (92 per cent) (Seru and Leslie 1986; Leslie and Seru 1998). Approximately 30 per cent of the mapped soils are classed as arable lands. Approximately 15 per cent of the area is classified as poorly drained soils, clustered around Labasa and coastal areas. Sugarcane is the principal crop (Leslie 2012).

Fiji, like most of the world, is urbanising. Fiji's population is growing overall, with all growth appearing in the urban population while the rural population is relatively stable (Figure 2). Macuata Province is generally more rural than Fiji overall. Higher portions of youth and the elderly reside in rural areas, while working age populations are concentrated in urban areas. Overall age distribution is skewed towards youth in Fiji as a whole, and for Macuata Province in particular (Figure 3). This suggests that population decline is unlikely to be a challenge nationally, but might present issues in rural-dominated areas such as Macuata Province, if younger populations move to more urban parts of Fiji.

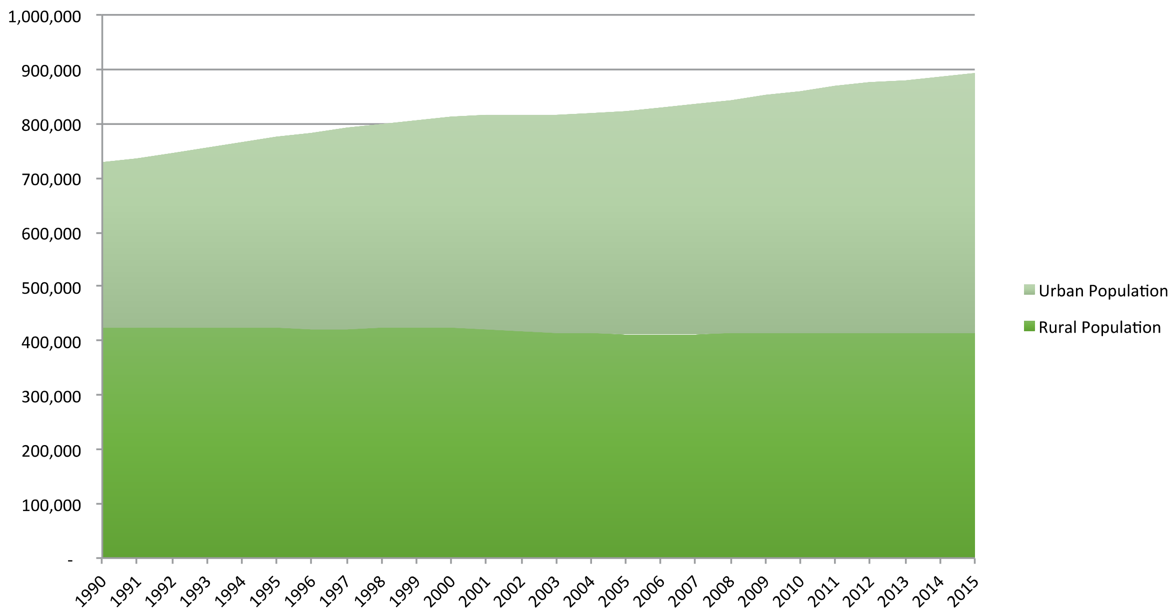


FIGURE 2. Fiji population, urban and rural, 1990-2015. Source: FAOSTAT 2016.

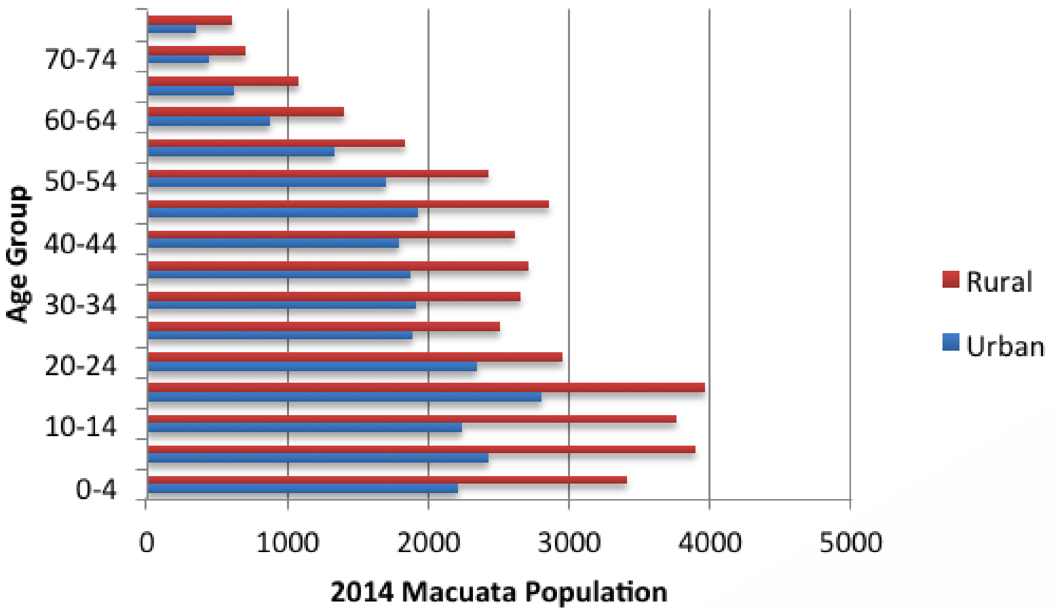


FIGURE 3. Macuata Province population by age group. 2014. Source: Fiji Bureau of Statistics.

2.2 MACUATA PROVINCE FOCUS AREA

While the scope of this ESRAM is to focus on the area within the Macuata provincial boundaries, administrative boundaries do not adequately describe or contain connected (e.g. 'ridge-to-reef') landscapes. There are 30 catchments, or watersheds, that are wholly or partially in Macuata Province (Figure 4). Catchments range in size from small (<10 km^2) coastal catchments to the 850 km^2 Dreketi River (Table 1). Overall, this contributing area encompasses ~3,000 km^2, of which only ~2,000 km^2 are within the Macuata provincial boundary. Many catchments cross boundaries into neighbouring provinces. Combined, the three largest major river systems in Macuata Province (Dreketi, Labasa and Nasavu Rivers) contain 64 per cent of the land area of the province, yet more than half (57 per cent) of the watershed areas are outside the provincial boundary. In contrast, only the headwaters of the Sarowaqa and Wainunu Rivers are within Macuata Province; the bulk of these catchments are located within Bua Province. Only 17 watersheds representing 19 per cent (~550 km^2) of the contributing area are within Macuata Province. Tikinas follow provincial boundaries, although they generally cross the physical principal watershed boundaries. Management of connected landscapes in true 'ridge-to-reef' fashion underscores the need and usefulness to cross administrative and ownership boundaries.

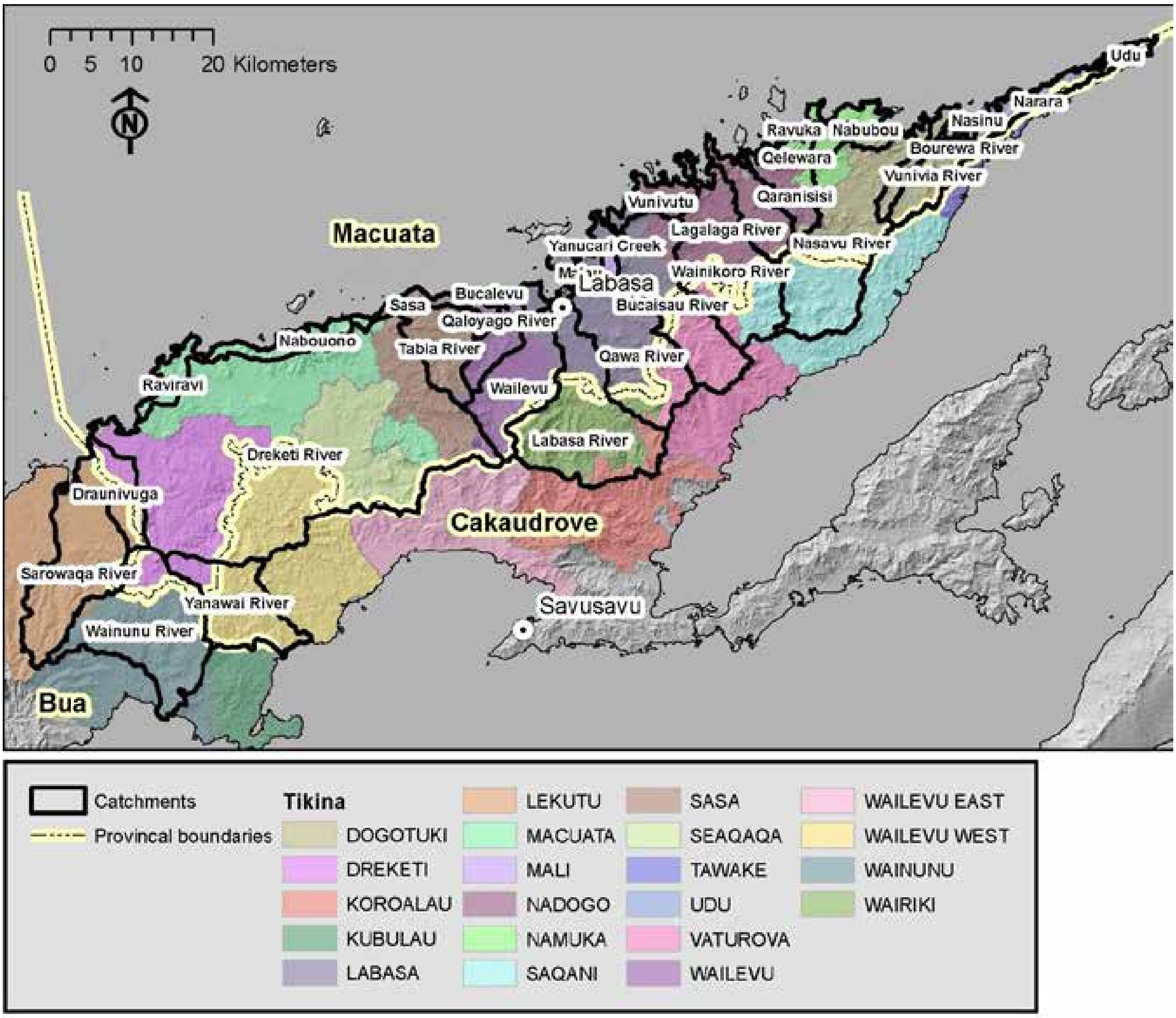


FIGURE 4. Catchments and tikina associated with Macuata Province. Catchment areas cross multiple administrative boundaries.

TABLE 1. Catchment area and proportion of total area by tikina for the connected landscapes of the Macuata focus area.

Catchment		Macuata Province											Cakaudrove Province							Bua Province		
	Area (km^2)	Dogotuki	Dreketi	Labasa	Macuata	Mali	Nadogo	Namuka	Sasa	Seaqaqa	Udu	Wailevu	Koroalau	Saqani	Tawake	Vaturova	Wailevu East	Wailevu West	Wairiki	Kubulau	Lekutu	Wainunu
Bourewa River	21.1	100%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bucaisau River	150.9	-	-	39%	-	<1%	15%	-	-	-	-	-	-	-	-	46%	-	-	-	-	-	-
Bucalevu	9.7	-	-	-	-	-	-	-	<1%	-	-	100%	-	-	-	-	-	-	-	-	-	-
Draunivuga	57.7	-	47%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	53%	-
Dreketi River	849.3	-	26%	-	27%	-	-	-	11%	19%	-	1%	-	-	-	-	<1%	16%	-	-	-	-
Labasa River	206.6	-	-	23%	-	-	-	-	-	-	-	<1%	13%	-	-	<1%	<1%	-	64%	-	-	-
Lagalaga River	59.0	<1%	-	-	-	-	100%	-	-	-	-	-	-	<1%	-	-	-	-	-	-	-	-
Malau	24.0	-	-	97%	-	3%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nabouono	19.9	-	-	-	100%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nabubou	27.1	52%	-	-	-	-	-	48%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Narara	31.8	-	-	-	-	-	-	-	-	-	97%	-	-	-	3%	-	-	-	-	-	-	-
Nasavu River	218.7	51%	-	-	-	-	1%	8%	-	-	-	-	-	40%	-	-	-	-	-	-	-	-
Nasinu	10.6	57%	-	-	-	-	-	-	-	-	43%	-	-	-	1%	-	-	-	-	-	-	-
Qaloyago River	41.1	-	-	-	-	-	-	-	<1%	-	-	100%	-	-	-	-	-	-	-	-	-	-
Qaranisisi	47.7	5%	-	-	-	-	75%	20%	-	-	-	-	-	<1%	-	-	-	-	-	-	-	-
Qawa River	152.0	-	-	66%	-	-	-	-	-	-	-	-	2%	-	-	22%	-	-	9%	-	-	-
Qelewara	24.5	-	-	-	-	-	14%	86%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Raviravi	44.5	-	-	-	100%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ravuka	15.8	<1%	-	-	-	-	-	100%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sarowaqa River	155.1	-	2%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	98%	<1%
Sasa	18.6	-	-	-	18%	-	-	-	82%	-	-	-	-	-	-	-	-	-	-	-	-	-
Tabia River	76.5	-	-	-	-	-	-	-	93%	-	-	7%	-	-	-	-	-	-	-	-	-	-
Udu	10.8	-	-	-	-	-	-	-	-	-	80%	-	-	-	20%	-	-	-	-	-	-	-
Vunivia River	56.3	100%	-	-	-	-	-	-	-	-	-	-	-	<1%	<1%	-	-	-	-	-	-	-
Vunivutu	39.3	-	-	17%	-	-	83%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Wailevu	114.8	-	-	16%	-	-	-	-	-	-	-	79%	-	-	-	-	<1%	-	4%	-	-	-
Wainikoro River	171.8	-	-	<1%	-	-	58%	-	-	-	-	-	-	25%	-	17%	-	-	-	-	-	-
Wainunu River	198.0	-	16%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	<1%	-	1%	4%	79%
Yanawai River	104.9	-	18%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	80%	-	1%	-	<1%
Yanucari Creek	16.1	-	-	51%	-	49%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Area	**2,974**	**211**	**302**	**263**	**297**	**9**	**255**	**77**	**180**	**161**	**44**	**155**	**30**	**130**	**3**	**132**	**<1**	**220**	**150**	**3**	**190**	**156**

2.3 LAND TENURE

Land use and land stewardship, follows land tenure practices. As elsewhere in the Pacific region, Fiji has had a long history of traditional, or customary (iTaukei), land ownership, 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 among 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. Freehold lands have shifted in ownership over time to include iTaukei owners, as well as non-indigenous Fijians, foreign residents and corporations.

The land ownership distribution within the 30 watersheds on Vanua Levu selected as part of the Macuata Province focus area are 91 per cent in iTaukei lands, with 7 per cent and 2 per cent in freehold and state lands, respectively (Figure 5; Table 2). The majority of the state land occurs in the Wailevu and Qawa River watersheds, mostly supporting small lot sugarcane plantations.

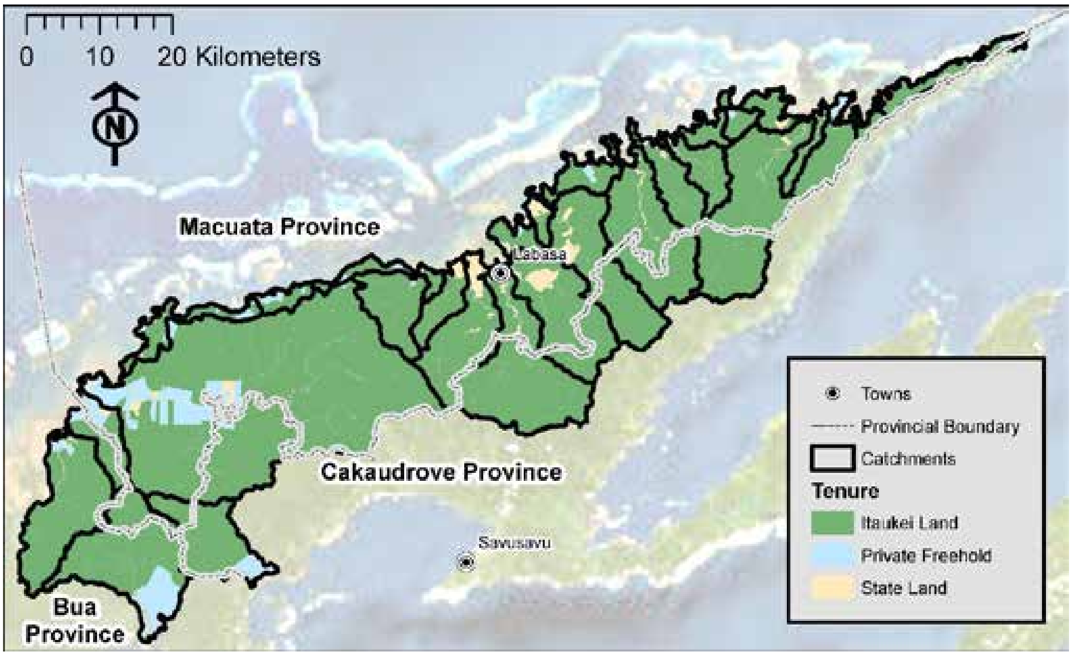


FIGURE 5. Land ownership and distribution within the Macuata Province focus area.

A farming community in Labasa, Macuata Province. Photo: PEBACC-SPREP

TABLE 2. Land ownership and distribution within the Macuata Province focus area by catchment

Catchment	Itaukei Land	State Land	Private Freehold	Catchment	Itaukei Land	State Land	Private Freehold
Bourewa River	92%	-	8%	Qawa River	94%	6%	<1%
Bucaisau River	96%	4%	<1%	Qelewara	96%	1%	3%
Bucalevu	91%	-	9%	Raviravi	78%	-	22%
Draunivuga	73%	3%	24%	Ravuka	89%	-	11%
Dreketi River	90%	1%	9%	Sarowaqa River	97%	<1%	3%
Labasa River	99%	1%	<1%	Sasa	76%	-	24%
Lagalaga River	99%	-	1%	Tabia River	98%	-	2%
Malau	86%	6%	8%	Udu	48%	-	52%
Nabouono	72%	<1%	28%	Vunivia River	89%	-	11%
Nabubou	91%	9%	-	Vunivutu	93%	<1%	7%
Narara	100%	-	-	Wailevu	91%	9%	-
Nasavu River	100%	<1%	-	Wainikoro River	100%	-	-
Nasinu	100%	-	-	Wainunu River	81%	-	19%
Qaloyago River	90%	10%	-	Yanawai River	89%	-	11%
Qaranisisi	100%	<1%	-	Yanucari Creek	57%	31%	13%

*Land areas of <1% are legacy aspects of GIS analysis and are retained for continuity.

Complicating matters of land ownership and land use is the practice of land leasing, where leases can be established, some for brief periods and others 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. Most agricultural leases in Macuata Province and 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 up to a century ago through agreements with corporations. This is a common practice across Fiji, although in recent times there has been some specificity as to the activities allowed for the land leases that extend to environmental safeguards (e.g. land clearing rules, planting objectives, adherence to natural resource management plans, etc.).

Incorporating conservation tactics and environmental safeguards for leases is an important and workable mechanism to improve degraded landscapes and seascapes, while also diversifying incomes away from extraction-based activities (e.g. farming, forestry and fishing). Additional safeguards relating to community-driven priorities for connected landscapes (such as watersheds and qoliqoli) for local management are also important mechanisms for developing long-term goals and increased stewardship in Macuata Province. These have been incorporated to some extent by the Macuata Province Natural Resource Management Strategy, where priorities are identified to improve capacity and safeguarding of resources through activities. In addition, safeguards in the marine environment include the establishment of temporary or permanent tabu areas, as well as fishing guidelines to prevent overfishing (e.g. no night fishing in certain areas, a ban on underwater breathing apparatus).

2.4 DRIVERS IN THE FORMATION OF TODAY'S LANDSCAPE

In recent years, there have been increasing social and economic demands on the local natural resources of Macuata Province, in part due to the government's 'Look North Policy' for major infrastructural developments and increased economic investments that allow for a streamlined development process involving landowners. This has led to an increasing trend of investments in projects such as mining, logging, tourism, agriculture and fisheries across the province. Concurrent with, and perhaps in response to, the boom of activity has been a rise in interest from donor-funded implementing organisations that have had a natural resource adaptation focus, largely aimed at the topics of sustainability, conservation and capacity building. They have implemented pilot projects over a range of themes: fisheries, coastal management, forestry, forest carbon, climate change resilience, adaptation, land management, agriculture, and green infrastructure.

Population growth rates in the recent decade have been negative overall (between 6.5 and 17.5 per cent decline), with the decline at least partially due to conversion of agricultural land leases back to traditional landowners, resulting in a displacement of non-iTaukei people from small lot farms, mostly in one of three ways: migration to Suva, migration to find agricultural solutions elsewhere (including Taveuni Island[1]), or consolidation into local, informal settlements in Macuata Province. These informal settlements are often located along the major transport routes, including the rivers and roadways, and are expanding into native forests, mangroves and critical riparian areas. These settlements lack basic services, including access to clean water, wastewater treatment or disposal, and protection from climate extremes (e.g. flooding, drought). Rural drift in search for subsistence livelihoods is widely distributed and extensive in the province, particularly in low-lying areas, and is a primary source of environmental degradation that affects terrestrial, aquatic, and marine resources.

A recent and ongoing study by the Fiji Government Climate Change Division gauged the perceptions of villagers throughout the province on topics such as ecosystem health, institutions and governance, financial and human resources, and the community's capacity to adapt and respond to past, present and future disasters and climate extremes. Included with ecosystem health were issues of forest health, coastal ecosystem integrity, and watershed health, with the perspective of short-term and long-term livelihoods. Categories were ranked on a scale of one to five, with one indicating community resilience at its lowest and five at its highest. Overall, communities in the 99 villages surveyed gauged the capacity of their environmental resources at a mean value of 3.07 and a range of two to 4.75. There was generally poor agreement among communities about any primary concerns for environmental resilience, but community perception for ecosystem health, watershed health and coastal resource health scored slightly below average (~2.5) in providing for future ecosystem services.

Most households in Macuata Province are subsistence-based, depending heavily on ecosystem services for water and food provisions, shelter, income generation and overall health and well-being. The ability of these ecosystems to continue to provide essential services is decreasing through activities such as small- and large-scale agricultural production leading to nutrient-poor soils, degradation of water bodies in marine and freshwater areas, and over-exploitation of marine, mineral and forest resources. Many traditional Fijian villages are located along riparian areas within watersheds or distributed along the low-lying coastal zone. As climate extremes increase in intensity, frequency, distribution and magnitude, detrimental impacts on local communities and economies of Macuata Province are anticipated to increase. Climate change outcomes that are projected to have the broadest impact on ecosystem services are an increase in air and sea temperature and associated ocean acidification and coral bleaching, an increase in extreme rainfall events (storms and droughts), and sea-level rise (see Section 3).

Vanua Levu has experienced several recent climate change trends, including extended drought periods, which greatly affected access to drinking water and subsistence agricultural production. Small farms have been unable to meet demands in local markets, resulting in loss of revenue for families and shortages in diversified diets. In the past few decades, Fiji has been affected by multiple devastating cyclones. In 2012 alone, Fiji

[1] See PEBACC reports for Taveuni Island.

experienced two major flooding events and one tropical cyclone (Evan), and frequent flooding events have affected Labasa and other low-lying areas on many occasions in recent years. The effects of natural disasters in Fiji are far-reaching and negatively impact agriculture, housing, transport infrastructure, tourism and primary industries, among other sectors. Increased intensity and duration of climate extremes has greatly affected the urban areas and local economies, and has largely resulted in 'reactive' rather than 'proactive' management responses to mitigate the effects.

Removal of reported forest cover, through logging operations, mining preparations and agricultural conversion, has been documented recently as ~1,570 ha for the time period between August 2016 and July 2017 (Department of Forests) for the Northern Division, with 760 ha documented as removed in Macuata Province. Only 40 ha have been replanted following this recorded period (5 per cent replanted), with only 144 ha replanted (9 per cent) in total over the three provinces in the Northern Division. Given the connected landscapes of Macuata Province that extend beyond provincial boundaries, and the fact that most forested environments are generally located in the upper elevations, it is important to recognise that activities in headwater areas outside the Macuata provincial boundaries can have downstream effects due to land uses that directly affect Macuata communities. Within Macuata Province, land use / land cover changes within smaller watersheds that are within short distances of the coastal environment can have emphasised effects on marine reef communities, as there are fewer opportunities for attenuation of sediments, nutrients, and other run-off.

Changes in forest cover are not known across the province, as these are generally small in scale and only observable through remote sensing or direct ground-based survey inventories.

The marine environment is bound by the Great Sea Reef, locally known as *Cakaulevu*, the third largest continuous barrier reef in the southern hemisphere, and provides substantial fishing resources to Macuata Province. The traditional fishing grounds *(*qoliqoli*)* provide for roughly 75,000 people in the province, many of whom are rural, indigenous and spread across 37 villages; approximately 4,000 people live adjacent to their qoliqoli. Over time, the Macuata qoliqoli have been exposed to increasing fishing pressures from both local subsistence and Labasa- and Suva-based commercial fisheries operators for export, largely to Suva. For many years, there has been significant outside project support to work with communities, the government, and industry to increase scrutiny of fisheries practices. These have included the establishment of permanent and temporary no catch *(*tabu*)* areas, monitoring strategies, and marine protected areas (MPAs) that package a range of marine conservation activities. Regulation of fisheries resources in any context represents significant challenges, including managing for subsistence, traditional ownership, rights to local control and self-regulation, government capacity and enforcement, and adjustment to national priorities. Inclusion of communities and activities in upstream (terrestrial) environments is less prevalent and represents a gap in ridge-to-reef management.

The most critical issue facing coastal and marine ecosystem services is over-exploitation of reef fish and marine invertebrates. Fiji is at a critical juncture in policy implementation to preserve coastal and marine ecosystems and increase their resilience to climate change and human uses. Excessive harvesting of fish and invertebrates, combined with pollution, soil erosion, and land-based run-off (sediment, wastewater, etc.) has led to a degraded marine habitat state, and has created a crisis in Fijian fisheries. Communities are highly dependent on local marine resources for subsistence. Overfishing is prevalent and on the rise in both near-shore and deep-water fisheries. Sea turtle nesting has declined dramatically, giant clams are locally extinct in most places and two species no longer occur in Fiji, and large and important near-shore fish species are now uncommon.

In response to this crisis, the Ministry of Fisheries committed Fiji to protection of groupers and coral trout at the worldwide United Nations Ocean Conference in 2017, by way of fishing bans, market bans during spawning season, and habitat protection via MPAs. Inclusion of the Macuata Qoliqoli Cokovata as a protected site under the Ramsar Convention on Wetlands of International Importance is under way, 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 thereby improve the ability to adapt to climate extremes and population pressures.

Management for ecosystem resilience at the provincial scale has emerged in recent years with the development of a Natural Resource Management Strategy (NRMS) for Macuata Province, which provides for consolidating action items to build capacity and improve ecosystem services. However, the capacity within the local provincial government has experienced many challenges, including integrating best management practices across sectors, provision of human resources and funding for operating and implementing the plan, and management of connected landscapes that fall under other provincial or local tikina jurisdictions. The current Macuata Province NRMS is scheduled to expire in 2018.

2.5 MARINE RESOURCES

The Great Sea Reef (GSR) stretches over 200 km along the northern coast of Vanua Levu westward to the Yasawa Island chain, crossing four provincial boundaries and containing ten customary fishing rights areas *(qoliqoli).* The GSR is the most expansive in Fiji, encompassing over 200,000 km^2, and is the third longest continuous barrier reef system in the world. The reef has exceptional marine biodiversity and endemism: 55 per cent of known coral reef fishes, 74 per cent of known coral species, 40 per cent of known marine flora and 44 per cent of Fiji's endemic reef fish species (Heaps 2005). In 2003, the Fiji Island Marine Eco-region process identified the GSR as an area of Global Significance in terms of biodiversity. It contains the highest number of species found on any reef in Fiji. The coast of Macuata Province contains extensive areas of deep lagoon, seagrass patches and various types of reef environment (Figure 6).

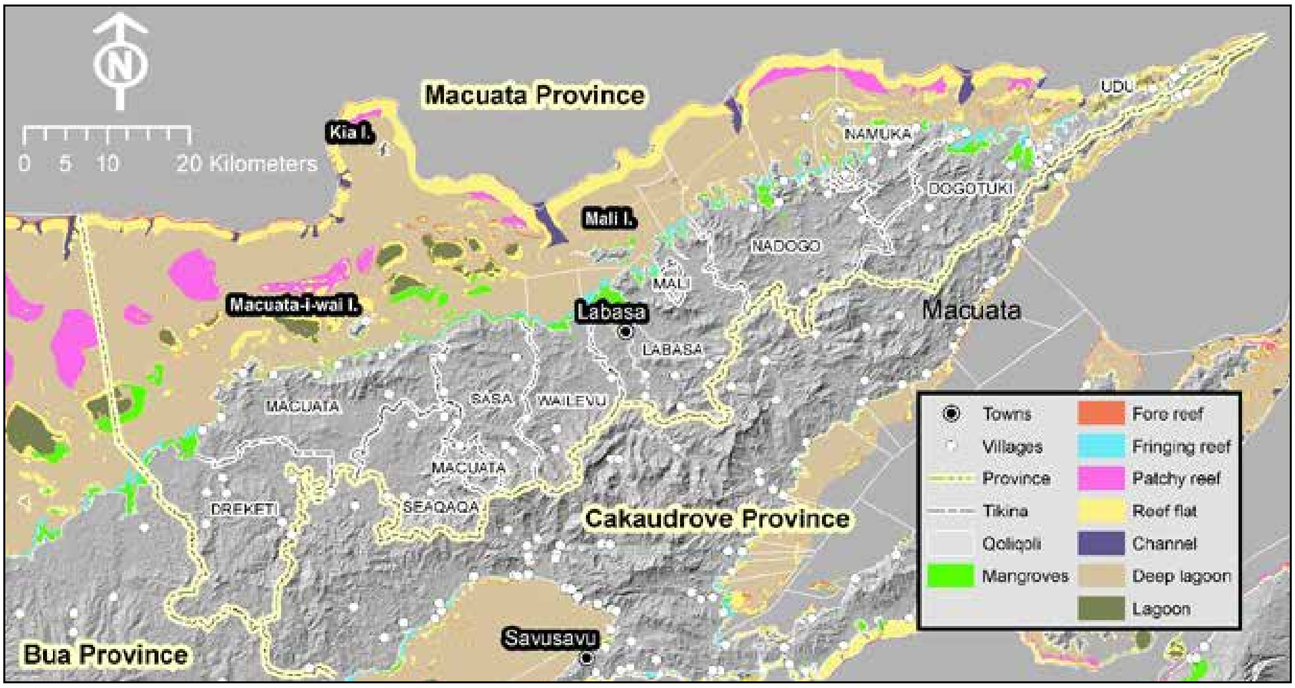


FIGURE 6. Macuata reef complexes, mangrove complexes, and traditional fishing grounds (qoliqoli).

Within the GSR is the Qoliqoli Cokovata (Figure 7). The Qoliqoli Cokovata is adjacent to the four districts of Dreketi, Macuata, Sasa and Mali, which collectively retain custodial ownership of the fishing grounds. Qoliqoli Cokovata covers a marine area of 1,349 km^2, with an upland direct impact area (i.e. catchments draining directly into the marine area) of an additional 1,878 km^2, 24 per cent of which is in Cakaudrove Province and 2 per cent in Bua Province (see Section 5.2).

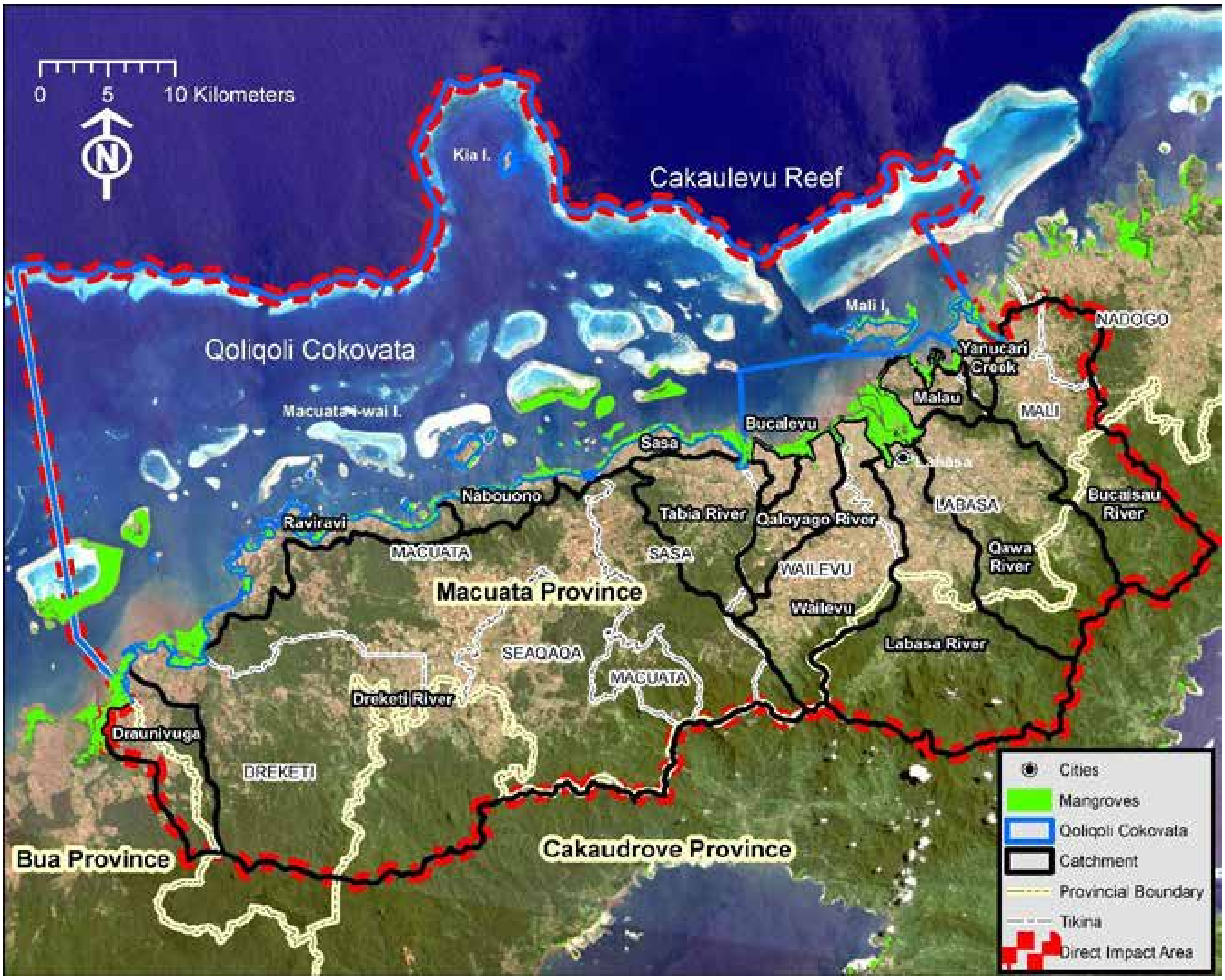


FIGURE 7. Map of Qoliqoli Cokovata and river catchments discharging into it.

The Qoliqoli Cokovata is a complex system of submerged and emergent coral reefs, mangrove and rocky islands, seagrass beds and other marine ecosystems. The Qoliqoli Cokovata habitats provide substantial fisheries resources and are also home to 12 species on the IUCN red list, including the Napoleon wrasse (*Cheilinus undulatus*), green and hawksbill turtles (*Chelonia mydas* and *Eretmochelys imbricata*) and spinner dolphins (*Stenella longiros*) (Heaps 2005). Mali, Kia and Macuata-i-wai are the primary inhabited islands (Figure 7).

The coastal and island mangroves (Figure 7), which are the third largest in the country, are culturally and economically linked to the livelihoods of Macuata's largely rural population, and serve important geophysical functions of shoreline stabilisation, preventing wave damage to villages. They also act as sediment and pollutant filters for coastal areas, and provide essential nursery areas for various organisms that inhabit the near-shore marine systems (Bolabola *et al.* 2006). Significant seagrass meadows are known to surround the coral/mangrove islets. Macuata Province also has four major river systems that drain into the sea (some with industrial activities nearby). They exert considerable influence on the composition and quality of coastal habitats via effluent of nutrients, sediment, wastewater, and solid waste disposal.

The condition of Macuata's marine resources is generally considered better than on Viti Levu, but overall marine resource health and extent are declining and degrading, as fishing pressures increase. Surveys from the locally managed marine areas (LMMA) within the near-shore reef areas show declines in important invertebrate and fish resources over time. Areas that are closer to export locations, including Labasa, are generally in worse condition than areas that are more remote. Habitat degradation of mangroves, seagrass and coral reefs is evident, particularly close to large rivers and streams that transport sediment and pollutants (see Section 4.1.3). The condition of Macuata's coastal and marine habitats suggest a combination of factors affecting marine health:

- terrestrial run-off from widespread deforestation and land conversion to agriculture;
- exposed and poorly designed road networks contributing sediment plumes; and
- constant small-scale and commercial fishing pressures, leading to declines in coastal resources.

Local community members have noted that pressure on coral reef invertebrates and fishes appears to be increasing in recent years. Small-scale fishers who supply large-scale exporters are putting constant pressure on Macuata coral reefs along the northern coast. Live-aboard vessels that house divers collect sea cucumbers, reef fishes and other high value target species for both the tourism and commercial sectors. The marine resources of the islands of Kia, Mali and others are generally in better condition, largely due to local community protective measures and limited access. In response to declines in giant clams, reef fish, sea cucumbers and sea turtles, a few areas have been designated or considered for protection.

There appears to be a growing and widespread understanding that land-based activities and overfishing affect fishing resources, and there is leadership momentum to create large and long-lasting sustainable fisheries areas. However, economic pressures, the need for food subsistence, complex ownerships, and a customary view of the 'sea as a provider' has deferred rapid progress. Increasing awareness of connected landscapes and linkages between land- and sea-based activities is important for improving total ecosystem health and sustainable livelihoods.

Reef fish for sale at the Labasa market. Photo: WPN/2016

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 temperature (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 coast, 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, however, 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). The prevailing south-east 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). Mean annual rainfall is less than 1,800 mm in leeward coastal areas and 3,500 mm or more in the mountains (Figure 8). Macuata Province is in the middle of the spectrum, ranging from 2,400 to 3,000 mm of annual rainfall, with highest amounts in the headwater areas, located largely in neighbouring Cakaudrove Province.

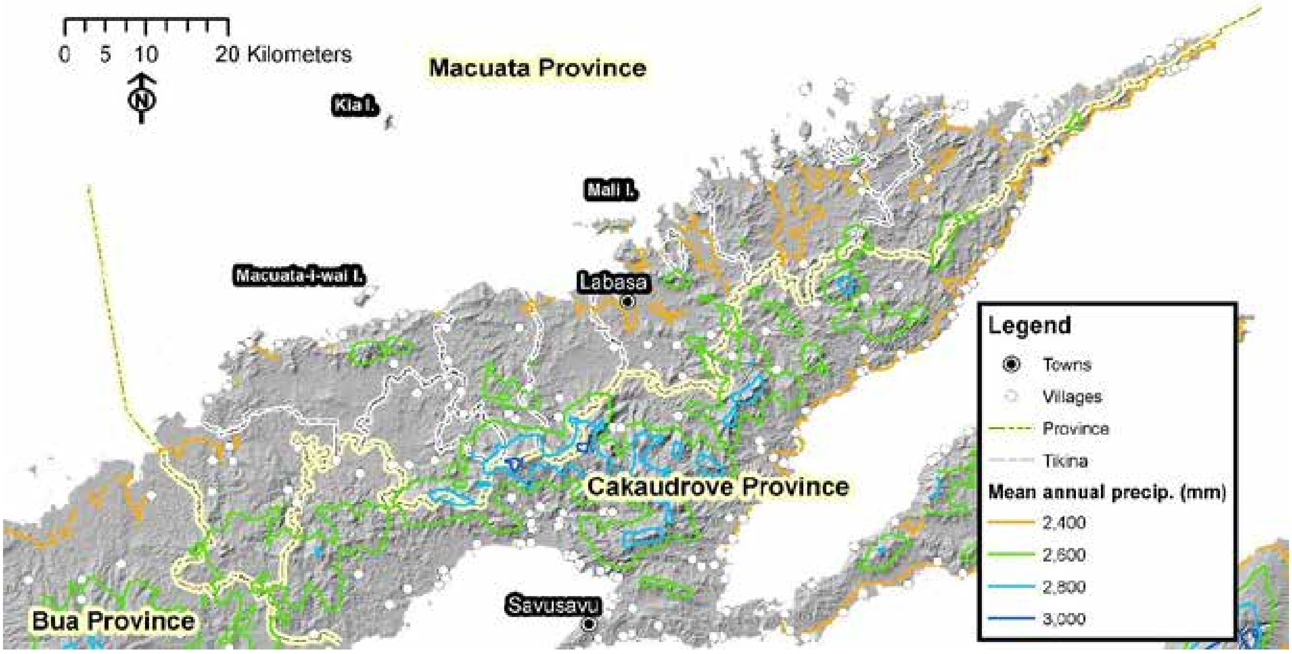


FIGURE 8. Mean annual precipitation isohyets for Vanua Levu. Source: Fiji Meteorological Service 2006.

Flooding is common in low-lying areas during most years (Govt. of Fiji, United Nations Development Programme 2014). Severe flooding is usually associated with periods of prolonged heavy rainfall from the passage of a tropical cyclone (TC) or depression. Most cities and large population centres on Vanua Levu (e.g. Labasa) 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 effects of drought 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. Macuata Province had relatively little damage compared to other provinces in Fiji, with few destroyed or disconnected houses and among the lowest declines in the quality of life index (<0.02) compared with Cakaudrove and Bua Provinces (0.22 to 0.26 decline) (Government of FIji 2016).

Yeo (2001) noted that the major rivers of Macuata are 'hydrologically independent', in that on many occasions major floods occurred in one catchment while only minor flooding occurred in adjacent catchments. This is due to the high spatial variability of rainfall and the relatively small size of catchments that may not experience nearby storms. For example, a large storm event in April 2000 produced only a minor flood event in the Labasa River, but was the largest in collective memory on the Lagalaga, Wainikoro, Bucaisau and Qawa rivers, and one of the largest on the Wainikoro River (Yeo 2010). The December 11–12, 1929 flooding was caused by a widespread and slow-moving hurricane. Floods were 'unprecedented' – the highest seen in several rivers, including the Labasa River and other parts of Macuata Province – with floodwaters reported to have extended 22.5 km inland at Labasa. There were six reported drownings (McGree *et al.* 2010).

For the period between 1840 and 2009 McGree *et al.* (2010) identified 'notable' flood events in the Labasa River in the following years: 1910 (Mar), 1912 (Jan), 1929 (Dec), 1950 (Feb), 1965 (Feb), 1986 (Dec), 1997 (Mar), 2003 (Jan), 2007 (Feb), and 2009 (Jan); approximately once every eleven years on average. More recently, flood events were noted in February 2016 as part of TC Winston, the most intense cyclone on record to affect Fiji, as well as single-day, high-intensity rainfall events in the weeks of April 2016 and, later, in March 2017.

3.2 CLIMATE CHANGE PROJECTIONS

The Pacific Climate Futures[2] Version web-based decision-support tool was used to characterise possible future climate conditions for Fiji. Pacific Climate Futures (PCF) were developed by the Australian Government through the Pacific Climate Change Science Program[3] and the Pacific-Australia Climate Change Science and Adaptation Planning[4] (PACCSAP) programme. Pacific Climate Futures 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[5] Fourth Assessment Report (CMIP3 models) and Fifth Assessment Report (CMIP5 models). For the purposes of this ESRAM, the scenarios were confined to the more recent CMIP5 results, which are available for up to 43 GCMs (depending on location and parameters of interest). Summary results are available for 13 time periods from 2030 to 2090 at five-year 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 the physical processes and components of the global climate system. Output values for all variables from a given model 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,

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

3 https://www.pacificclimatechangescience.org/

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

5 http://www.ipcc.ch/

how strong that consensus is, and what the outliers (least change, greatest change) might be. Given that the GCMs project 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 9 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.

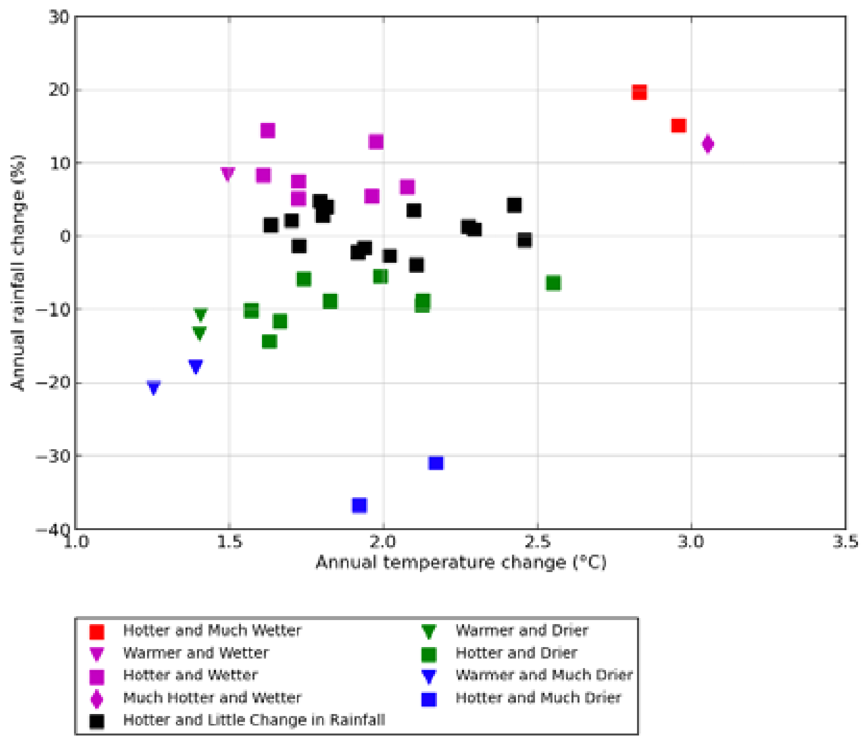


FIGURE 9. Projected mean annual change in rainfall (y-axis; expressed as a percentage) plotted against projected mean annual temperature change (x-axis; °C) for all 43 models for the period centered around the year 2070. Reproduced from Pacific Climate Futures web-based tool: (https://www.pacificclimatefutures.net/en/climate-futures/future-climate/).

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[6]) and smoothed values (smoothed GISS, Figure 10, 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[7]) and smoothed values (smoothed GPCP, Figure 10, bottom).

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

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

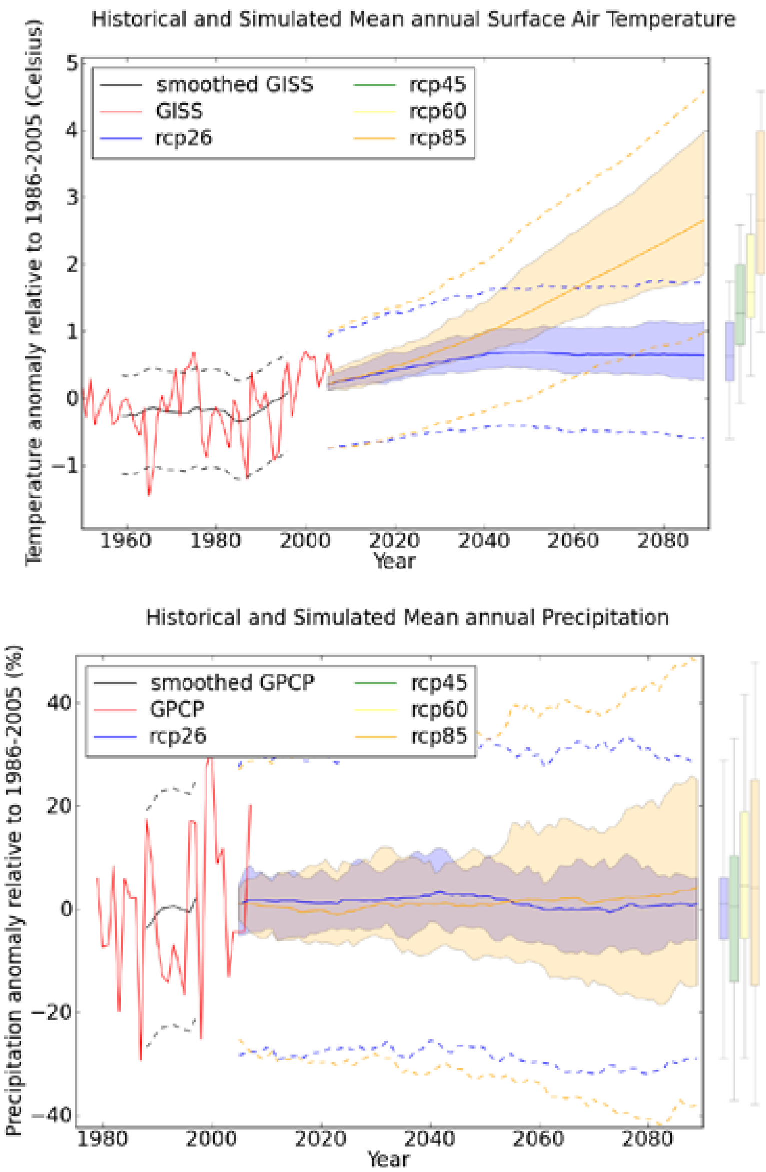


FIGURE 10. Historical and simulated mean annual surface air temperature (top) and precipitation (bottom) for Fiji. Reproduced from Pacific Climate Futures web site (https://www.pacificclimatefutures.net/en/climate-futures/future-climate/).

The future time series plots shown in Figure 10 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 is shown for the four projections to the right of the graphs.

3.3 SUMMARY OF CLIMATE TRENDS AND PROJECTIONS FOR FIJI

The Pacific-Australia Climate Change Science and Adaptation Planning (PACCSAP 2014) 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 (2014) 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 the following.

- 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).

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 from 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 summarised by thematic groupings:

- marine vulnerabilities;
- freshwater vulnerabilities;
- agricultural systems;
- terrestrial ecosystems;
- transportation and energy; and
- ecosystem service values.

4.1 MARINE VULNERABILITIES

Generally, the marine resources in Macuata Province are increasingly threatened by human-based causes, notably commercial level fishing from off-island operators (Bell *et al*. 2011; Gillet *et al*. 2016). In combination with the additive stressors of climate change and extremes, and increasing inputs from non-point source pollutants from terrestrial land practices, the marine ecosystems around Macuata Province are degrading and experiencing declines (Bell *et al.* 2011, Gillet *et al*. 2016). Table 3 provides a synthesis of the additive and climatic forces that contribute generally to vulnerabilities of marine ecosystems in Macuata Province. Where available, specific locations for each vulnerable condition are discussed in this section. The principal climatic forces threatening Macuata marine resources include temperature and sea level fluxes, storm intensities, and ocean acidification.

TABLE 3. Summary of forces of change creating vulnerable conditions with marine resources

Climate Forces	Additive Forces	Vulnerable Conditions
Storm frequency and intensity	Overfishing/Overharvesting	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	
	Use-related damage	

4.1.1 Coral reef health and extent

Coral reefs are vulnerable to local conditions across the province, primarily due to terrestrial run-off from agricultural practices on land and from commercial level overfishing, as demand for seafood exports increases within the region (Chin *et al*. 2011). Ocean warming and acidification from rising dissolved carbon dioxide (CO_2) are widely considered the greatest threat to coral reefs globally, and Macuata is no exception (Clarke *et al.* 2011; Ellison and Fiu 2010). The coral reefs of Fiji are comparatively resilient to perturbation, 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.

The qoliqoli within the province are exposed to increasing fishing pressures from both internal and external activities, from commercial fishing vessels originating outside the area (including small boats from Suva), conversion of mangroves to agricultural lands, degradation and isolation of mangroves along the Labasa River delta, and sediment/nutrient pulses from land-based erosion and agricultural practices.

Coral reef habitats located offshore around the coral/mangrove islets are generally in a better condition than those closer to the mainland (Cumming *et al*. 2002). Within Macuata qoliqoli, 2 km from shore lies the Mali District (Figure 6), which has six tabu areas, and consists of four villages (Matailabas, Vesi, Nakawaga, and Ligaulevu) with 65 households and 317 people (Figure 11). Residents are largely dependent on fishing for subsistence and the main source of protein.

Cakau Vuata tabu was established in 2004, and includes 10 km^2 of Vuata reef (Figure 11). This reef is a matrix of fringing and patch reefs, many of which are exposed during low tides, interspersed with seagrass and sandy patches. Deladravu and Bulewa Vula tabu areas were established to protect important food species – *kawakawa* and *donu* (grouper) – spawning aggregation sites (Sadovy and Batibasaga 2006). The northern portion, Vesi village on the north-eastern portion of Mali, contains dense mangrove forests. Overlooking four of the qoliqoli tabu areas, a watchtower was built on the cliff to enforce no fishing rules near the Mali Passage.

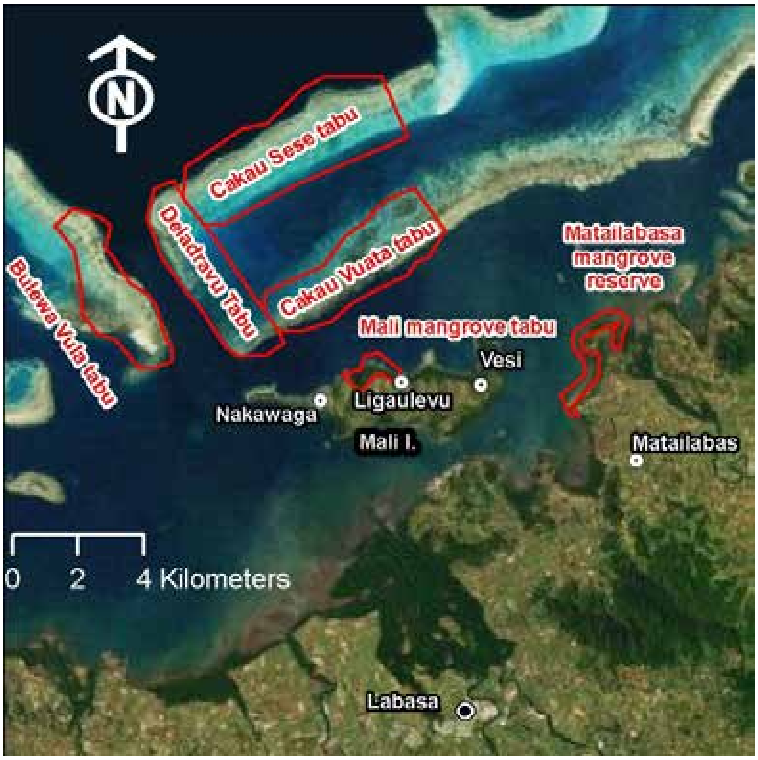


FIGURE 11. Cakau Vuata tabu was established in 2004, and includes 10 km^2 of Vuata reef.

The 2014 Macuata Province Natural Resource Management Strategy (NRMS) identifies a number of high priority activities, including awareness training for local communities, training for fish wardens, mapping of tabu areas, and best management practices for agriculture, which will require an estimated FJD 2 million over five years to implement. Recent measures by Macuata show some promising signs towards sustainable management. The Qoliqoli Cokovata (see Figure 7) Management Committee of Macuata Province has banned the catch of *kasala* fish (camouflage grouper). Fishermen who apply for fishing licenses in the districts of Mali, Macuata, Sasa and Dreketi will not be allowed to catch the *kasala* species for a month following license issuance. This decision was based on a survey that showed that spawning of *kasala* was 11 per cent, which is well below the standard of 30 per cent. Additional surveys using the length-based spawning per recruit (LB-SPR) data collection method are planned for other locations within Macuata later in 2017. In 2017, local governance proposed a village bylaw to legalise the issuing of penalties against poachers by qoliqoli customary rights owners. The Paramount Chief of Macuata Province, Tui Macuata Ratu Wiliame Katonivere, said it was imperative to stop poaching in their qoliqoli, which had become a growing problem.

The ongoing building of awareness, along with assistance from donor-funded projects, has increased the capacity of coastal communities to generate tactics for marine management, with momentum in focus on the Qoliqoli Cokovata. This is an important addition towards long-term sustainability to curtail extractive-driven pressures on the marine environment, though there are considerable capacity gaps in linking management of land-based activities with marine management (see Section 5).

4.1.2 Factors affecting fish and coral reef populations

Climate change can be expected to amplify existing local threats to coral reefs, mangroves, seagrasses and intertidal flats in the province, resulting in declines in the quality and area of all habitats of important food resources. Coral reef habitats located in proximity to the mainland of Vanua Levu experience heavy fishing pressures, with reduced abundance of reef fish, sea cucumbers, giant clams and other high value species. Night fishing and commercial level harvesting and poaching remain large issues, driven by the increasing market demands for export of fish to growing urban areas in Fiji, including Labasa and Suva, as well as offshore markets. The total volume of fish caught from the Qoliqoli Cokavata Macuata areas (Figure 1) from Mali to Dreketi in 2016 is estimated to amount to 114,430 kilograms, with 85 per cent of the fish caught by spear fishing (WWF 2016). The survey also revealed that the most fished reef in the Qoliqoli Cokovata was Cakau Levu, followed by Kete Yalewa, Natualevu and Utulei reef (MACBIO 2016).

Terrestrial run-off is a major contributor to decline in coral reef health Fiji-wide. For Macuata Province there are no known data sources and no monitoring of 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). Estimated increases in rainfall intensity (i.e. ‘pulses’) will likely increase large-scale plume releases from terrestrial sources, causing concentrations that can cause additional damage.

Land clearing, sugarcane farming (and subsequent burning), 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. 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.

In response to declines in reef resources, the late Macuata paramount chief Tui Macuata, Ratu Aisea Cavunailoa Katonivere, instituted management approaches in 1992 to maintain fish stocks and work towards achieving sustainability for future generations. Approximately 59 km^2 of the marine area in Macuata was established in 15 locally managed areas, some of which were marine protected areas or tabu areas within the qoliqoli (WWF 2013), and a management plan was developed in 2004 (Figure 12). The current Tui Macuata, Ratu Wiliame Katonivere, is pursuing locally-driven management that potentially changes the ruleset to increase local control for regulation and enforcement, outside central government (personal communication); however, careful thought, expertise and monitoring are all sound measures, should any pilot projects be considered. In 2017, Ratu Wiliame Katonivere said that the 2017 fishing license prohibited fishermen from fishing in the MPAs in Macuata, stating that communities have been rewarded by the development of MPAs, requiring long-term safeguarding.

In addition, there has been a ban on licensed fishing within one kilometre of Mali, Kia and Macuata-i-Wai areas, and the exclusion of night-diving and SCUBA in the qoliqoli Macuata. The use of underwater breathing apparatus was banned nationwide for processed sea-cucumber at the end of 2016. Further limitations in Macuata licensees include the extraction of any live rock, coral, aquarium fish and marine fauna and flora from the qoliqoli in the districts of Mali, Sasa, Macuata and Dreketi. Poaching is a serious concern from both licensees and non-licensed fishers, requiring locally-based enforcement.

Coral reef fishes and invertebrates are a main source of protein for most communities around the island, but as stocks continue to decline from over-harvesting, basic needs of communities will likely not be met. Reef fish populations inside marine protected areas (Figure 12) may render these locations less vulnerable, but poaching and heavy exploitation from outside commercial operations has been widely reported by locals. Interviews with local residents suggest that fishing is curbed only within the Mali and Kia (to a limited extent) MPAs (MACBIO 2016).

FIGURE 12. Macuata tabu areas.

As climate changes, storm intensity in Fiji is expected to increase and, as local communities begin to make decisions in response to severe weather events, trade-offs between short-term and long-term food security are being made. For example, government agencies have stated that communities with qoliqoli areas affected by TC Winston need to consult the Ministry of Fisheries before considering lifting the tabu on their qoliqoli. While communities have the right to open or close these areas, the Department of Fisheries is recommending they consult first with them in an effort to keep protected areas intact for the fast recovery of coastal resources.

Commercial scale fishing is expanding in Macuata Province. It increasingly deploys small live-aboard vessels with divers and fishers. These boats are supplying the growing markets for export to Labasa and Suva fish markets. Marine resources are being commercialised for both national and international export and consumption. With commercialisation, investments in more efficient gear and equipment contribute to increasing rates of overexploitation. Local communities who subsist on marine resources are deriving short-term benefits from income from fish sales, but over the long term are suffering from loss of local sources of protein. This is occurring as Fiji fishes down the food chain, exploiting lower value fish as higher value species are overfished.

4.1.3 Mangroves, coastal marshes and seagrass ecosystems

Mangroves extend along the northern coastline of Macuata Province, and cover 8,350 ha of coastal and riverine area (~4 per cent of the provincial land area, Figure 6) (Atkinson *et al*. 2016). Mangrove patch size and quality has not been known to be surveyed, although rapid field reviews indicate general declines in structure and quality where there are adjacent land uses, especially near large river outlets and urban centres (e.g. Labasa).

Conversion of mangrove to agricultural lands, particularly sugarcane, is evident with 'hard edges' of vegetation change in flatland areas between large river mangrove systems (Figure 13) that also correspond with state land tenure areas. While the original landscape and date of conversion to agriculture is not known, the topography, soil structures and suitability indices at the time of the soil surveys indicate low productivity and high water table/saline environments on the sugarcane parcels seen in Figure 13, which is indicative of former mangroves or coastal marsh ecosystems. Filling of topsoil or long-term agricultural uses have allowed for conversion to sugarcane from what was likely a floodplain marsh, mangrove area, or salt marsh complex that allowed for slow water movement and sediment to be deposited prior to entry into the lagoon and near-shore reef areas.

Complicating the conversion process is the development of road networks in lowland areas. These can be farm access roads 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. 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 13 is one example area that has limited inland expansion of a mangrove system, although even low-lying furrows in the sugarcane fields can alter the hydrology.

FIGURE 13. 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 15. Image Source: DigitalGlobe 2017, Google 2017.

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. In ideal circumstances, where terrain allows mangrove extent to migrate inland, they can mitigate the effects of sea-level rise. In areas near Labasa (Figure 13) where multiple rivers converge, the delta regions are formed that historically have had fluctuating coastal community edges at both the inland and seaward edges. With urban growth, conversion to agriculture and road networks that limit tidal and land-based water movement, sea-level rises will consume, rather than create, coastal ecosystem areas. Losses of mangrove and coastal marshes will greatly reduce the capacity to mitigate land-based pollution to the marine environment and cause substantial reductions in breeding and rearing grounds for fish and invertebrates.

Other stressors, such as the use of mangroves for subsistence firewood harvest, untreated wastewater disposal and agricultural run-off, further degrade mangrove habitat for fish and invertebrates, as well as limit the growth and reproductive capacity for mangrove expansion, where topography allows.

Seagrass extent or quality of habitats are not known to be available for Macuata Province; however, seagrass meadow areas are found in shallow lagoon areas, typically near shore. 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, aids in the accretion of coastal flats that provide habitat for seagrass meadows to establish. Linkages 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 linkages highly vulnerable.

4.1.4 Coastal erosion and flooding

The effects of sea-level rise are likely to be considerable along the coast and islands of Macuata, with some communities already experiencing the impacts. As sea levels rise and storm surges increase with the increasing intensity and frequency of cyclones, erosion rates in certain areas appear to be increasing. In addition, with the reduction and degradation of ecosystem services – providing buffer zones from storm surges and waves from coastal and marine habitats, shoreline erosion can be expected to rise. Sections of low-lying coastline of Macuata Province are faced with increased erosion inundation, flooding, and salt water intrusion.

In a study of 29 villages in Vanua Levu and Taveuni, 27 were experiencing problems with beach erosion and sea encroachment (Mimura and Nunn 1998). A more recent survey of community perceptions of vulnerability (CCD unpublished) indicated that most (55 per cent) of the 49 communities surveyed in Macuata Province for coastal ecosystem health conditions indicated neutral resilience, while 39 per cent indicated low resilience to climate change and one village (2 per cent) indicated having extreme concern.

Digital elevation model data were used to create spatial coverages of two potential inundation areas; one from oceans and one from major rivers. The potential ocean inundation areas were defined as areas that are at elevations from 1 metre above sea level. Potential river inundation areas were defined as areas that are 1 metre higher than the elevation of the adjacent river (i.e. a 'relative elevation' difference as compared with the river). Estimating potential river inundation areas required projecting the river elevation perpendicular in 'plan view' to the direction of flow and subtracting this from the ground surface elevation. Areas having a potential for inundation due to riverine flooding or sea-level rise are shown in Figure 14. The portions of major roads and tramlines within these potential inundation areas are also shown (see Section 4.5.1). Roads and tramlines within the potential seal-level rise inundation area would be the most susceptible to coastal erosion and flooding, as well as causing potential threats to mangrove expansion. These areas are located primarily in and around Labasa and adjacent river deltas.

4.1.5 Key drivers of change

The key drivers of change affecting marine resources in Fiji were summarised from work conducted by Gillet and Cartwright (2010), modified for specific conditions occurring in Macuata Province, and include the following.

Urbanisation and expansion of settlements and communities without strong ties to marine resources. Demand for fish from coastal fisheries will increase, but as overharvesting and habitat degradation continue unchecked, production will not be able to meet demand.

Patterns of economic development occurring in Vanua Levu will affect coastal fisheries. As jobs decline, and as unemployed people seek income or subsistence in food security, demand on coastal resources will increase. The capacity of the Department of Fisheries is limited in revenue and ability to provide basic fisheries-related management services and infrastructure. In addition, global markets for reef fisheries is increasing, and demand and scarcity are only expected to rise, placing additional pressure and increased economic opportunity to extend harvest efforts of Macuata's marine resources.

Status of fisheries resources and developments in other oceans. 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.[8]

Governance. Generally, there is a challenge for capacity, qualified personnel, funding, and priority directed at marine resource management in Fiji. Challenges also exist with the levels of government (national, divisional, provincial, district) and traditional ownership *(mataqali)*.

Climate change. Offshore fisheries in Fiji provide limited economic gains or food security for local Macuata communities. Coral reefs are expected to degrade in response to projected effects of coral bleaching, acidification, increased cyclone intensity, and increased turbidity from land-based run-off. Coral reef fisheries are consequently likely to become less productive.

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.

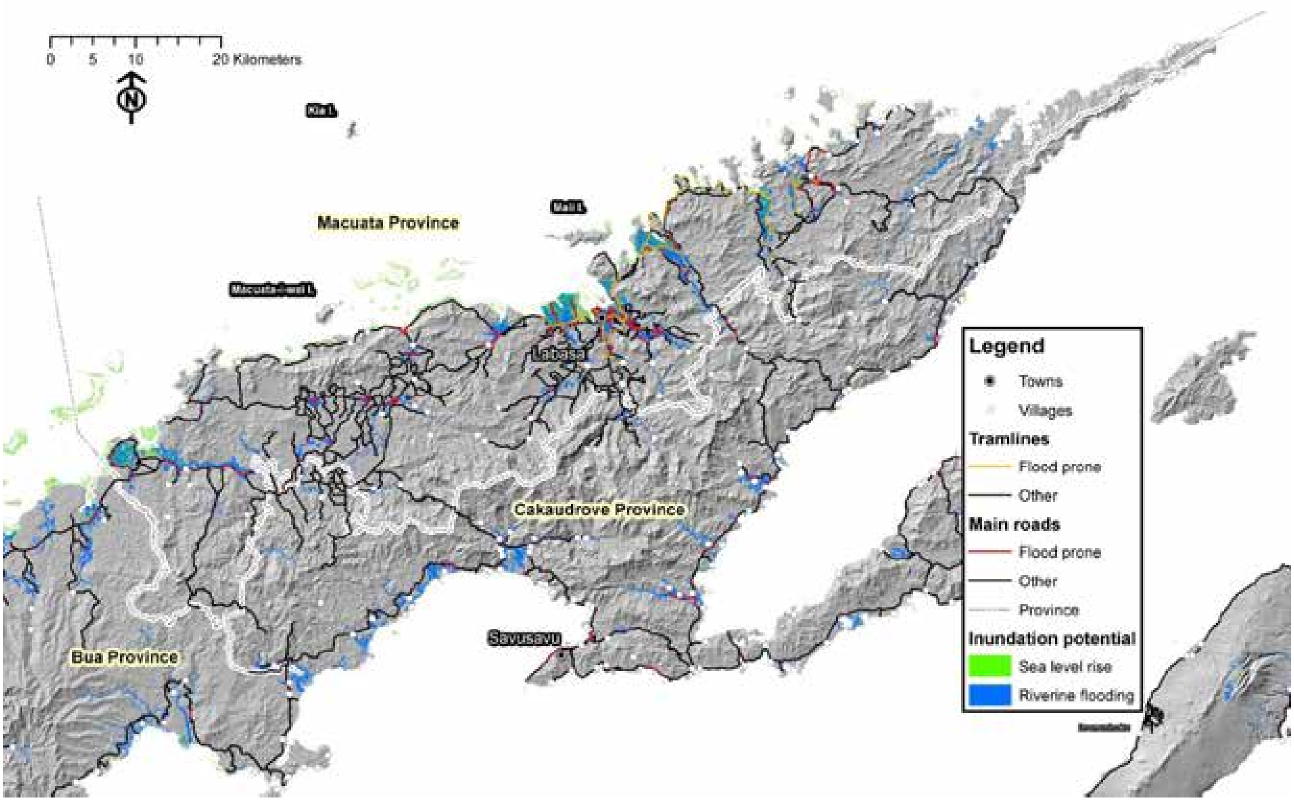


FIGURE 14. Inundation potential from riverine flooding and sea-level rise, and flood-prone portions of major roads and tramlines.

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

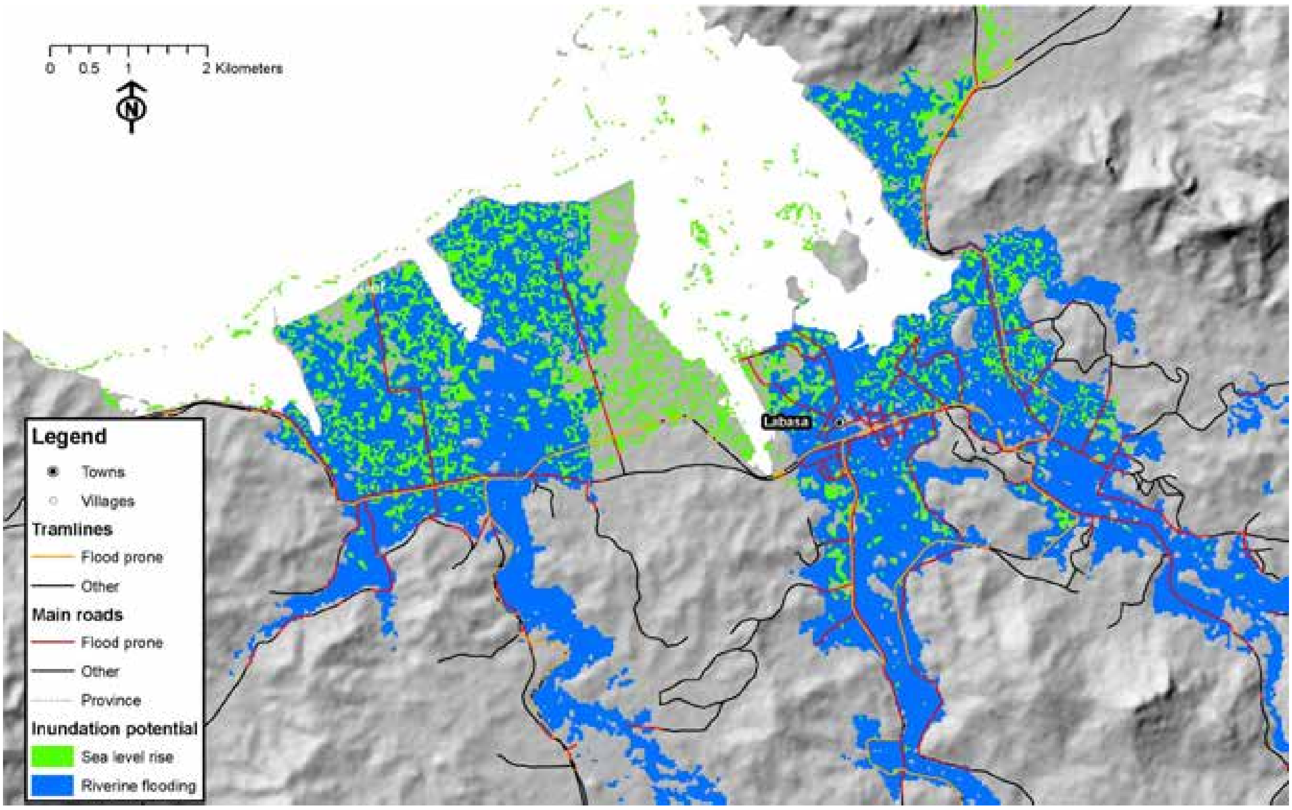


FIGURE 15. Inundation potential from riverine flooding and sea-level rise, and flood-prone portions of major roads and tramlines with a focus area on the Labasa River Delta (see Figure 13).

Talailau island and coral reef between the Macuata coastline and the Great Sea Reef (the Qoliqoli Cokovata). The marine ecosystems around Macuata Province are degrading and experiencing declines due to overfishing, land based pollution, deforestation and climate forces. © Stuart Chape

4.2 FRESHWATER VULNERABILITIES

Macuata Province has abundant freshwater resources, derived from a mix of ground- and surface-water sources. Stream catchments range in size from small streams draining directly into marine waters to the 850 km^2 Dreketi River Basin at the western end of the Province (Figure 1). Portions of Macuata contain catchments draining to the southern coast of Vanua Levu. The additive forces shown in Table 4, particularly agricultural production, forestry, and mining, probably have a greater influence on vulnerable conditions than do predicted climate changes.

TABLE 4. Summary of forces affecting vulnerable conditions of freshwater resources

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

4.2.1 Groundwater supply

Groundwater within Macuata Province is found in both recent (quaternary) deposits and medium-depth fractured rock or sedimentary formations. High-yield aquifers are found in the alluvial deposits of unconsolidated sand and gravel in the valleys of the Labasa, Bucaisau, Qawa, Wailevu, and Wainikoro Rivers (Fiji Department of Mineral Resources 2015). Fissured aquifers in upland areas are major sources of groundwater for Labasa and other cities. Coastal groundwater sources may exist as thin lenses on top of salt water and are subject to salt-water intrusion with over-pumping (SOPAC 2007). Little is known about the rate or sustainability of groundwater extraction; however current withdrawal rates are probably 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 use.

Annual rainfall levels (Figure 8) are predicted to remain largely unchanged into the future (see Section 3). Given the long sub-surface 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. This, coupled with continued losses of forests, may contribute to lower rates of groundwater infiltration due to soil heating, evaporative loss, and surface 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 Macuata Province (SOPAC 2007). 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 (e.g. Labasa River) and, at present, there is no single regulatory authority to adjudicate water disputes. The majority of surface water use is for agriculture.

A freshwater stream flows through bushland and a small plantation. © E.Salmenien

4.2.3 Pollution attenuation capacity

Freshwater pollutants in Macuata Province are primarily water-borne sediments from agricultural and forest land management practices, run-off of agricultural chemicals, mining run-off and, in localised areas, untreated human waste. Attenuation capacity is compromised by lack of riparian buffers, floodplain degradation, and loss of channel complexity due to gravel extraction. Gravel mining operations are common within the Labasa River, and several active logging operations have been identified in the headwaters of the Dreketi River (Figure 16).

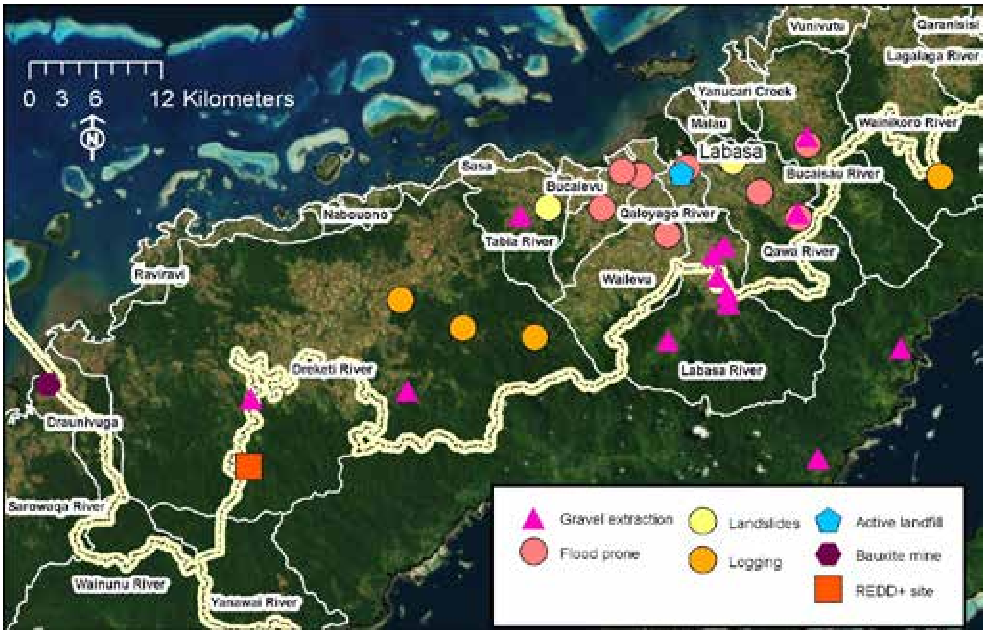


FIGURE 16. Recent disturbance activities within the vicinity of Macuata Province. Source: Multi-agency workshop.

Sixty per cent of the area of catchments that intersect Macuata Province is in forest cover, 25 per cent in grass or shrublands, 14 per cent in agriculture (mostly sugarcane) production, and 1 per cent each in coconut plantation, settlement and water (Figure 17, see Section 4.4). When managing pollution sources, both point source (e.g. wastewater treatment) and non-point source (sediment from road erosion, lack of riparian buffers) would reduce vulnerability to freshwater resources downstream, as well as the marine environment.

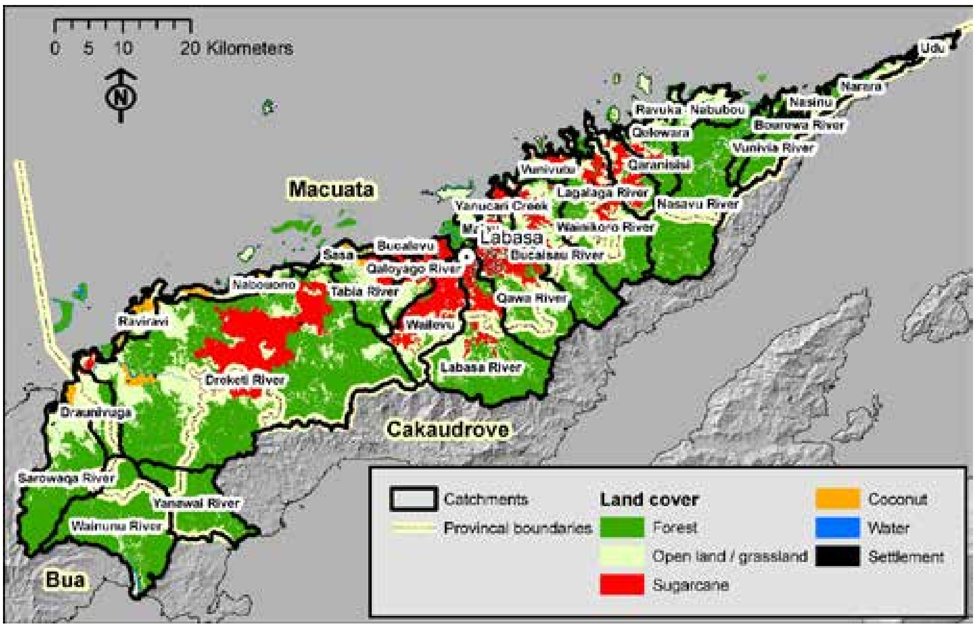


FIGURE 17. Land use and land cover within catchments intersecting Macuata Province.

The agricultural Land Use Capability Classification of the soils of Macuata Province are shown in Figure 18. The classification system is based on several physical factors that influence the range of potential crops and crop productivity, as well as the difficulty of managing these lands and the potential for degradation. Classes are ordered by increasing degree of limitation for agricultural use; classes range from Class I as the best quality land with few limitations up to Class VIII, which is not suitable for agricultural use. Classes I–IV are considered arable lands, and higher numbered lands are best suited to forest or non-arable uses. Approximately 28 per cent of the mapped soils within catchments intersecting Macuata Province are classed as Class II–IV (arable lands), 39 per cent as Class V–VII (non-arable), 14 per cent as Class VIII (unsuitable for agriculture) and 19 per cent of the area is not classified.

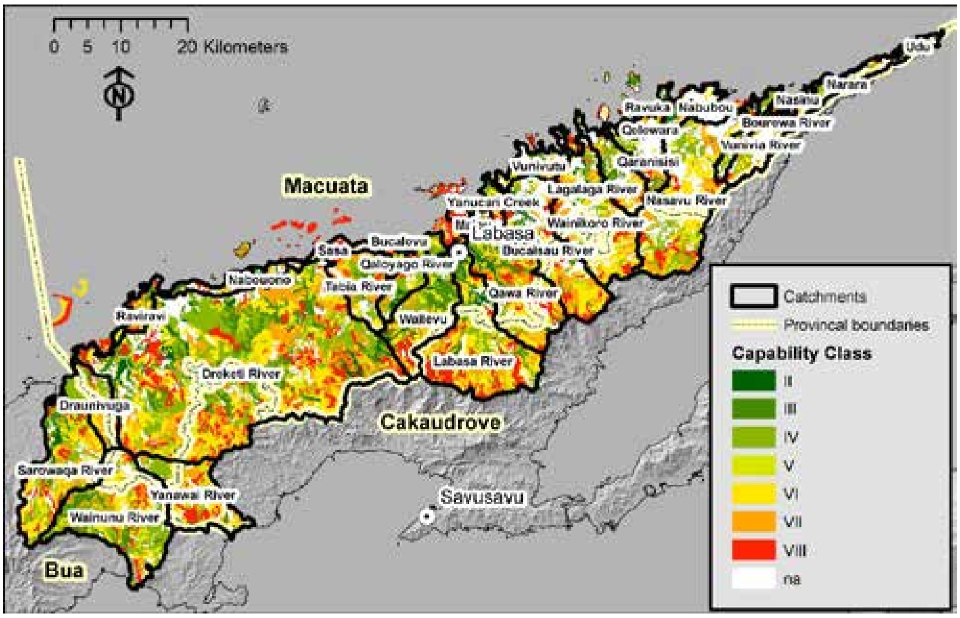
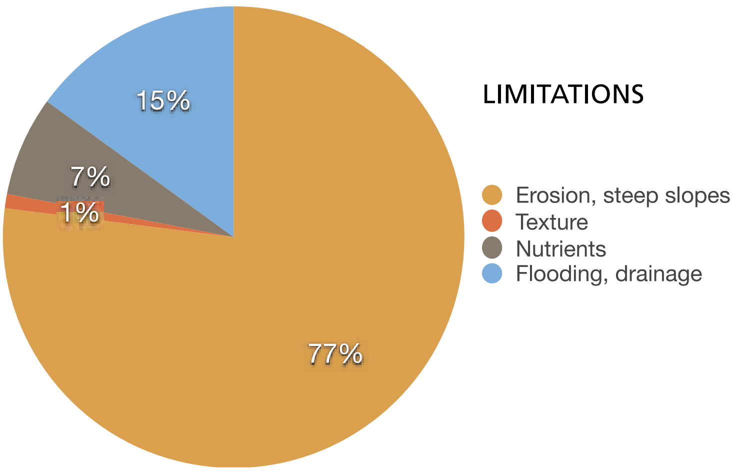


FIGURE 18. Land use capability class within catchments intersecting Macuata Province.

In addition to the overall capability class, the agricultural Land Use Capability Classification system also identifies the primary source of limitation for each soil type. The primary limitations were grouped by similar limitation type and are summarised in Figure 19. Approximately 77 per cent of the identified soil limitations are due to erosion and steep slope conditions, 15 per cent due to flood and drainage problems, 7 per cent due to nutrient problems, and 1 per cent due to textural issues.



4.2.4 Floodplain vulnerability

Floodplains in Macuata Province occur along the major river systems. These areas contain a large proportion of the urban areas, much of the economic infrastructure (e.g. sugar plantations and mills) and a significant amount of agricultural lands. In addition, most large floodplain areas are in close proximity (longitudinally and elevationally) to marine areas (Figure 14 and Figure 15). Flooding is common and will be exacerbated by projected increases in more extreme rainfall events and sea-level rise. 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). Increased sediment loads and run-off efficiency will amplify flooding problems. Options for wetland attenuation are slight in these circumstances, other than mangrove systems in both riverine and estuarine areas. The effects of gravel mining on flooding are unknown and likely contradictory, depending on location; 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.

Flooding occurs primarily, although not exclusively, during the November to April wet season (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. Prolonged wet seasons may result in a series of events, or the complication of flood effects from landslides and other debris.

As stated in Section 3.1, notable flood events to the major and hydrologically independent river systems occur every ~11 years since 1910 on average. Dredging, seawalls and floodgates have been built in response to flooding events, although effectiveness/monitoring outcomes are not known, nor are consequences associated with losses in lowland coastal ecosystem connectivity and ecosystem services. Mapping of these efforts are likewise not known or consolidated.

4.2.5 Aquatic habitat and species risk

The primarily sandstone, marl and andesitic volcanic geology of Macuata Province dates back seven million years. Erosion has created relatively low gradient valleys extending landward, with steep headwater areas rising to elevations of up to 900 m 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. As noted above, many of the 30 catchments that intersect Macuata Province (Figure 4) cross boundaries into neighbouring provinces. Catchment-based management is particularly useful in these inter-provincial catchments.

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 in the production of dalo, enter the stream system and contaminate habitats. Subsistence uses, including laundry and bathing have contributed to the formation of algae in the stream systems, with concentrating effects downstream.

Some rivers are being degraded by gravel and bauxite mining (Figure 16); waste material can result in a rise of river-bed level, clogging of the stream channel, increased siltation and downstream flooding (Falkland 2002). Depending on site characteristics, gravel extraction can occur at sustainable levels with little or no effects. However, excessive removals can result in major consequences, which have been seen in many of Fiji's rivers, particularly in proximity to urban centres (NatureFiji-*MareqetiViti* 2010). Extraction of gravels and modification to the streambed composition change 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 habitat. This habitat differentiation (pools and rapids) is lost with excessive or misplaced gravel extraction. NatureFiji-*MareqetiViti* (2010) has recommended replacing much of the river gravel extraction with quarried rock – the benefits or unintended consequences of which would require careful review for each site recommended to restore.

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 in dispersed rural villages that dispose of human waste directly into the stream channel (CCD 2016). Direct faecal contamination from cattle and pigs and run-off from animal feedlots is another direct source of freshwater contamination (UNEP 2000), as is solid waste disposal from villages and municipalities.

Strong seasonality in the 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 (Fiji has four endemics) (Abell *et al*. 2008). Most aquatic species live in permanent freshwater rivers, and in estuarine and mangrove areas. Generally, aquatic species inhabit areas with high water quality and intact riparian vegetation. Declines in diversity and abundance are often a reliable early indication 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 Macuata's rivers, lakes and estuaries for subsistence and small commercial fisheries. Population trends for most of Fiji's freshwater fauna are unknown.

Comparisons of catch per unit effort (fish biomass kg yield per hour) between rivers in Macuata Province and the near-pristine rivers of Tetepare, Solomon Islands, using identical sampling methods suggest that the Fiji rivers are already severely ecologically compromised (Jenkins and Jupiter 2011).

4.2.6 Livelihoods

The rivers and streams of Macuata are locally important to several communities. While harvest quantities are largely unknown, freshwater and estuarine habitats provide areas for reproduction, feeding, recruitment, growth, and migration important to livelihoods and a consistent source of local protein. Similarly, stream systems are important to local communities for sourcing drinking water, bathing, laundry, and (in some cases) wastewater removal. Since freshwater ecosystems are at risk from climate change effects, 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, and parasites and viruses from infected food and water).

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

The principal climate change-related effects on freshwater habitats and species in Macuata Province include potential increases in flood-related disturbance, 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 effects will favour some species at the expense of others, with a likely shift in community composition. Additive forces will, however, likely 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.

4.2.7 Recreation and tourism

Freshwater resources play a minor role as key destinations for tourists within Macuata Province, with most tourist destinations being in the marine environment. Threats to healthy river systems and the associated freshwater amenities will likely increase vulnerabilities and have unintended negative consequences on tourism in the province.

4.2.8 Key drivers of change

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

- Lack of a single regulatory authority to adjudicate water disputes – conflicts over water availability are currently limited to certain local areas (e.g. Labasa River).
- Freshwater pollutants – the majority of 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, in localised areas, untreated human waste.
- Attenuation capacity – this is compromised by lack of riparian buffers, floodplain degradation, and loss of channel complexity due to gravel extraction (common in the Labasa River).
- Erodibility – this is the primary soil limitation.
- High vulnerability to inundation – urban areas, transportation and other infrastructure are located on floodplains and/or in sea-level rise areas.
- Increased storm intensity – this is likely to exacerbate flooding and coastal erosion.
- Strong seasonality in flow and steep topography – these increase susceptibility to climate change (increased storm severity, increased drought periods) and land management practices (soil disturbance, erosion).

4.3 AGRICULTURAL SYSTEMS

Agricultural resources are critical to Macuata Province food security and the economy of the country, and are vulnerable to climate change in several ways (Table 5). Storms can damage infrastructure and crops, erode soils, and damage transportation systems necessary to transport produce to market and sugarcane to the sugar mill. Changes in climate patterns can affect crop suitability and vulnerability to disease or pests. 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, and 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 5. Forces affecting agricultural vulnerabilities

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
	Land-use history and practices/ intensities	Eroding soils
Changes in rainfall distribution (temporal and spatial)	Market demand	Soil infertility
	Operating costs	Agricultural land base
	Disease vectors	

Agricultural practices are also a leading additive force to creating vulnerable conditions for other important ecosystem services. Intensive use and expansion of agricultural areas for short-term gain is possibly a leading force affecting change to ecosystem health in two key ways: conversion of forest environments to agriculture and rapid degradation of soil resources (nutrients). Small-scale subsistence farming through a cycle of deforestation, agricultural conversion and abandonment create a cycle of large-scale ecosystem degradation and forest losses. Nevertheless, increasing diversity of income sources from maximising land efficiencies and minimising impacts is a key mechanism to strengthen the role of agriculture in providing sustained services.

4.3.1 Household revenue and dependence

Macuata's primary agricultural crop is sugarcane, a cash crop generally used for income with no direct role in subsistence. The Labasa Sugar Mill, owned by the Fiji Sugar Corporation (FSC), processes all sugarcane harvested in Macuata, generally for export (FSC 2017). In 2017, the Labasa Sugar Mill crushed 653,000 tonnes of sugarcane, up from 544,000 in 2014. This resulted in 73,000 tonnes of sugar produced and 26,000 tonnes of molasses. Labasa is responsible for roughly 35 per cent of national production, although this fluctuates year-to-year. As of 2012, there were reported approximately 4,000 sugarcane growers in all of Vanua Levu.

FSC owns a tramline for transport of sugarcane to the mill in Labasa, but degradation of the tracks and sea-level rise has slowed the pace of transport and the train's reliability (see Figure 15). Sugar industry leaders in Macuata Province believe that production volumes could greatly increase with irrigation, but there is little irrigation currently available. Operations are sensitive to water availability, and so are vulnerable to predicted climate change aspects affecting regularity and annual distribution in rainfall. Waste material from the Labasa Sugar Mill is now being used for energy cogeneration as biomass fuel and the mill would like to increase production.

Pineapples at the Labasa market. Agriculture is an important economic activity in the Macuata Province. Photo: WPN.

The majority of land in Macuata Province is in iTaukei ownership (Figure 5), and land tenure issues are central to challenges facing sugarcane growers, 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 use-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.

Rural households in Macuata Province rely on agricultural production for subsistence and income. As with sugarcane, agricultural productivity overall has been in decline, and without appropriate adaptation strategies will likely suffer from climate change via loss of soil and soil fertility, droughts, and damage to crops, infrastructure, and homes during storm events.

Distribution of local food production (within Macuata Province and across Fiji) 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.

4.3.2 Eroding soils

Soil erosion is a central issue for Macuata Province, due to steep slopes, high rainfall, and soil characteristics that combine to create a naturally erosive condition. Sugarcane production occupies much of the lower-gradient lands, but has pushed into steeper headwater areas (Figure 17). As noted above, uncertainties with regards to land tenure (Figure 5) make it difficult to apply best management practices needed to minimise soil erosion or make other long-term investments in soil conservation.

Brown *et al*. (2017) used satellite data and GIS models to estimate the contribution of catchments on Vanua Levu to ocean turbidity at river mouths. Sediment yield at the mouth of each catchment was estimated. Only two land uses were considered: forested and non-forested. Results are displayed in Figure 20.

These results indicate that the Dreketi River catchment and the aggregated catchments around Labasa have a large influence on turbidity in the nearshore coastal areas (Figure 20). These catchments have some of the highest proportion of non-forested agricultural lands, in particular sugarcane.

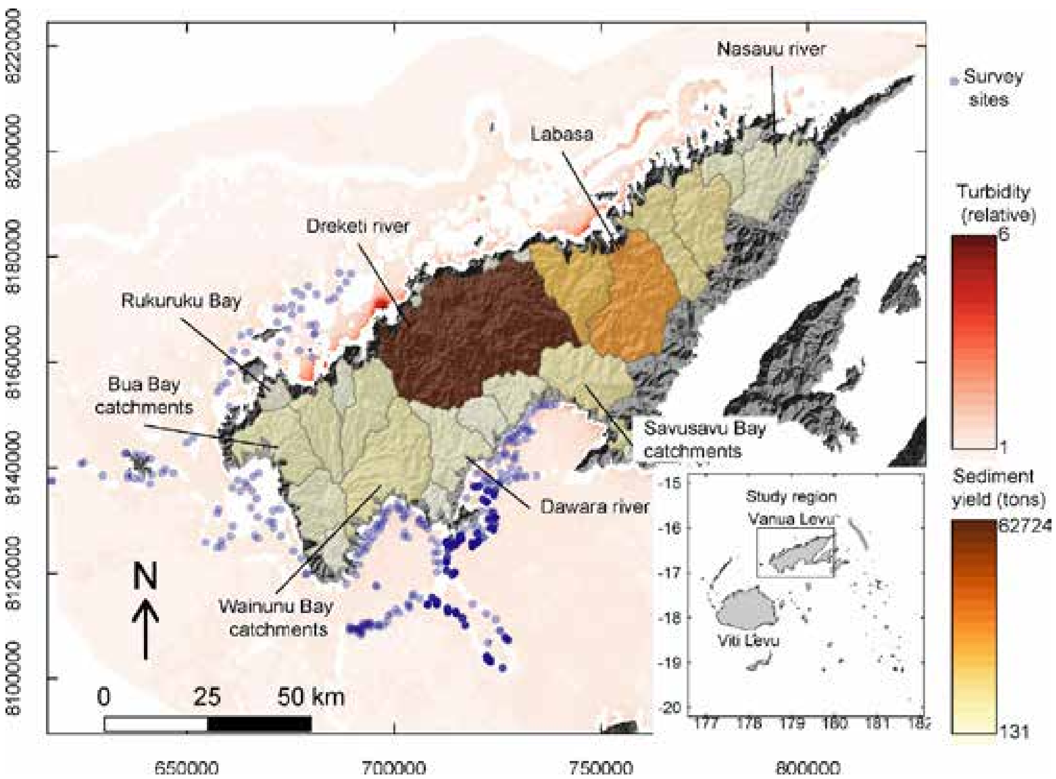


FIGURE 20. Catchments showing estimated sediment yield (tons per wet season) and ocean turbidity estimated from satellites. Reef survey sites are shown in purple. White ocean areas were excluded due to shallow water or being too distant from catchments. Source: Brown et al, 2017

4.3.3 Soil infertility

The same climate and additive forces that affect eroding soils also affect soil fertility. Soil fertility limitations are magnified by weak land tenure security for growers who cannot make long-term investments either in terms of direct improvements to soil, nor use of soil in a conservative way that maintains fertility. This is 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, lending to higher deforestation and fragmentation for short-term crop cycles. Addressing the need directly takes a focused effort by government to encourage investment in diversification of crops, agricultural extension, and land-use laws.

4.3.4 Agricultural land base

As noted above, land tenure issues are an additive force contributing to climate change vulnerability. Without secure land tenure, farmers 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 crops or value-added processing. The use of irrigation and crop rotations require investment. Without direct investment and security of investment, choices narrow for subsistence farmers. Working more efficiently with the land currently under agriculture, rather than converting new lands for short-term gains, requires land stewardship and security of investment.

4.3.5 Key drivers of change

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

- Market forces for sugar production – export markets and efficiencies determine demand for sugar production and land uses to favour farming.
- Coastal erosion affecting infrastructure – tramlines used to transport cane to the sugar mill are threatened by coastal erosion and sea-level rise.
- Lack of irrigation makes cane and other crops susceptible to drought.
- Intensive rainfall predicted by climate change can damage crops.
- Land tenure issues discourage conservation and long-term stewardship.
- Well-distributed food production system is needed to build resilience to localised storm damage and disaster response.
- Sediment load is proportional to catchment size and agricultural intensity.

4.4 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 6).

TABLE 6. Summary of forces contributing to the vulnerable conditions for terrestrial ecosystems

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	

4.4.1 Land use/land cover (LULC)

Land use/land cover (LULC) estimations were made in 2010 (SPC-GSD) 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, coconuts) and little differentiation on forest types at the national scale. Forest type differentiation requires more ground truth analysis and typically first-hand background knowledge of forest conditions in order to accurately delineate subtle differences (e.g. species types), as well as overall condition (e.g. degradation). Large-scale LULC inventories often do not stratify to great detail within forest types unless it is within a specific priority interest, such as a national forest inventory that is used for greenhouse gas and especially 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). A summary of Macuata Province, including the neighbouring areas where watershed boundaries extend into Cakaudrove and Bua Provinces (‘Connected Areas’, see also Figure 4) are displayed in Figure 23 and summarised in Table 7. Table 8 displays the disaggregated LULC categories within each major group.

For Macuata Province proper, nearly all of the land area was accounted for in forest lands (50 per cent), open grasslands/ shrublands (28 per cent) and agriculture (19 per cent). The ‘connected areas’ within watersheds that crossed into Macuata Province were mostly classified as forest lands (79 per cent) with grasslands/ shrublands as the subdominant feature. This mostly reflects the upper elevation areas of Cakaudrove Province that serve as the headwaters for most of the watersheds crossing the boundary (though not all; some originate in Macuata and flow to the south in Cakaudrove).

Overall, LULC coverages provide a good basis for determining the overall land cover types and they track land cover changes using systematic and repeatable methodology. Currently, there are no direct comparisons of inventories to address LULC change for Macuata Province. Rates of deforestation or change resulting from licensed timber operations are described in Section 2.4, with ~1,570 ha harvested for all of Northern Division over the past year, of which approximately one-half (760 ha) was located in Macuata Province, with only 40 ha replanted. Data for extracting trends in conversion to agriculture are problematic, as deforestation is often on a small scale (5 ha) for conversion to subsistence farming. No data are known to exist, although there is clear evidence of recent activity. Repeated measures for LULC to address change are needed and are part of ongoing programmes within the Fiji Government (e.g. Forestry REDD+ Programme).

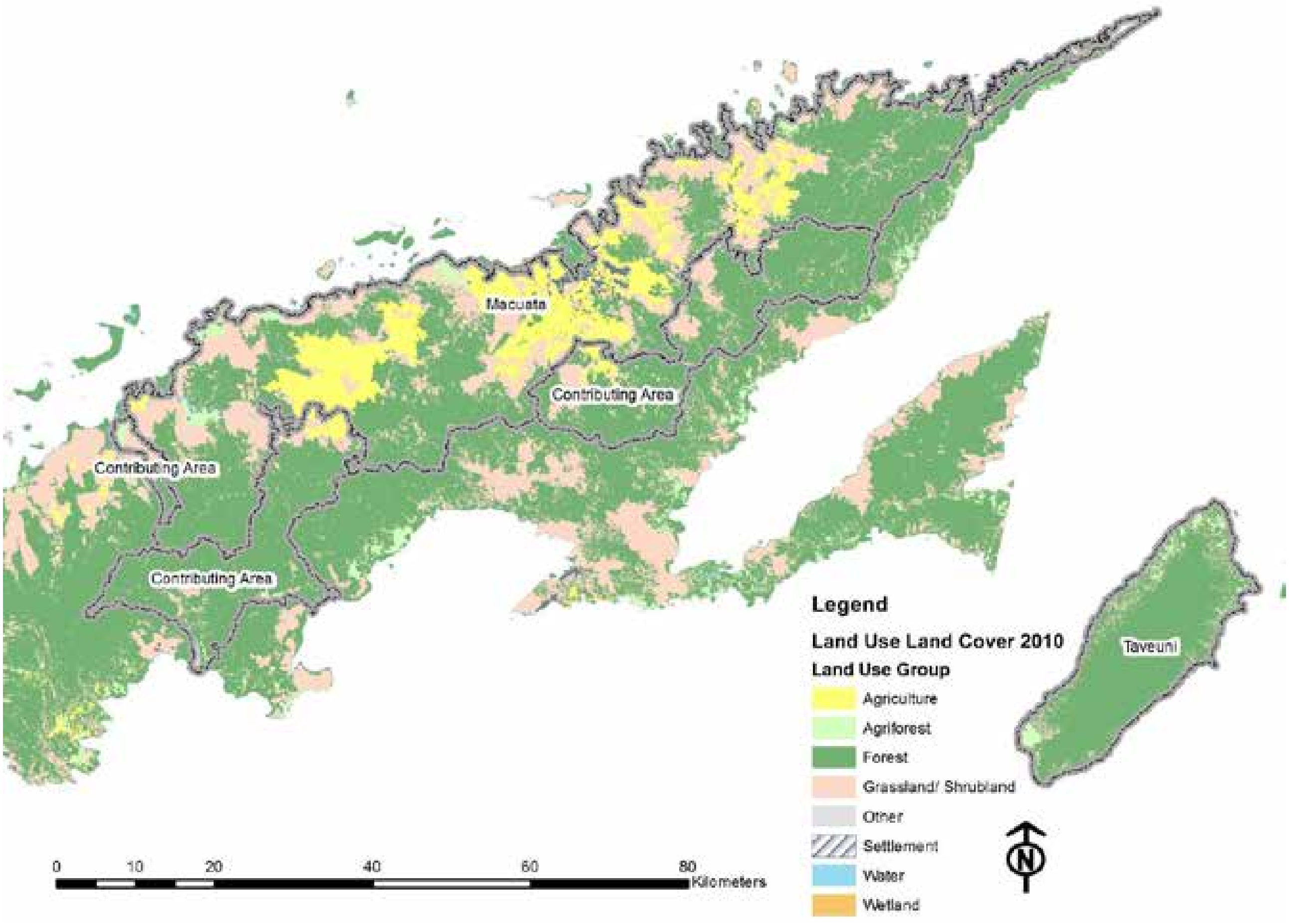


FIGURE 21. Land use/ land cover aggregated classifications from 2010 LULC mapping efforts. Source SPC-GSD unpublished.

TABLE 7. Land use/land cover aggregates for the focused areas of Macuata Province. 'Connected' lands are within watershed boundaries associated with Macuata Province but are located in neighbouring Cakaudrove and Bua Provinces. Source: SPC-GRD unpublished

	Macuata Province		Connected to Macuata		Total Catchments	
LULC Group	**Area (ha)**	**Area %**	**Area (ha)**	**Area %**	**Area (ha)**	**Area %**
Agriculture	39,147	19%	2,991	3%	42,138	14%
Agroforest	3,931	2%	555	1%	4,486	2%
Forest	106,304	50%	67,624	79%	173,928	58%
Grassland/ Shrubland	58,441	28%	14,620	17%	73,061	25%
Other					0	0%
Settlement	1,244	1%	18	<1%	1,262	0%
Water	2,419	1%	263	<1%	2,682	1%
Wetland	4	<1%			4	0%
Total	**211,490**		**86,072**		**297,562**	**100%**

TABLE 8. Land use/ land cover categories and aggregates for the focused areas of Macuata Province. 'Connected' lands are within watershed boundaries associated with Macuata Province but are located in neighbouring Cakaudrove and Bua Province. Source: SPC-GRD unpublished

		Macuata Province		Connected to Macuata		Total Catchments	
LULC Group	**LULC Category**	**Ha**	**Area %**	**Ha**	**Area %**	**Ha**	**Area %**
Agriculture	Cassava	-	-	-	-	-	-
	Coconut Crops	35	<1%	-	-	35	<1%
	Cultivated Land	2	<1%	21	<1%	23	<1%
	Mixed Crops	<1	<1%	34	<1%	34	<1%
	Orchards	-	-	-	-	-	-
	Rice	16	<1%	-	-	16	<1%
	Sugarcane	39,094	18%	2,936	3%	42,030	14%
Agroforest	Coconut Forest	-	-	-	-	-	-
	Coconut Plantation	3,926	2%	555	1%	4,481	2%
	Oil Palm	5	<1%	-	-	5	<1%
	Scattered Coconut Plantation	-	-	-	-	-	-
Forest	Forest	106,263	50%	67,624	79%	173,887	58%
	Scattered Forest	40	<1%	-	-	40	<1%
Grassland/ Shrubland	Grazing Land	-	-	-	-	-	-
	Open Land/ Grassland	58,248	28%	14,620	17%	72,868	24%
	Shrubs	193	<1%	-	-	193	<1%
Other	Barren Land	-	-	-	-	-	-
Settlement	Settlement	1,244	1%	18	<1%	1,262	<1%
Water	Water	2,419	1%	263	<1%	2,682	1%
Wetland	Wetland	4	<1%	-	-	4	<1%
	Total	**211,490**	**100%**	**86,072**	**100%**	**297,562**	**100%**

4.4.2 Fragmented forests

Forest fragmentation in Macuata has resulted from development and population growth, and especially expansion from small-scale, subsistence agriculture activity. Timber harvest or slash-and-burn activities associated with land clearing and conversion to agriculture typically occur in small plot areas (~5 ha) and are farmed for a number of years, followed by fallow and abandonment. This leads to a fragmented forest network, 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. Though not quantified, forest fragmentation is high in the upper reaches of nearly all watersheds; much of this conversion is occurring on the connected landscapes of Cakaudrove Province, contributing to effects downstream in Macuata Province.

Climate 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 around the given patch (e.g. fire). In general, the more landowners or lessees in a given area, the more fragmented a landscape becomes due to individual management decisions on a small scale. As settlements increase in size, so does the level of fragmentation around that settlement.

4.4.3 Invasive species expansion

Current biosecurity programmes affecting international air travellers appear to be adequate, and there are inspections for 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. Macuata is an important agricultural producer for Fiji and there does not appear to be a systematic method for controlling soil movement from other islands (e.g. washing stations for transport vehicles, soil removal), transfer of pests that affect food security, or for inspection of potential soils spread. Invasive species are widely considered to have an advantage with 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.

4.4.4 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.

Freshwater river surrounded by healthy forest, Macuata Province, Vanua Levu. Photo: WPN, 2016.

4.4.5 Key drivers of change

The key drivers of change impacting terrestrial ecosystems in Macuata Province include the following:

Economic stability. A key driver in deforestation and conversion of lands is having economic stability that trends away from extractive, subsistence uses to more efficient and higher-value uses. A 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 Island.[9] 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, such as cyclones and other destructive forces, can have large-scale effects on vegetation structure and functioning. Increases in rainfall intensity increase flooding and scouring events that damage soils or reduce opportunities for native species, especially in riparian zones. Prolonged drought events likewise cause mortality and stress to native ecosystems, allowing for invasive species expansion and losses in hydrologic functioning and other services.

Road networks. Increases in road networks open new areas of the landscape to settlements, resulting in land conversion to settlements and agriculture, as well as increases in opportunities for invasive species introduction.

4.5 TRANSPORTATION AND ENERGY INFRASTRUCTURE

Transportation and energy infrastructure are vulnerable to storm events, particularly as sea levels rise on the coast of Macuata (Figure 14). Many of the principal roads and tramlines are close to the coast or alongside major rivers, and are already experiencing erosion, flooding and vulnerability to climatic and additive forces (Table 9). Separation of communities from commercial, industrial and governmental service centres make them particularly vulnerable during disaster response and recovery periods. It can also exacerbate effects of disasters and the time it takes to restore fuel supplies and recover from infrastructure failure.

TABLE 9. Summary of climate forces, additive forces and transportation and energy infrastructure vulnerable conditions

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	

9 See Ecosystem and socio-economic resilience analysis and mapping: Taveuni island, Fiji. SPREP 2020.

4.5.1 Transportation infrastructure

Roads are vulnerable to storm events, including flooding and erosion. Roads and train tracks in Macuata Province vary in condition and general maintenance. Interior access is limited, and roads are steep and often impossible 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 in Figure 14 and Figure 15 (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 is displayed in Figure 22.

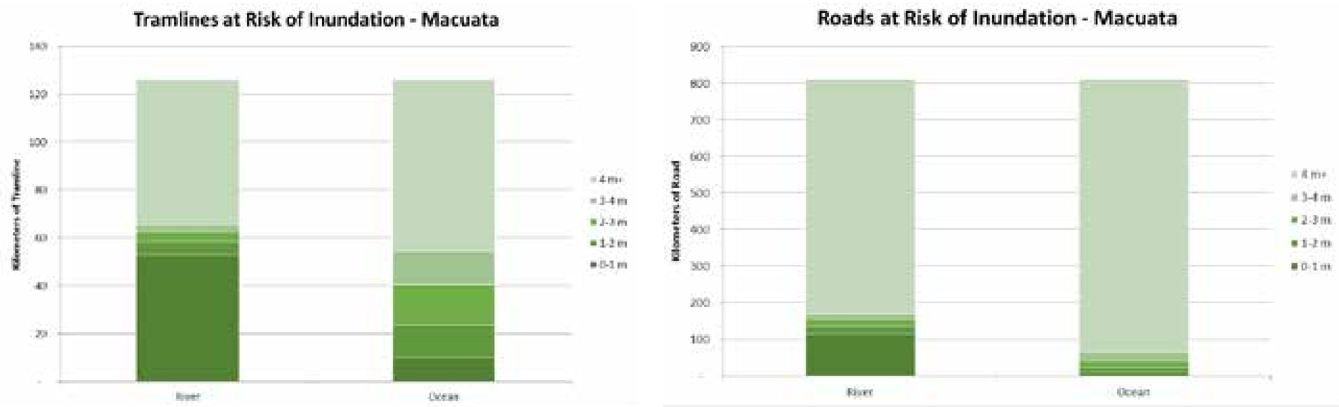


FIGURE 22. Tramlines (left) and roads (right) at risk from inundation due to flooding. Elevations are relative to stream elevation (river) and sea level (ocean).

4.5.2 Disaster response capability

Areas of low-lying roads are susceptible to flooding and erosion, which can limit disaster response; landslide-prone areas have the potential to block roads; and there are limited air-services and some dependence on ferry services to other islands. These, combined with the increased severity and general unpredictability of storm events, leave Macuata Province vulnerable to major storm events. Recovery can take months or even years in rural areas. The major town of Labasa is likewise at risk, with relatively low elevations on a coastal flat and several bridges at risk from floodwaters that may minimise or disrupt delivery of goods and services.

4.5.3 Community connectivity/geographic separation

Macuata Province has more capacity for self-reliance under extended periods of separation due to disaster than do smaller islands in Fiji. While it does have some reliance on goods and services originating on Viti Levu, there are fewer system redundancies (road networks, air and sea ports, water networks, energy, etc.) for transportation and energy than are found on Viti Levu. More specialised and skilled services, including important healthcare systems, can be an adaptive strength for Macuata residents. Adaptation strategies that improve self-reliance for Macuata and Vanua Levu overall will also support other smaller island regions of eastern Fiji under periods of separation or disruption.

4.5.4 Power grids and distributed energy

Macuata Province currently relies on a variety of energy sources, including hydropower, fossil fuels (diesel and kerosene) and emerging distributed generation using solar and biofuels. Currently, the primary sources of generation for the power grid in Macuata are the Labasa Power Station, which utilises diesel fuel with 11.24 megawatts of capacity, and the Wainikeu Power Station, which provides less than 1 megawatt of hydropower capacity (FEA 2015).

The Fiji Sugar Corporation is increasingly generating electricity based on biofuels during sugarcane harvests. This powers its own operations, as well as supplying the power grid. The Labasa Mill cogenerates 10 megawatts, with four for on-site use and six for sale to the Fiji Electricity Authority (Drauna 2015). Timber processing-related biofuels are increasingly under investigation and development for electricity generation. Such systems utilising locally-available fuel sources are resilient to exogenous price and supply shocks.

The feasibility and value of biofuel cogeneration also demonstrates the type of value and resilience offered by increased solar electricity generation for Macuata. Fiji's Department of Energy (DOE) has worked for over 15 years to expand solar generation for remote villages in Macuata, where connection to power grids is not feasible. DOE focuses on installation of solar home systems, which are sufficient to provide basic demands, including battery storage. While the systems involve government financing and ownership, rural residents are able to pay all operating and maintenance costs (DOE 2013).

4.5.5 Key drivers of change

The key drivers of change for Macuata Province transportation and energy 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.
- Price trends and shocks for fossil fuel imports.
- Emerging technological opportunities for locally-sourced distributed generation with alternative energy sources.
- Energy conservation and transportation efficiency technologies and opportunities.

Tramline across Labasa river, Macuata Province. Transportation and energy infrastructure are particularly vulnerable to storm, flood and erosion events. Photo: WPN.

4.6 ECOSYSTEM SERVICE VALUES

Fiji's functional ecosystems and natural resources provide a multitude of essential goods and services to residents and visitors, and form the core of determining community resilience to climate extremes and other factors affecting change. While it is impractical to compile a complete list of ecosystem services and their values, important examples 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 make 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 any at all, 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 principal 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 nonsensical. Therefore, budget constraints – 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.

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 they may be 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 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.

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. As such, these values should be considered representative rather than precisely accurate. This compilation of values represents a wide range of valuation techniques, including survey-based stated preference techniques, whereby people are asked how much they would be willing-to-pay, revealed preference techniques that use observable behaviours or indirect market expenditures (such as travel costs or real estate prices), and 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 10. Examples of 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 caveats and the utility of describing ecosystem service values by habitat type to those habitat types for Macuata Province, applying the de Groot values per hectare yields hundreds of billions of dollars (FJ) per year for the country as a whole and nearly one hundred billion dollars for Macuata Province (Table 11). The coral reef values dominate these values. Coastal wetlands in this table represent areas of mapped 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 11. Annual economic value of Fiji's ecosystem services by habitat type. Source of values: de Groot et al. 2012

		Republic of Fiji		Macuata Province	
Habitat Type	**Median value (FJD 2016)**	**Area (ha)**	**Value (FJD 2016)**	**Area (ha)**	**Value (FJD 2016)**
Coral Reefs	472,902	670,000	316,844,232,800	193,000	91,270,055,120
Coastal systems	63,946	NA	NA	NA	NA
Coastal wetlands	29,065	38,000	1,104,458,782	9,751	283,409,937
Inland wetlands	39,510	200	7,901,929	NA	NA
Fresh water rivers and lakes	9,410	18,100	170,325,431	2,419	22,763,382
Tropical forests	5,628	1,060,900	5,970,223,237	106,304	598,226,610
Grasslands	6,447	577,700	3,724,513,240	58,441	376,777,355
Total	NA	2,364,900	327,821,655,420	369,915	92,551,232,404

5. MANAGING CONNECTED LANDSCAPES: FRAMEWORK FOR EBA DESIGN

5.1 DELINEATING LANDSCAPES

As part of the ESRAM process, there was a need to identify logical boundaries for deploying EbA activities that meet common goals for communities, provinces, the nation, and outside funding sources and NGOs. To be effective land management units, boundaries also had to contain linked physical and ecological environmental processes, including the hydrology, soils and vegetation responses to climate change and climate extremes (e.g. ridge-to-reef connectivity). The obvious choice for a framework to link land uses and land-use changes with the environmental processes (and downstream consequences) are the catchment boundaries as currently defined (Figure 4, Table 1). Within these units, sub-catchments can be later developed with communities that identify common goals for management, or high-level goals for managing entire landscapes.

5.2 QOLIQOLI COKOVATA DIRECT IMPACT AREA

Management of the Qoliqoli Cokovata for future marine conservation is a priority issue facing Macuata Province. To be effective, it is important to recognise potential impacts from terrestrial sources and expand from stakeholders who are traditional owners of the qoliqoli and include communities that may have activities that ultimately affect the marine environment through land uses or management.

The Qoliqoli Cokovata direct impact area was delineated by watershed boundaries that are direct contributing areas to the qoliqoli. Stakeholder groups are mapped and summarised by tikina and watersheds in Figure 23 and Table 12. Also summarised is the 2010 LULC summary information for each watershed in Table 13.

Key factors associated with management design for future EbA activities is to view the connected landscapes of the direct impact area to Qoliqoli Cokovata and work with the suite of stakeholders in the catchment units to identify a range of potential activities:

- identify the limiting factors affecting communities access to ecosystem services;
- identify terrestrial factors and human activities on land that affect marine resources;
- identify and locate vulnerable locations where management is particularly sensitive;
- mitigation measures to improve ridge-to-reef functions;
- benefit-sharing within and among communities;
- development of long-term management goals;
- identify terrestrially-based projects that improve watershed function; and
- identify funding sources to implement activities.

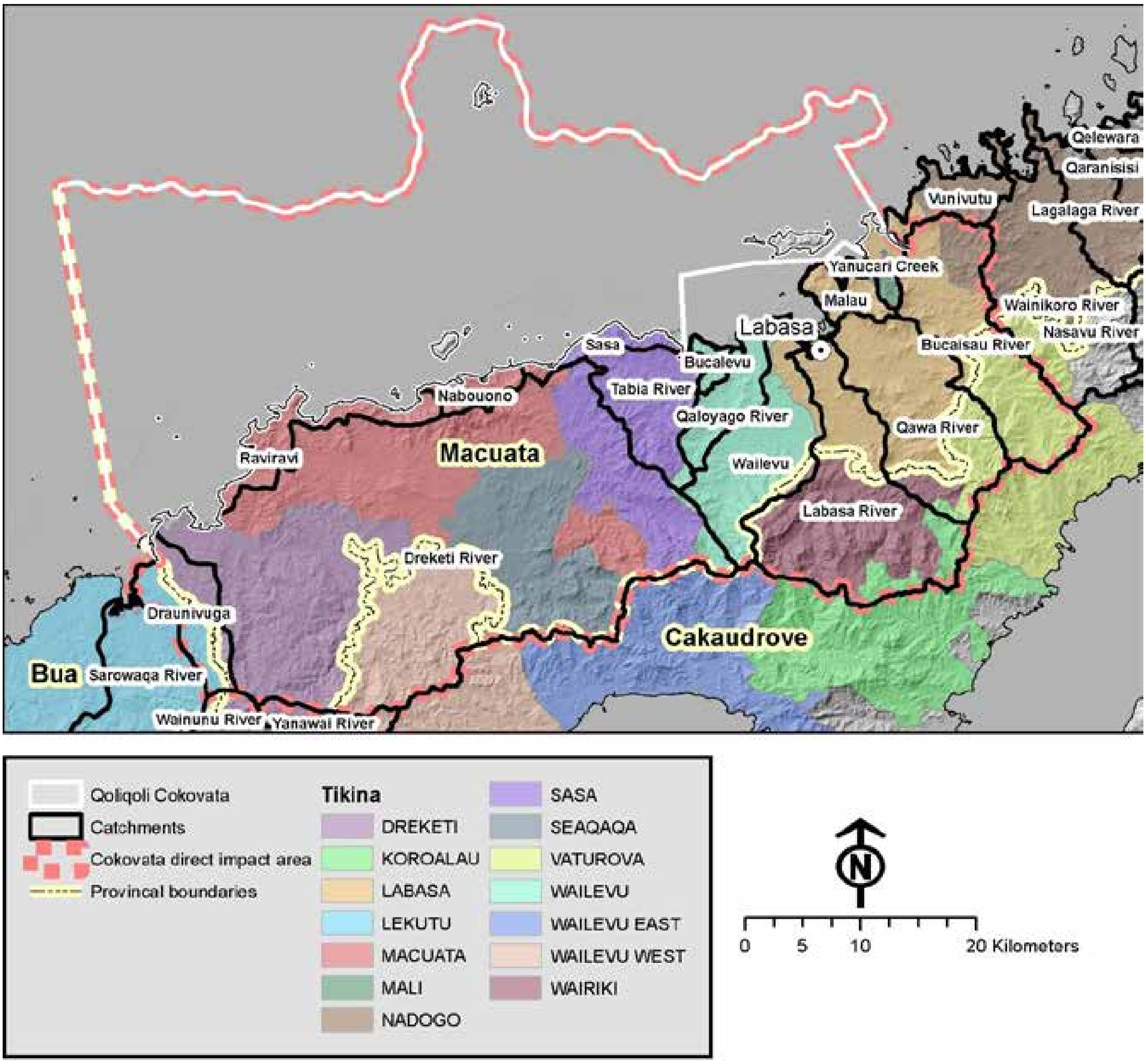


FIGURE 23. Qoliqoli Cokovata with adjacent river catchments and tikina.

TABLE 12. Major river catchments associated with the Qoliqoli Cokovata direct impact area (rows) and the percentage of the catchment area represented by each tikina (columns). Approximately 75% of the total catchment area is in Macuata Province, 24% in Cakaudrove Province and ~2% in Bua Province.

		Tikina													
Province		**Macuata**								**Cakaudrove**					**Bua**
Catchments	**Total Area (ha)**	**Dreketi**	**Labasa**	**Macuata**	**Mali**	**Nadogo**	**Sasa**	**Seaqaqa**	**Wailevu**	**Koroalau**	**Vaturova**	**Wailevu East**	**Wailevu West**	**Wairiki**	**Lekutu**
Bucaisau River	15,085	-	39%	-	-	15%	-	-	-	-	46%	-	-	-	-
Bucalevu	970	-	-	-	-	-	-	-	100%	-	-	-	-	-	-
Draunivuga	5,768	47%	-	-	-	-	-	-	-	-	-	-	-	-	53%
Dreketi River	84,928	26%	-	27%	-	-	11%	19%	1%	-	-	<1%	16%	-	-
Labasa River	20,659	-	23%	-	-	-	-	-	-	13%	-	<1%	-	64%	-
Malau	2,404	-	97%	-	3%	-	-	-	-	-	-	-	-	-	-
Nabouono	1,985	-	-	100%	-	-	-	-	-	-	-	-	-	-	-
Qaloyago River	4,114	-	-	-	-	-	-	-	100%	-	-	-	-	-	-
Qawa River	15,201	-	66%	-	-	-	-	-	-	2%	22%	-	-	9%	-
Raviravi	4,453	-	-	100%	-	-	-	-	-	-	-	-	-	-	-
Sasa	1,856	-	-	18%	-	-	82%	-	-	-	-	-	-	-	-
Tabia River	7,651	-	-	-	-	-	93%	-	7%	-	-	-	-	-	-
Wailevu	11,480	-	16%	-	-	-	-	-	79%	-	-	<1%	-	4%	-
Yanucari Creek	1,610	-	51%	-	49%	-	-	-	-	-	-	-	-	-	-
Total Area (ha)	**178,164**	**24,426**	**25,692**	**29,922**	**886**	**2,257**	**18,165**	**15,906**	**15,852**	**2,992**	**10,395**	**286**	**13,281**	**15,057**	**3,049**

TABLE 13. Land use/land cover (LULC) distribution among major watersheds within the Qoliqoli Cokovata direct impact area

Watersheds	LULC						
	Agriculture	**Agroforest**	**Forest**	**Grassland/ Shrubland**	**Settlement**	**Water**	**Total Area (ha)**
Bucaisau River	12%		49%	38%	<1%	<1%	15,085
Bucalevu	88%		<1%	12%			980
Draunivuga	3%	7%	46%	45%		<1%	5,797
Dreketi River	17%	1%	59%	22%	<1%	<1%	85,049
Labasa River	19%		60%	19%	2%	<1%	20,727
Malau	30%		17%	52%	1%	<1%	2,476
Nabouono		14%	23%	63%			2,006
Qaloyago River	40%		12%	48%	<1%	<1%	4,116
Qawa River	20%		51%	27%	2%	<1%	15,205
Raviravi	<1%	29%	12%	59%		<1%	4,524
Sasa	12%	27%	13%	47%	1%		1,878
Tabia River	22%	5%	39%	34%	<1%	<1%	7,651
Wailevu	52%	<1%	17%	30%	1%	<1%	11,493
Yanucari Creek	51%		23%	26%		<1%	1,635
Total Area (ha)	**35,607**	**3,688**	**88,143**	**49,773**	**941**	**470**	**178,623**

5.3 STAKEHOLDER INVOLVEMENT

An understanding of the key ongoing and successful initiatives that are operating in the province is a key pre-requisite to developing EbA options for Macuata Province. Successful projects will often build on pre-existing efforts. It became clear throughout the ESRAM process that a central need was to enhance the government's capacity to manage resources in connected landscapes, to help organisations guide how the many types of planned activities can include elements of protecting and enhancing ecosystem services, and to build long-term resilience into management decision-making at high political levels. Several tasks were identified that would help to understand and develop EbA options. These tasks included:

- meetings outlining the ESRAM findings;
- meetings and workshops with government stakeholders to identify constraints and how decisions are made within and among agencies;
- meetings and workshops with government stakeholders in Cakaudrove Province to address landscape management in areas that are shared with Macuata Province;
- prioritisation of methods to approach resilience in decision-making;
- workshops, interviews and meetings to identify key strengths and challenges in managing ongoing projects, plans and regulatory issues;
- site visits across the province: major and minor streams, coastal areas, mangroves, water sources, native forest areas, road networks, sugarcane plantations, commodity markets, energy and processing infrastructure, etc.;
- GIS and data reviews, where appropriate; and
- events, meetings and workshops with NGOs and other operators working on large and small donor-funded projects operating in the province.

Interviews and meetings were held at key ministry offices, headquarters and field offices of NGO implementation partners and Fijian consultants that work across Macuata Province. This provided an overview of the provincial landscape and the status of ongoing initiatives, and helped to narrow the EbA options to be considered. Additional meetings with government and organisational entities in Savusavu were conducted to better understand the capacity of Cakaudrove Provincial management in working across provincial boundaries in connected watersheds of Vanua Levu. Labasa served as a focal point for interviews, meetings and workshops with provincial governments, ministry representatives, NGOs and key partners.

During the past ten years, a large number of international organisations appeared on the Macuata landscape. While many pilot projects have been initiated, there has not been a commensurate increase in conservation success at the provincial scale, nor have there been clear and widespread elements of coordination between multiple projects and inter-provincial government collaboration for management across catchments, or within a single catchment. Typically, it appears that communities and government entities see projects come and go, depending on the focus of the implementing entity, shifting governmental priorities, and limited provincial government resources. Hence, long-term capacity-building toward resilience in ecosystem services at both the government and community levels is elusive.

Planning documents, particularly an important Natural Resource Management Strategy (NRMS) for Macuata Province, have been in place over the past few years and have provided a key resource for the direction of adaptive management currently under way. The NRMS is described as a working document, and there is good opportunity to build on past awareness-building to strengthen the strategy to include managing for resilience and provide central mechanisms for governance at the divisional level to transcend sectors and political boundaries.

Several themes emerged from stakeholder inputs and interactions, defining specific needs:

- 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 a 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, and make these available during the planning and implementation process for all proposed projects or interventions; this 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 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; and
- 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).

To address these needs at the provincial level, organisational EbA options will need to identify strategies and frameworks to guide and reinforce resilience of ecosystem services to individual choices and decision-making and climate extremes. These options should strengthen pre-existing efforts where possible, maximise current awareness campaigns, and build on strengths of existing capacity.

6. NEXT STEPS: DEVELOP EBA OPTIONS

The ESRAM process incorporated available data sources with interviews, community workshops, and field reviews to identify key vulnerabilities on the landscape. While site-specific data were not available in many cases, themes emerged that defined the circumstances and challenges associated with the supply and demand of ecosystem services for Macuata Province over time.

The following elements are recommended for the development of EbA options for Macuata Province:

- increase management focus toward resilience through ecosystem-based mechanisms, empowering government and central resources to manage across sectors and political divisions;
- employ adaptive management, where natural resource professionals can identify how actions and mitigations are increasing resilience, and apply working techniques and methodologies to avoid management-related problems;
- create opportunities to allow for individual, community and government decision-making to opt for resilience-based options over activities that degrade or make resources scarce;
- manage for connected landscapes, using existing and emergent watershed stakeholder groups; and
- develop activities that build on strengths in the community, supplementing training to add to existing knowledge, rather than making drastic changes.

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