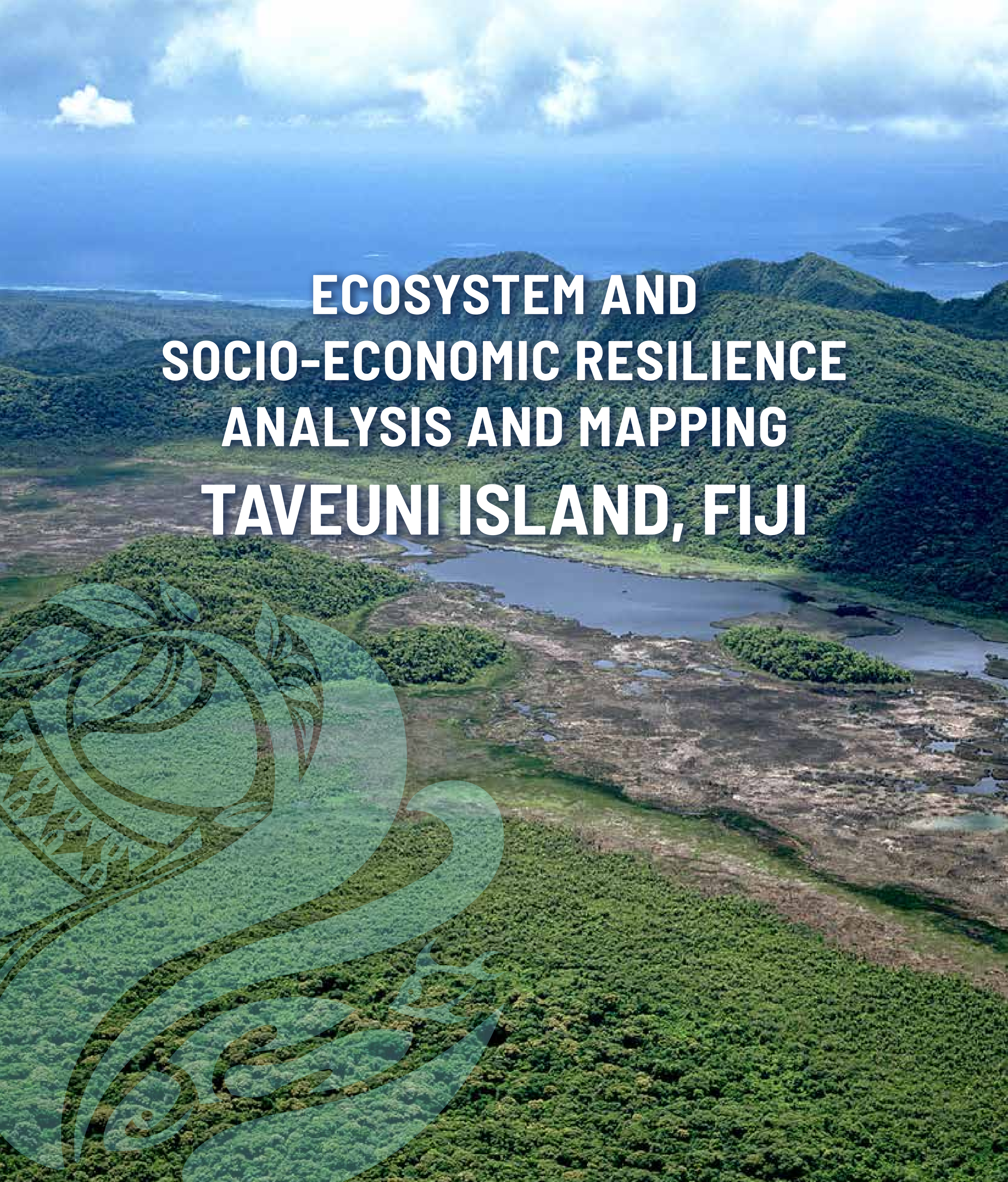
ECOSYSTEM AND SOCIO-ECONOMIC RESILIENCE ANALYSIS AND MAPPING

TAVEUNI ISLAND, FIJI



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

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ECOSYSTEM AND SOCIO-ECONOMIC RESILIENCE ANALYSIS AND MAPPING
TAVEUNI ISLAND, FIJI

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

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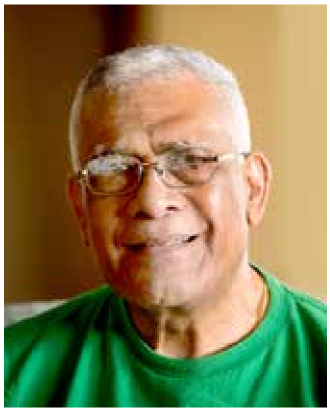
ACRONYMS

EbA	Ecosystem-based Adaptation
EEZ	Exclusive Economic Zone
ESRAM	Ecosystem and Socio-economic Resilience Analysis and Mapping
GDP	Gross Domestic Product
GIS	Geographic Information System
GCM	Global Climate Model
IKI	International Climate Initiative
LMMA	Locally Managed Marine Area
LULC	Land Use/Land Cover
MPA	Marine Protected Area
NDVI	Normalised Difference Vegetation Index
NGO	Non-Governmental Organisation
PEBACC	Pacific Ecosystem-based Adaptation to Climate Change
Rcp	representative concentration pathways
SPREP	Secretariat of the Pacific Regional Environment Programme
TC	Tropical Cyclone
UBA	Underwater Breathing Apparatus

GLOSSARY

Dalo	a starchy root crop, also known as taro (*Colocasia esculenta*)
Mataqali	traditional landowners, clans
Tabu	forbidden, usually with respect to use or approach
Vanua	traditional community chiefly structure, also as it pertains to local community
Yaqona	a root crop also known as kava (*Piper methysticum*)

FOREWORD



With the largest forest reserves in Fiji and host to a number of endemic species, Taveuni is considered a 'hotspot' for biodiversity and enjoys a small but thriving eco-tourism sector. Often referred to as the 'Garden Island', Taveuni is also blessed with high rainfall and fertile soils - features that over time have resulted in an influx of farming communities.

As this Ecosystem and Socio-economic Resilience Analysis and Mapping report points out, the development of Taveuni's agricultural potential has at times been at odds with the need to protect and conserve its high quality natural environment. Over zealous clearance of forested areas to plant dalo and yaqona in particular has led to a reduction in the ecosystem services provided by these natural assets. The most noticeable indicator of this is the periodic water shortages that the island now faces resulting from loss of forest cover in watershed areas. Not only does this impact negatively on the well-being and development status of local residents and businesses, it also places a constraint on the growth of our small, but important, tourism sector.

Climate change adds an additional stressor to some of the unsustainable land use practices that are already at play. Achieving a balance between environmental protection and economic development is never easy and climate change adds to this challenge.

The study informing this ESRAM report was conducted in a participatory and inclusive manner which in turn had the effect of sensitising our community leaders to the linkages between environmental management, tourism and agricultural development and the currently unsustainable development pathway that Taveuni finds itself on. The ESRAM was followed by an Ecosystem-based Adaptation Options Assessment study which in turn led to a major reforestation initiative being undertaken across the island under the guidance of the PEBACC project and in partnership with government. While we still have a long way to go, these are important steps in changing the course of development in Taveuni to one that is within the ecological limits of our natural environment.

I extend my thanks to SPREP for partnering with us in conducting these studies and for guiding us in strengthening our resilience to development pressures and climate change.

Ratu Naiqama Lalabalavu

Tui Cakau (Paramount Chief of Cakaudrove 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. The focus of this report is Taveuni island, and it emphasises seeking the drivers of change that create vulnerabilities from both climate- and non-climate related forces.

This report emphasises the following facts:

- Taveuni society is rural and there is a heavy reliance on agriculture for economic support.
- Intensive cash-crop dalo (taro root) and yaqona (kava root) farming has led to losses in soil fertility and productivity (80% decline per hectare).
- Agricultural expansion to meet national objectives for demand have led to an 11-fold increase in land area converted to dalo, including deforested areas and areas converted to agriculture.
- Historic and current land abandonment from failing agricultural yields has led to a widespread degraded condition that requires intervention.
- Key human-caused drivers of marine resource decline are overfishing and land-based pollution. Managing for connected landscapes for both land- and sea-based activities is needed.
- Extreme climate events, including Tropical Cyclone Winston, record rainfall and record maximum temperatures in 2016 have caused significant stress to forest and wetland ecosystems; the reserve areas are under threat of degradation.
- Ecotourism has been a steady source of income for communities; additional innovation with non-timber forest product items for sale could be another avenue to increase revenues.
- Climate change is expected to increase air and sea temperatures, sea levels and levels of ocean acidification – all forces that exacerbate the effects of human-caused challenges to natural resources.
- Taveuni communities have delineated 11 watersheds to manage as ridge-to-reef units, and have identified key values and actions to improve the environmental conditions and diversify their future choices for income and livelihoods.

Vuna coral reef, Taveuni. © Stuart Chape.

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 (PEBACC) project is focused to identify, prioritise and implement EbA strategies to meet critical needs in three countries (Fiji, Vanuatu and Solomon Islands) at three different scales: national, provincial and a focused island scale.

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

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

1. Ecosystem and socio-economic resilience analysis and mapping (ESRAM). A baseline study to identify vulnerabilities in ecosystem services at the national, provincial and community scales to identify needs for adaptation planning.
2. 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.
3. Implementation plans. A plan of action for deployment of funding and capacity support to be delivered at appropriate scales.
4. Implementation of EbA options. Commence activities according to the implementation plans, with monitoring and adaptation where appropriate.
5. EbA and policy implications. Synthesis of how EbA activities support community and resource resilience, and what successful approaches should be considered for future policies for the host country and communities.

This report presents the Taveuni island-scale ESRAM synthesis. The goals of the island-scale synthesis include a more focused analysis on natural resources and community-based linkages between environmental factors and the socio-economic fabric. The ESRAM analysis seeks to identify critical climate- and non-climate related drivers of change that threaten the sustained supply of ecosystem services to communities, offering a framework on developing EbA options to address those vulnerabilities.

1.2 FIJI IN CONTEXT

The Fijian archipelago is approximately 18,700 km^2 with ~80% 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% indigenous Fijians and 37% 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% of the EEZ borders international waters and the rest borders five Pacific island nations: the Republic of Vanuatu to the west, Solomon Islands to the northwest, the Republic of 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

Considerable efforts were made to gather existing spatial and quantitative data from a wide range of governmental and non-governmental organisations working in Fiji. This resulted in some summary information, with spatial data for Taveuni, but not across all sectors. Locally-based information was obtained from government officials, specifically with regard to agricultural lands and trends in the island's major crops. In general, there is generally low capacity for mapping or natural resource use tracking across Taveuni, including land use/land cover change. This document works towards consolidating what is known, as well as providing new information or new contexts about natural resources and challenges faced.

A major supplement to obtain necessary background information outside of sources based in Suva or Savusavu came from locally-based workshop activities, interviews, field site visits, and rapid assessments. Major outcomes included the following:

- land tenure process, outcomes and historic challenges;
- general community life and socio-economic circumstances;
- characterisation of historic use of natural resources through community frameworks;
- watershed delineation to identify connected landscapes as management units;
- processes to identify stakeholders in watersheds; and
- development of key goals and values for each watershed group of stakeholders.

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. The core of the approach for Taveuni involved the majority of landowners (by numbers and by land area) within their traditional community structure, or vanua, with the objective to build on current strengths and abilities, and define the appropriate level of engagement and the need of communities for resilient livelihoods. In many cases, the traditional vanua extended to include non-iTaukei stakeholders due to close family ties and general closeness of the island community.

Workshops were held in a central setting and later at the three district levels, which allowed for a focus on ecosystem and community dynamics across Taveuni, and within each district. This led to identifying specific sub-district boundaries around connected landscapes, where ecosystem service attributes, supply and demand were similar and relevant to stakeholders. Eleven watersheds emerged and workshops with community members focused on identifying broader groups of stakeholders to work as collectives in defining a suite of stakeholder values and needs.

Working as watershed groups, stakeholders self-organised around mapping activities; they discussed the current condition of resources in a sector-based way (agriculture, fishing and marine resources, forests, freshwater, community leadership, etc.) and identified vulnerabilities, strengths, opportunities and gaps. A working ‘desired future condition’ was formulated by these groups, with key priorities for meeting that future condition. Equipped with maps, watershed groups subsequently held community meetings with their broader group of stakeholders to solicit input and clarify the community vision, their priorities and their capacity strengths and needs.

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

Sea grass meadow, Naselesele village, Taveuni Island. © Tim Carruthers

2. OVERVIEW OF TAVEUNI ISLAND

2.1 GEOGRAPHY AND SOCIO-POLITICAL BOUNDARIES

Taveuni is the third largest island in the Fiji group (Figure 1), covering a land area of approximately 435 km^2, and is ~42 km long by approximately 10 km wide. The island is relatively young and volcanic in nature, with steep slopes rising to an elevation of over 1,200 metres, formed from basaltic volcanic island flows. Soils are relatively fertile for tropical soils, especially on the leeward (western) side of the island, which has contributed to it being referred to as the Garden island of Fiji. There are three upland protected areas: the Taveuni Forest Reserve (11,000 ha, designated 1914), Ravilevu Nature Reserve (4,000 ha, designated 1956), and Bouma National Heritage Park (3,800 ha, established 1991). The National Trust of Fiji, along with the Fiji Department of Forests, has advocated that these three contiguous areas be merged into the Taveuni National Park.

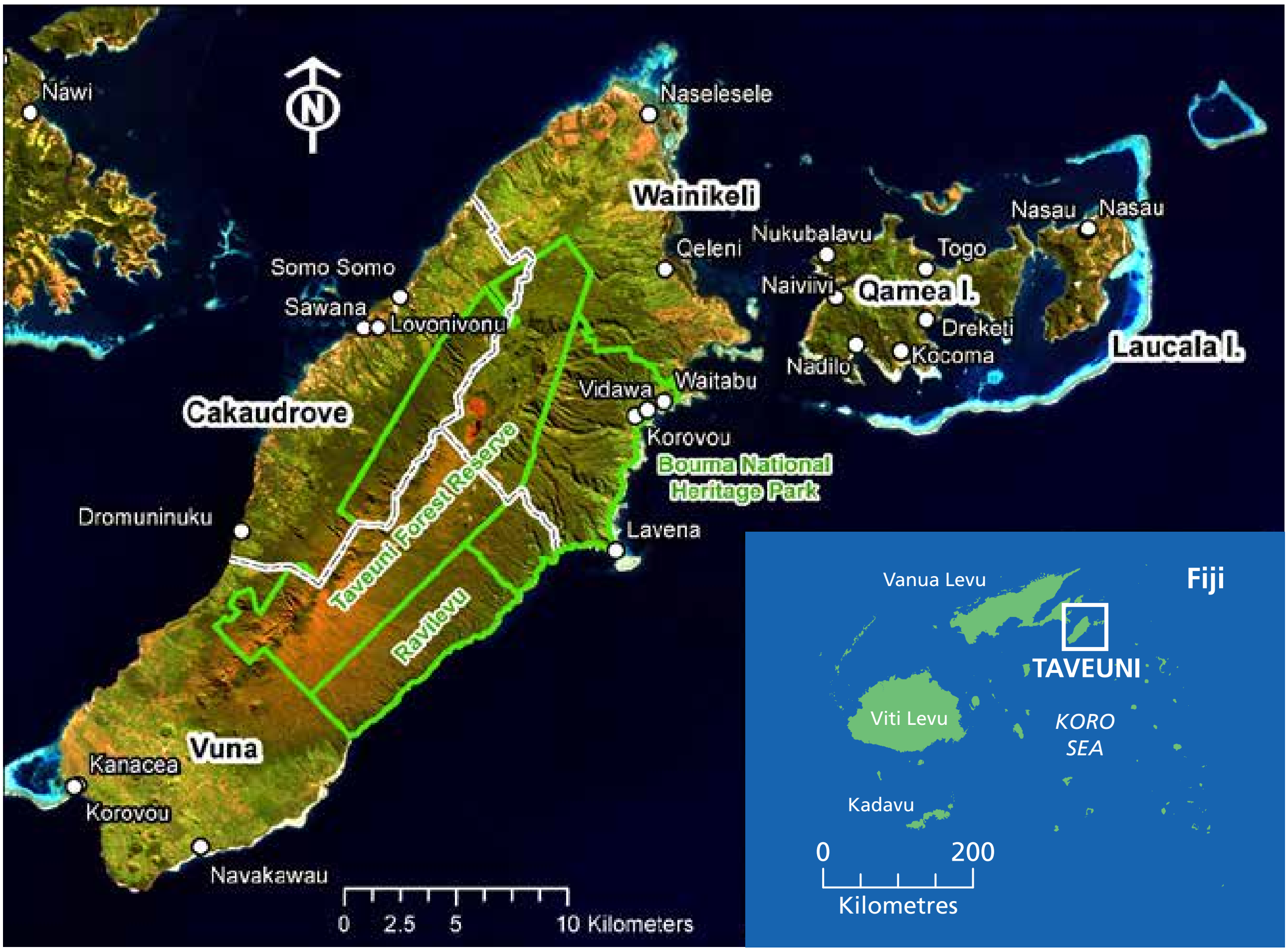


FIGURE 1. Map of Taveuni island with conservation areas outlined in green

Taveuni has three districts: Vuna to the south, Wainikeli in the north and north eastern section of the island (extending to Qamea island), and Cakaudrove District to the west (extends to Vanua Levu). Taveuni is within Cakaudrove Province, with the provincial seat in Savusavu on Vanua Levu. The total population is approximately 14,000, with a growth rate of 1.9% over the last twenty years. 75% of the population are indigenous Fijians[1]. Village data collected in March 2015 indicates that men outnumber women by ~5%, with an island average of 47% female and 53% male (Ministry of iTaukei Affairs), which is slightly more male

[1] Figures derived from the 2017 National Population Census.

dominant than the national ratio (48.8% female, 51.2% male). Overall, the population age is bimodal, with peak populations in youth (6–14 years old, 20%) and middle-aged adults (36–65 years old, 65%); nearly half of the population is of working age (22–65 years old, 44%), with even distributions across the districts (Figure 2).

Most of Taveuni island is considered rural, with town centres in Somosomo, Naqara and the administrative seat of Waiyevo.

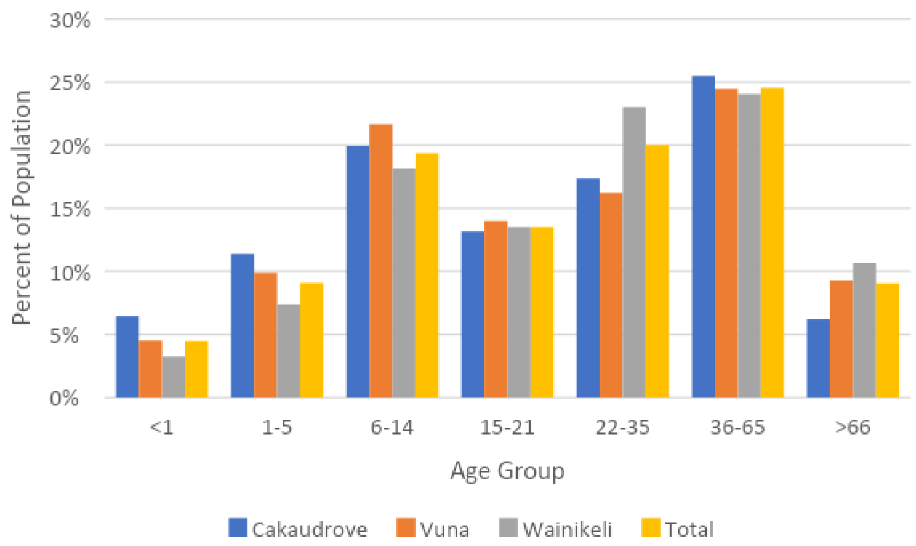


FIGURE 2. Population age distribution for the three districts and Taveuni island as a whole. Source: Ministry of iTaukei Affairs (unpublished).

2.2 LAND TENURE

Land uses, and land stewardship, follow land tenure practices. As elsewhere in the Pacific region, Fiji has had a long history of customary (iTaukei) land ownership, where land areas and traditional fishing grounds (qoliqoli) are retained by right to a clan-based system (mataqali)[2] as the core unit, and is further divided into families and individuals within the clan. As a legacy of the colonial period, approximately 80% of the land area of Fiji was retained by the iTaukei, with some allocated to the state (~7–10%), and the remainder as legacy freehold lands (~8–10%) 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 on Taveuni is markedly different from the national; iTaukei land represents only 54% of the land area, with 33% freehold land and the remainder 13% state land, including those designated as reserve areas (Figure 3). Land ownership is distributed among many landowners, with concentrations in freehold residential development estates near Dromuninuku, and wide swathes in the Vuna District. There are many small (~3–10 ha) freehold landowners as well as large, corporate landowners who have contiguous ownerships that span both sides of the island. Generally, increasing numbers of landowners leads to increased fragmentation of land uses, given that each landowner has different objectives and timeframes for management.

[2] See Fiji national ecosystem and socio-economic resilience analysis and mapping, SPREP 2020, for additional details.

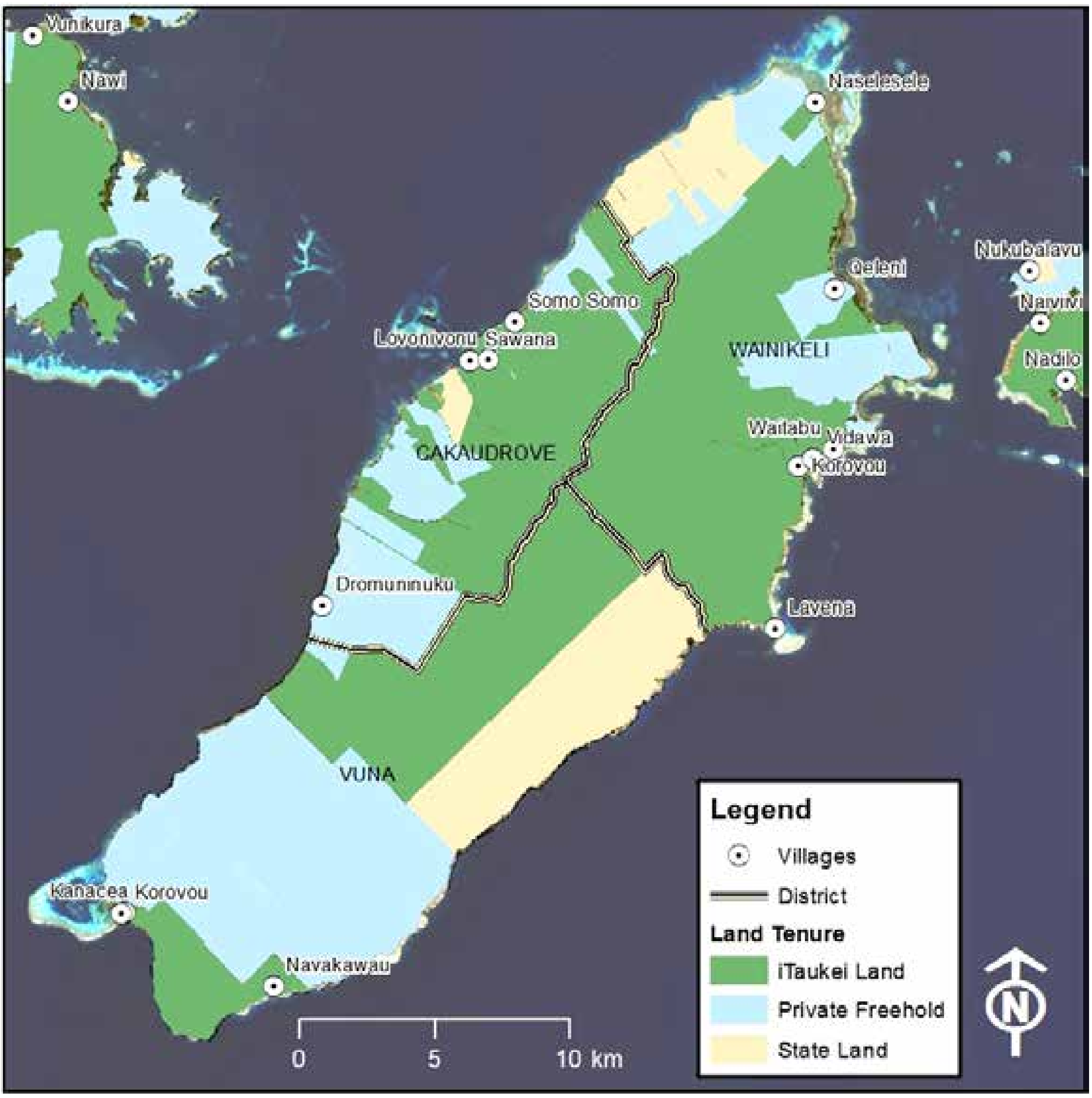


FIGURE 3. Land ownership distribution of Taveuni island.

Complicating matters of land ownership and land-use change is the practice of land leasing, where leases can be established lasting for brief periods and extending up to 99 years, depending on the type of lease and primary use. Most leases are registered with the government (as per regulation) and provide for limited intervention by landowners during the lease period; some leases are not registered and are operating under direct agreements. Most agricultural leases on Taveuni 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 decades to a century ago through agreements with corporations. This is a common observance 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. For example, the iTaukei community of Welagi on Taveuni recently purchased freehold lands adjacent to their traditional landholdings. The community established a series of lease agreements with non-iTaukei residents to farm, with the requirement that lessees plant native forest in the upper reaches of these landholdings, and that any standing trees cannot be felled without prior consent.

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 Taveuni.

2.3 DRIVERS IN THE FORMATION OF TODAY'S LANDSCAPE

Long-term leases (i.e. 66 and 99-year terms) on Taveuni that have expired in recent years were generally large land areas, did not have safeguards in place, and the current condition reflects a broadly degraded and fragmented land condition. The cycle of deforestation and conversion of forestlands to a period of agriculture, followed by abandonment is especially observed for lands cleared for coconut/copra production during a Pacific-wide market boom that subsequently collapsed (ca. World War II era). These lands are now primary areas that landowners have identified as priorities for rehabilitation or land uses that can provide some diversity of economic gain; increased awareness of ridge-to-reef functions have also led to interest in reforestation activities, including plantations and agroforestry.

Long-term land leasing to maximise resource extraction has effectively 'locked in time' land uses that may have been economically viable in the past, but offer few incentives to improve conditions through direct investment. Long-term stewardship of ecosystems services by lessees is generally not a priority, as the land use is deemed to be only temporary and all incentives appear to favour extracting the highest value from the land in the shortest timeframes.

Reversing the trend of land conversion from forestlands to abandoned and degraded agricultural lands is not generally economically viable for a lessee who would ultimately have to return the land to the owner. In many respects, this has led to a sense of disenfranchisement by lessors (landowners) on Taveuni receiving degraded lands and having few choices regarding what is within their capacity to accomplish on those lands after their return.

Based upon outreach and workshop activities from this project, communities on Taveuni are faced with an emergent question on defining stewardship of the landscape, especially how land-use practices can produce long-lasting benefits to communities. For many degraded lands on Taveuni, this will require long-term and steady investment in time and resources to restore ecosystem functions, as well as changes in land uses to avoid further degradation of ecosystem resources.

Aside from historic conversion of lands and potential re-establishment of coconut plantations, trends in recent decades (>1990s) have brought a considerable wave of expansion of agriculture to Taveuni. Land conversion from native forest or degraded lands to agriculture has been widespread across Taveuni, although changes are not known to be mapped (see section 4.1). In large part, this expansion is due to small-lot farmers who have found leases or have purchased small parcels of freehold land. Many of these farmers sought opportunity on Taveuni when agricultural land leases expired and were not renewed in neighboring Macuata Province (mostly sugarcane farmers), to meet a booming demand for dalo (taro) and yaqona (kava root). Local communities likewise increased production and land areas to meet the significant demand for Taveuni farmers to produce 60–70% of Fiji's dalo for export, which was introduced as a national goal to facilitate higher capacity dalo farming (Tei Tei Taveuni unpublished and Ministry of Agriculture, unpublished). This dramatically shifted the role of agriculture from subsistence toward small-scale, semi-commercial ventures.

The success spread with a rapid rise in dalo and yaqona farming over the past 20 years, with small-scale farms moving upslope into forested areas soil where nutrient capacity was enough to maintain high rates of production. Mechanistically, this cycle often begins with logging of valuable trees and planting of high-value and shade tolerant yaqona in shade break areas, followed by removal of the overstory trees within 1–3 years of planting yaqona. Dalo is interplanted with yaqona and later converted to dalo monocropping, with a six-month rotational harvest. This highly extractive form of agriculture creates a feedback loop of declining forest, declining yield, and diminished soil nutrient properties that have fundamentally changed the landscape potential at large scales. Local NGO groups (Tei Tei Taveuni) and the farming community have been making strides in shifting to organic practices; although cost/yield efficacy has been described as variable.

Data gathered by the Taveuni Office of the Ministry of Agriculture documents that, overall, dalo production rates have dropped from 30 to less than 7 tonnes per hectare (a four-fold decrease from peak production) over the last 20 years (Figure 4). To meet the high demand for export, cultivated lands increased from less than 100 ha in 1994 to 1,150 ha in 2013 (more than an 11-fold increase). This is mostly observed through incremental and progressive movement upslope by small-scale farmers into intact forest lands to reap short term (3–5 years) benefits from nutrient "pulses" released from forest soils before witnessing further decline, causing eventual abandonment and a repeat of the cycle. Land areas in Taveuni's restrictive Blue Line forest conservation area have been converted to agriculture in recent years, resulting from 'poor soil fertility' (as described) found in the lowland areas.

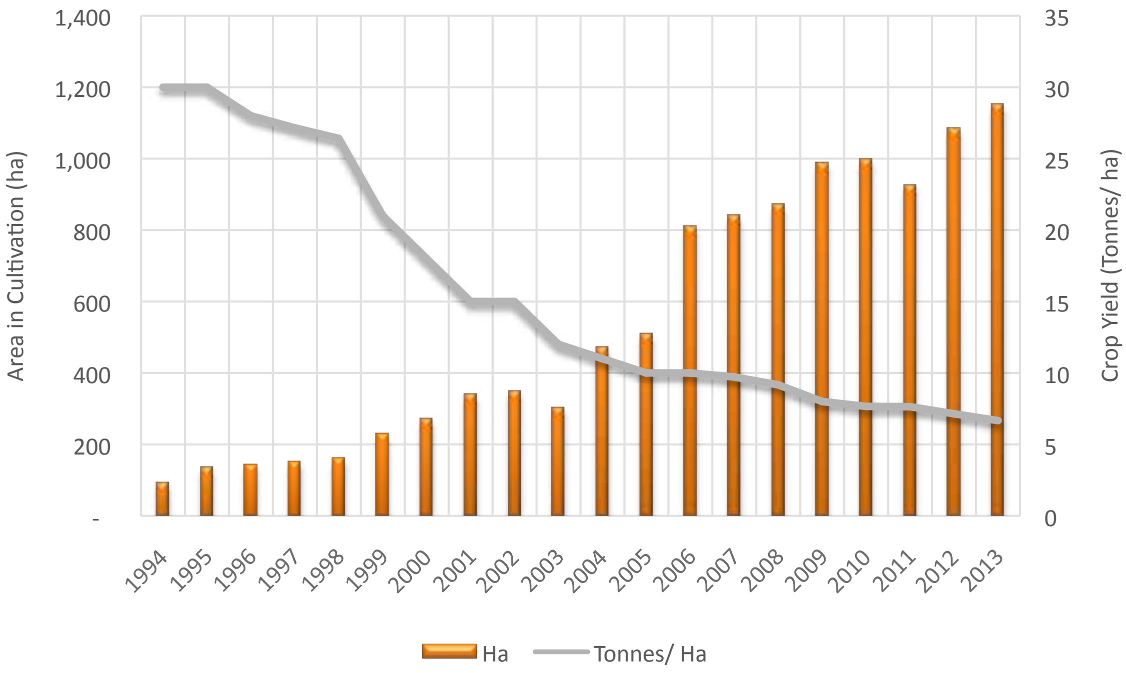


FIGURE 4. Dalo production area and productivity for a 20-year period.

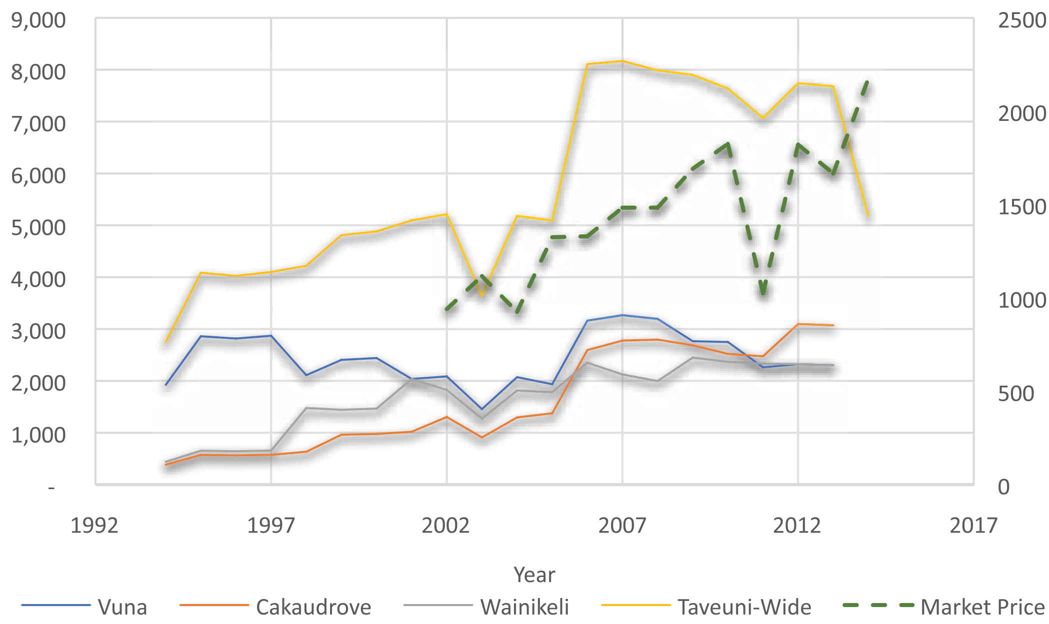


FIGURE 5. Total dalo production and market price trends. Not all years are populated. Source: Ministry of Agriculture, unpublished data.

The cycle of decreased productivity and declines in total tonnes of dalo is actively leaving many farmers on small freehold (or iTaukei) parcels with unfertile soils and few options. Further consequences of forest loss and observed changes in rainfall, coupled with climate change, has made lands for many farmers impossible to cultivate beyond basic subsistence. Narrowing of options to make a steady income is causing widespread migration into upper elevations (through formal lease agreements or not) to continue production, further continuing the cycle of deforestation, degradation and abandonment. This cycle of forest conversion to agriculture and abandonment continues at unknown rates for Taveuni, and is a widespread condition across the tropics. It has been reported by the Intergovernmental Panel on Climate Change to be the leading cause of forest loss worldwide for decades. Notably this is directly tied to the economies of local farmers and their lack of economic alternatives in rural areas.

For human-caused events, in large part the landscape of Taveuni was shaped through historical deforestation and conversion by agricultural boom cycles – from copra and sugarcane in the late 19th and early 20th centuries to dalo and yaqona in recent decades. Climate change issues are discussed in Section 3 below.

2.4 FISHING AND MARINE RESOURCES CIRCUMSTANCES

Taveuni has several customary fishing rights areas (qoliqolis), including Naselesele, Lavena, Waitabu, and Bouma, containing extensive mudflats, seagrass patches, small fringes of mangroves, and a few small areas of fringing reef, primarily off the northern islands and in the southern part of the island (Figure 6). The barrier reef is located far from shore, and small, isolated patches of fossil coral and beach rock dot the coastline. Taveuni is a diving destination for tourism, catering to SCUBA enthusiasts. Three distinct reef-diving areas exist: North islands, Somosomo Straits and Vuna. To the northwest are the islands of Qamea and Matagi with large surrounding reef ecosystems that are fished by local villages, including Dreketi, Kocoma and Togo. To the west, in the Somosomo strait between Vanua Levu and Taveuni, is the horseshoe-shaped and world-renowned Rainbow Reef system, a premier soft coral dive area (Figure 6).

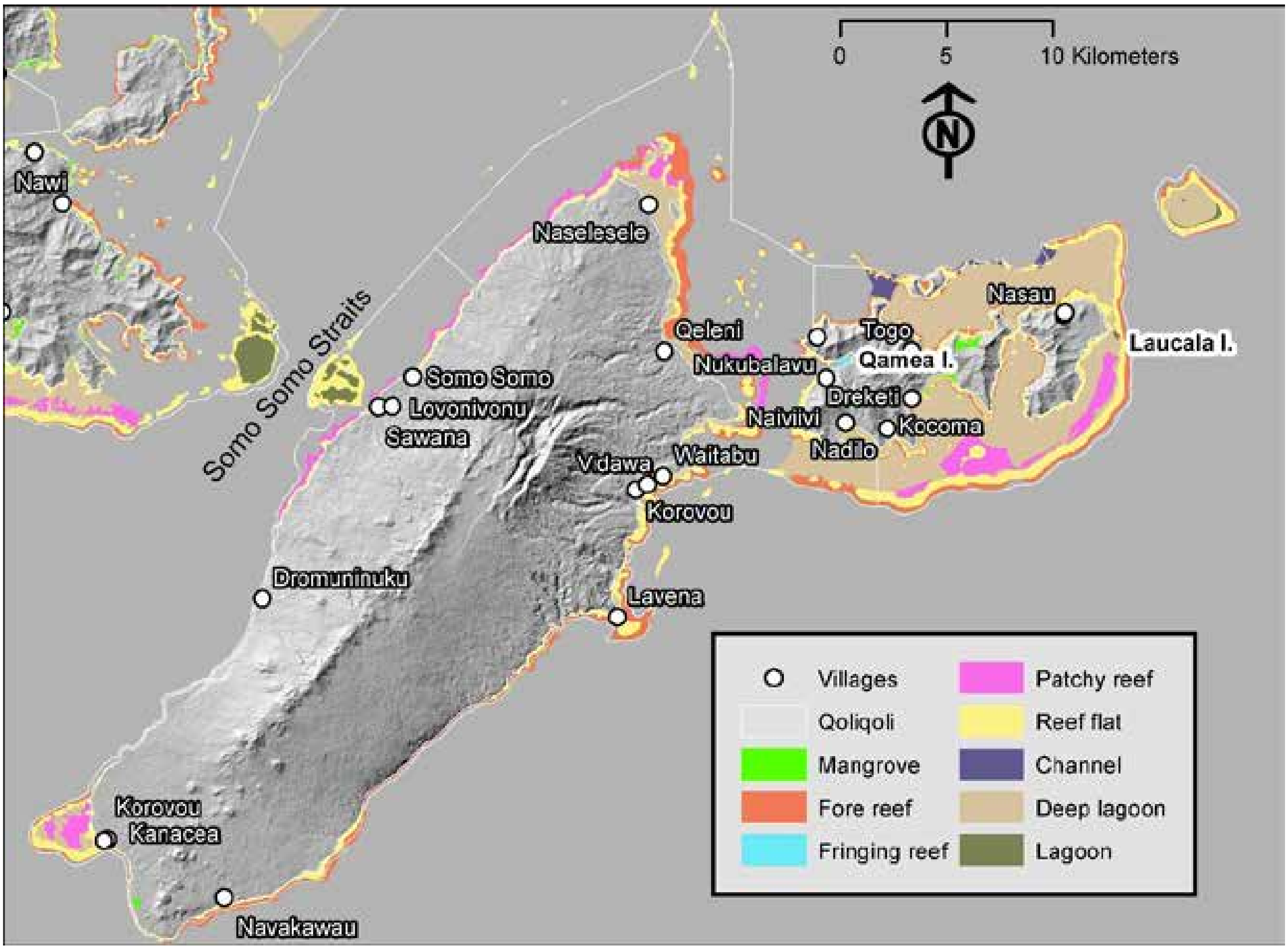


FIGURE 6. Taveuni, Qamea and Laucala island reef and qoliqoli environments.

Reef condition in Taveuni is generally considered better than in other parts of Fiji, but overall marine resources are declining and degrading, except within protected areas. One survey found reefs in good condition (Yanuca), fairly good (Naselesele), and poor and heavily impacted by sediment (Vunitarawau) (Yakub *et al.* 2011). The condition of Taveuni's reefs 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 steady and pulses of sediment; and
- constant small-scale and commercial fishing pressures degrading coastal habitats.

Surveys across the island have noted that the absence of holothurians (sea cucumbers, or bêche de mer) is possibly linked to overfishing by local communities for commercial purposes. At extensively damaged sites such as Vunitarawau near the village of Qaleni, heavy siltation from coastal erosion and land run-off has had a noticeable effect on the algal biodiversity and distribution, with plants occurring in small isolated clumps, often exhibiting stunted growth, possibly due to lack of nutrients and poor light intensity. Locally polluted sites with domestic wastewater run-off or porous and shallow coastal terrace soils (e.g. Naselesele) had blooms of indicator green algae. The relatively inaccessible, remote Rainbow Reef offshore is less affected by fishing and terrestrial run-off, and schools of snappers and fusilier are common. The severely endangered humphead wrasse is sometimes seen (two seen in 2010 and 2013). Rainbow Reef is one of the few places where large giant clams are visible.

Recent conservation mechanisms have been put in place, including a recent ban (December 2016) by Department of Fisheries on harvesting using underwater breathing apparatus (UBA), both for health issues associated with UBA and for expanding searches to less accessible habitat areas. Also banned is the selling and export of sea cucumbers, although subsistence harvesting remains legal. These measures and increases in capacity for locally managed marine areas (LMMA) are positive steps toward potential recovery, if implemented and enforced.

Threats to Taveuni's seagrass and mangrove forests originate on land from small-scale agriculture and conversion of forestlands to other land uses. Firewood and pole harvest of mangroves and filling of sediments from upland areas may also be contributing factors to the decline in health. In response to declines in giant clams, reef fish, sea cucumbers and sea turtles, a few areas were designated or considered for protection. In 1998, Waitabu Village declared its qoliqoli as a no-take tabu area, in response to heavy overfishing and expanded these areas in 2017. In 2005, the vuna tokatoka (subclan) and mataqali (clan) leaders declared a tabu no-take marine protected area (MPA) in the Vanua Vuna Qoliqoli, with an eventual view to developing the area for tourism and aquaculture projects. However, the after effects of Tropical Cyclone Winston in 2016 have taken a toll on site accessibility and appeal for tourism, as well as priority commitments for communities to rebuild homes and infrastructure.

There appears to be a growing and widespread understanding that land-based activities and overfishing affect fishing resources. However, economic pressures, the need for food subsistence, and a customary view of the sea as a provider has deferred progress. Increasing awareness of connected landscapes and linkages between land- and sea-based activities is an important mechanism to reinforce for improving total ecosystem health and sustainable livelihoods.

2.5 ECOTOURISM AS A CONSERVATION MECHANISM

In addition to the creation of the three upland conservation areas and marine protected areas with local tabu areas, communities on the eastern coast of Taveuni have been active in developing ecotourism opportunities to provide some financial gain from conservation. The three land-based tourism activities are widely advertised and encouraged on the island: Tavoro (Bouma) Forest Park offers hikes and waterfalls, Lavena Coastal Walk offers a long coastal walk through forest and river areas, and the Waitabu Marine Park offers kayaking, snorkeling and beach experiences.

Recent data (July 2015–May 2017) from the Tavoro Forest Park Cooperative showed steady monthly visits averaging 500 people mostly from overseas. This provided steady annual revenue of FJD 123,000 for that time period (Figure 7). This is a significant increase from previous years; revenue from July 2011 to June 2013 was FJD 79,000 and FJD 83,000 for each 12-month period, mostly from park fees (~92%) with minor sales in merchandise (~7%) and event services (~1–2%). Part of the recent increase was due to increases in entry fees for foreign visitors (FJD 15 to FJD 30 in 2016). Data also showed total operating expenditure of approximately 67% of revenue (38% profit margin), with nearly half (45%) of expenses accounted as direct wages to community members, with the profit margin distributed for community-level priorities.

Financial data were likewise provided by the Lavena community's coastal walk tours between July 2015 and June 2017 (Figure 8) with additional summaries from earlier years. Lavena is furthest from the hotels and is known to be a good activity for the more active tourists. Overall revenue for the time period showed months of no activity and an annual income of FJD 45,000. Lavena was greatly affected by TC Winston in February 2016, resulting in months of inaccessibility and revenue losses. In the years 2011 to 2013, Lavena income was similar to that at Tavoro (~FJD 90,000) with similar margins.

All three areas are subjected to extreme climate events, particularly storms and flooding. In Waitabu Marine Park, exposure is high along the coastal edge and damage to the community infrastructure detracted many tourists, although no data were made available. The route of the Lavena Coastal Walk follows the coastline and crosses rivers at or near their mouth but TC Winston effectively wiped out routine trail maintenance and improvements. Lavena is among the wettest areas on Taveuni, with steep terrain and high flows during heavy rainfall events. Given the record-setting rainfall events of 2016, restoration and maintenance of the coastal walk infrastructure has been a challenge. Overall, the community has relied on this income to fund and support village needs, and to further increase awareness for conservation and, considering recent events, the impacts of climate extremes.

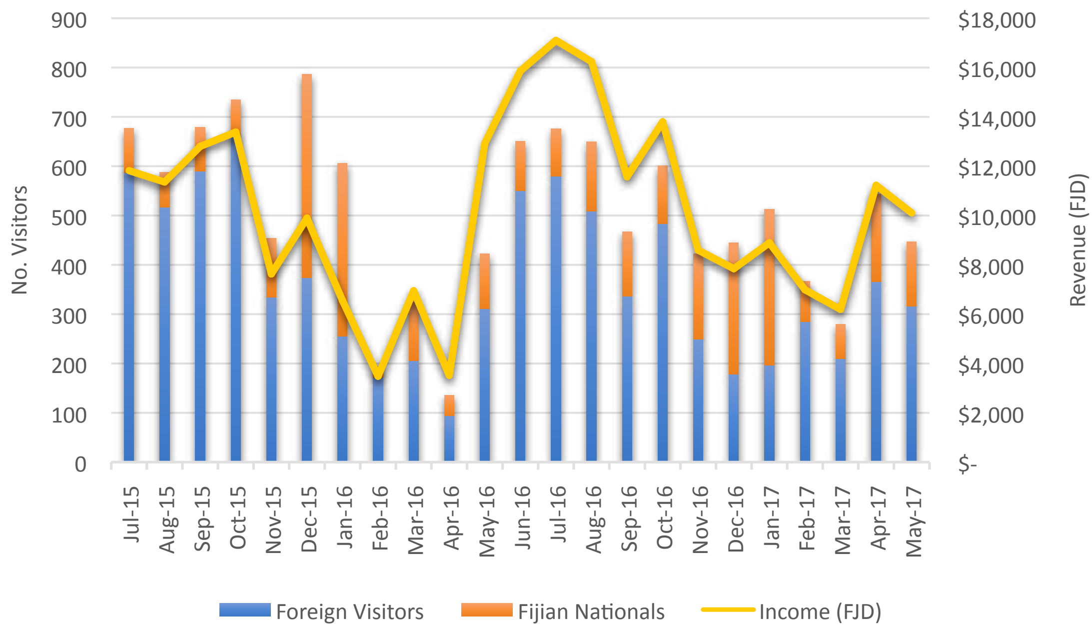


FIGURE 7. Ecotourism visitors at Tovoro Forest Park Cooperative, and total monthly revenue from 2015–2017.

Note: TC Winston occurred in February 2016.

Tourists interviewed at the three areas on Taveuni in 2017 said that, while they were willing to buy souvenir merchandise, the selection and supply was not satisfactory. Some tourists noted that the damage from TC Winston had not been repaired, and said that if a local programme or fund were in place, there would be enthusiasm for even minor financial donations to support the recovery effort.

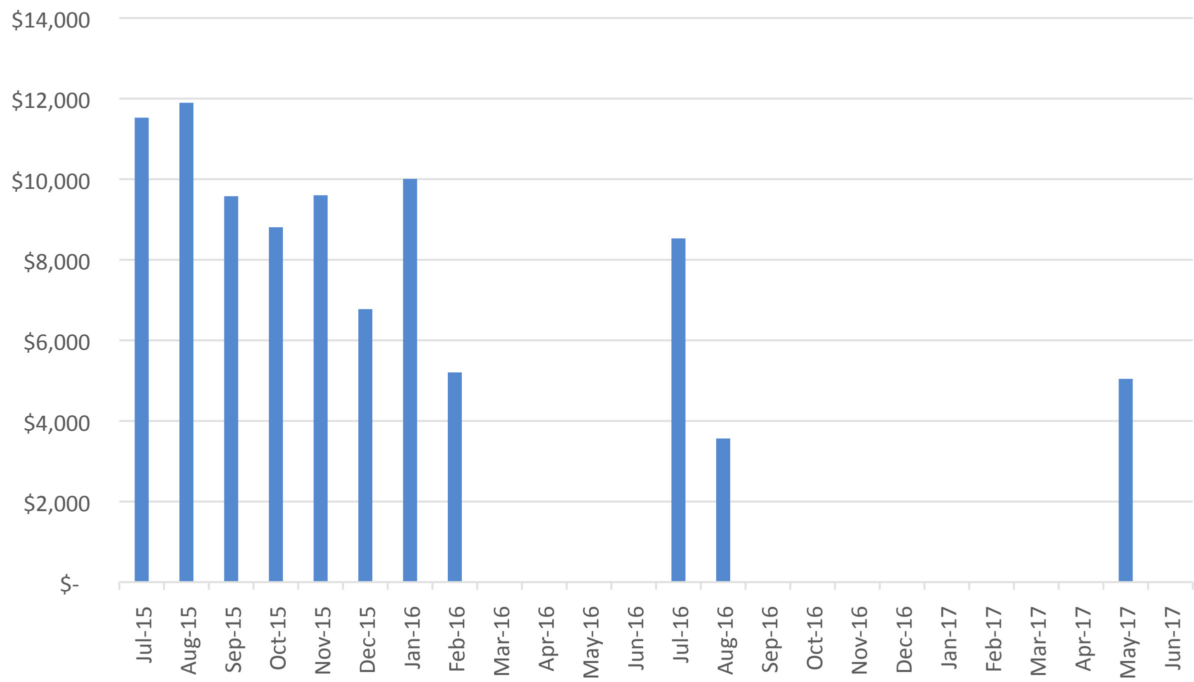
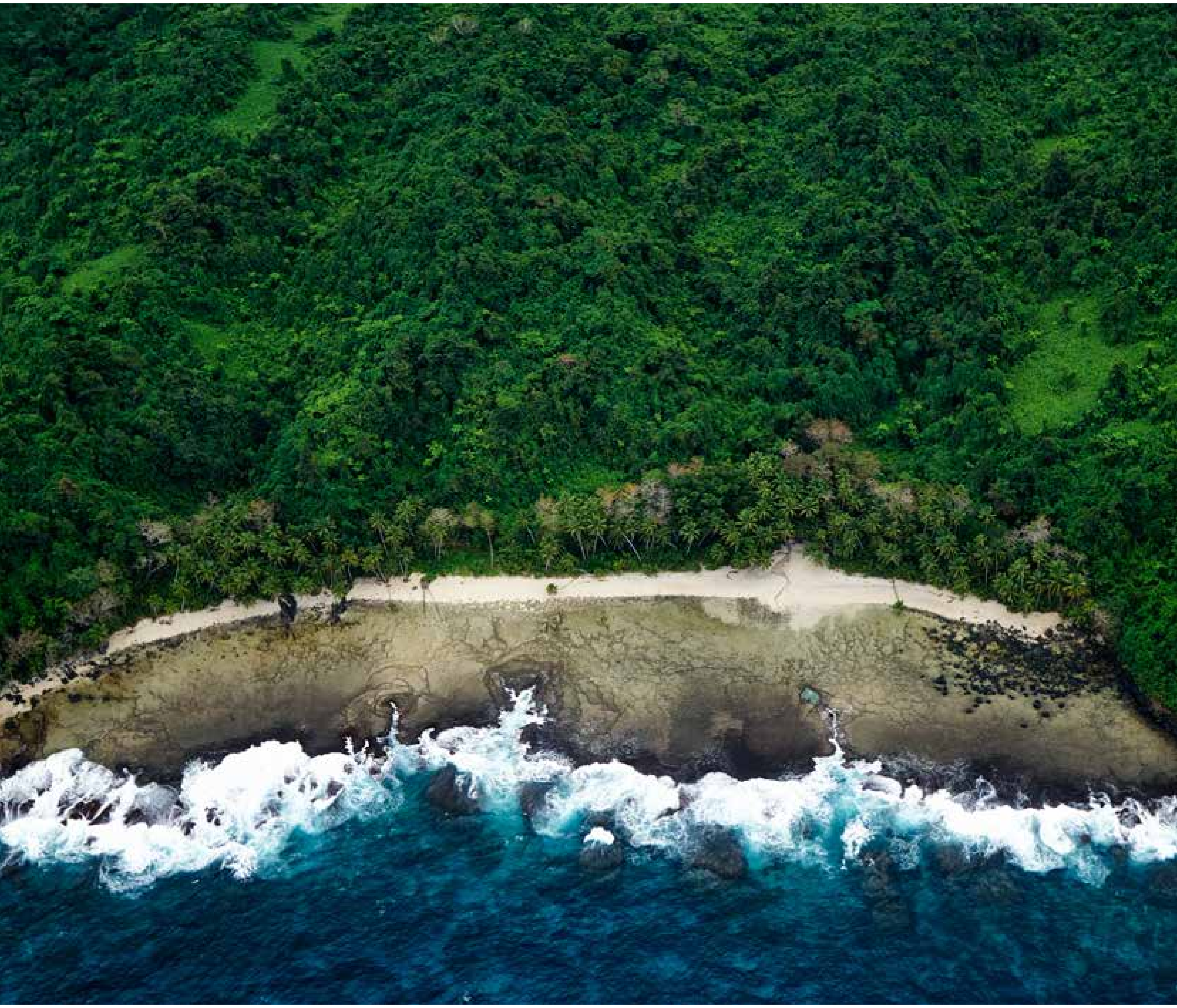


FIGURE 8. Revenue for the Lavena Coastal Walk, July 2015–June 2017, where data were available. TC Winston occurred in February of 2016 and had a marked effect on tourism.



Protected area, Taveuni. © Stuart Chape.

3. CLIMATE, CLIMATE CHANGE AND EXTREMES

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 coasts the average night-time temperatures can be as low as 18°C and the average daytime temperatures can be as high as 32°C. Past records, 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 southeast trade winds result in the main islands having pronounced dry leeward zones in the north west and wet windward zones in the south east (Hijmans *et al.* 2005). Tropical cyclones and depressions can cause high winds, especially from November to April. The wet season in Fiji coincides with the period of cyclonic activity (November to April), with dry conditions for the remainder of the year. Rainfall patterns are controlled primarily by the north and south movements of the South Pacific Convergence Zone, the main rainfall producing system for the region, with much of the rain falling in locally heavy but short-term periods. Mean annual rainfall for the country is less than 1,800 mm in leeward coastal areas and 3,500 mm or more in the mountains. Taveuni is on the wetter end of the spectrum, ranging from 2,400 to 3,200 mm of annual rainfall.

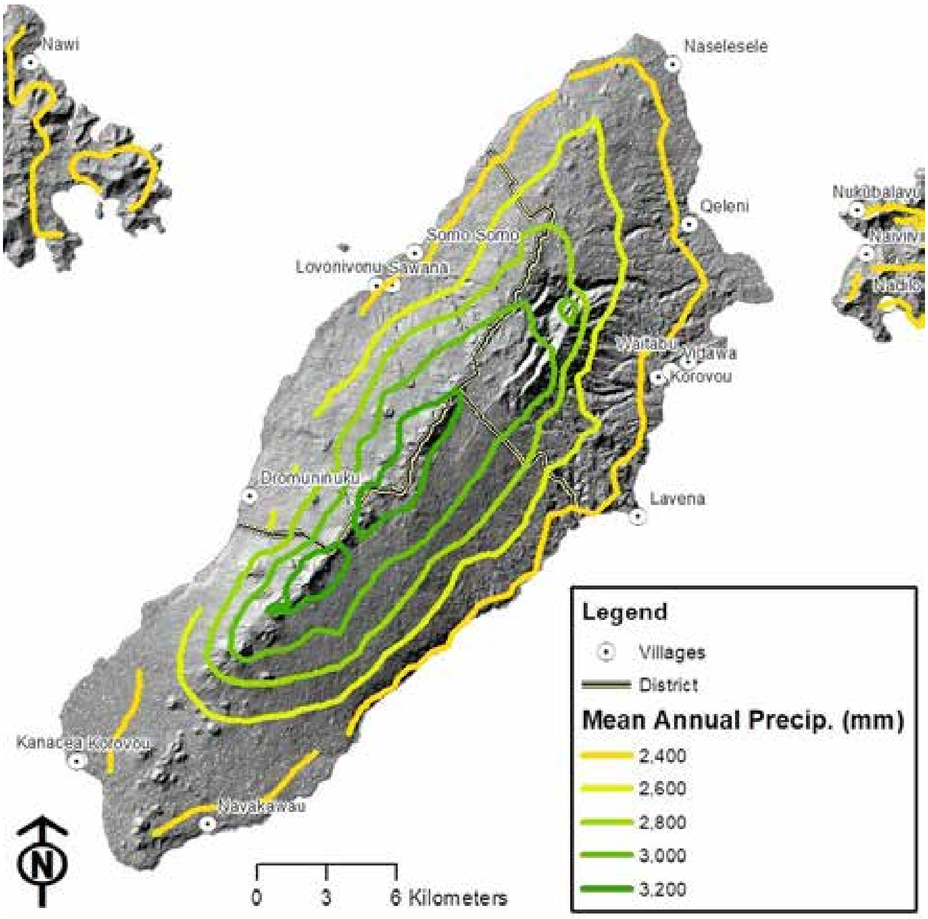


FIGURE 9. Mean annual precipitation isohyets for Taveuni island. Source: Fiji Meteorological Service 2006.

Flooding is common in low-lying areas during most years, causing damage to roads and an increased potential for landslides (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 or depression. In late February 2016, Tropical Cyclone (TC) Winston, the most intense cyclone on record to affect Fiji, made landfall on Taveuni, causing extreme destruction of infrastructure and crops. The communities along the windward side were hardest hit, especially those in Vuna District and Wainikeli. Rainfall totals at Matei airport in the north recorded the highest single day rainfall event in 60 years – 325 mm in a 24-hour period on 23 February – exceeding the historic average monthly totals for the period of record. Two other historic single day rainfall records were set in 2016: on April 16 and December 17 (357 mm and 254 mm, respectively).

In addition to extreme and record-setting rainfall events in 2016, severe drought and record high monthly maximum temperatures affected Taveuni. February saw record high temperatures of 33.5°C in the weeks before TC Winston and there was also a record maximum temperature of 31°C in September. Drought conditions during May–September led to water rationing.

3.2 CLIMATE CHANGE PROJECTIONS

The Pacific Climate Futures[3] 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 Programme[4] and the Pacific-Australia Climate Change Science and Adaptation Planning[5] (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[6] 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, 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.

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

4 https://www.pacificclimatechangescience.org/

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

6 http://www.ipcc.ch/

Figure 10 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 centered 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.

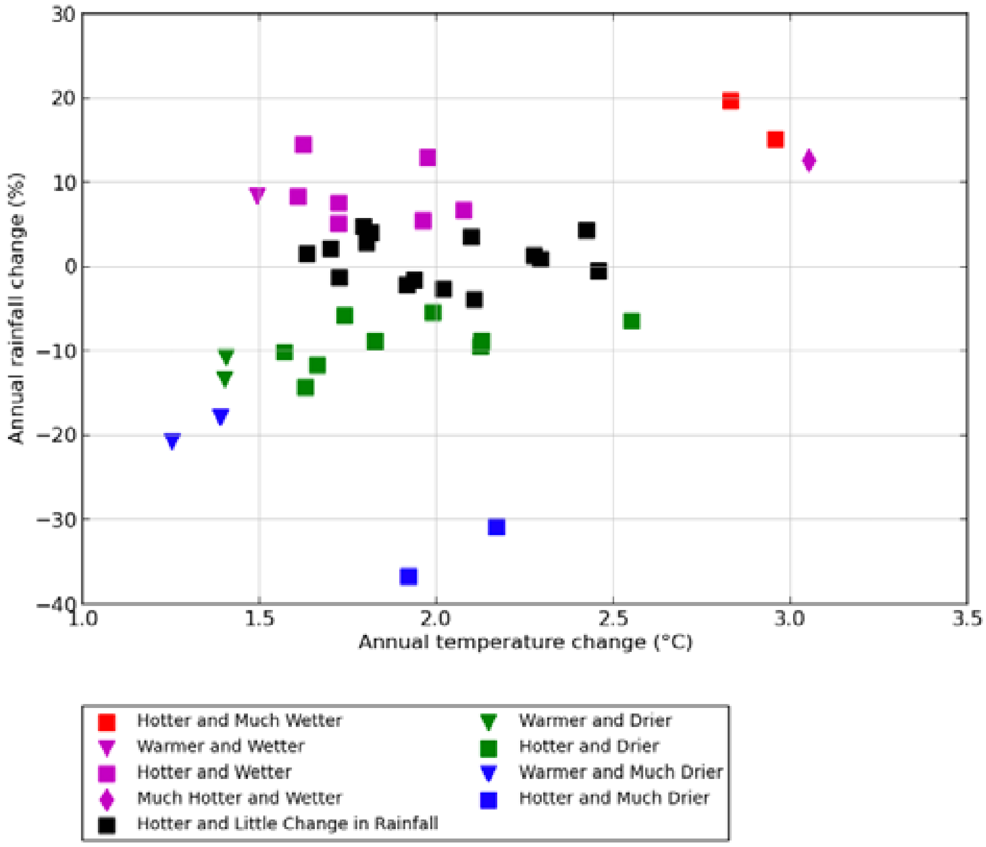


FIGURE 10. Projected mean annual change in rainfall (y-axis; expressed as a percentage) plotted against projected mean annual temperature change (x-axis; °C) for all 43 models for the period centered around the year 2070. Reproduced from Pacific Climate Futures web site (https://www.pacificclimatefutures.net/en/climate-futures/future-climate/).

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 (Figure 11). 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[7]) and smoothed values (smoothed GISS, Figure 11, 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[8]) and smoothed values (smoothed GPCP, Figure 11, bottom).

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

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

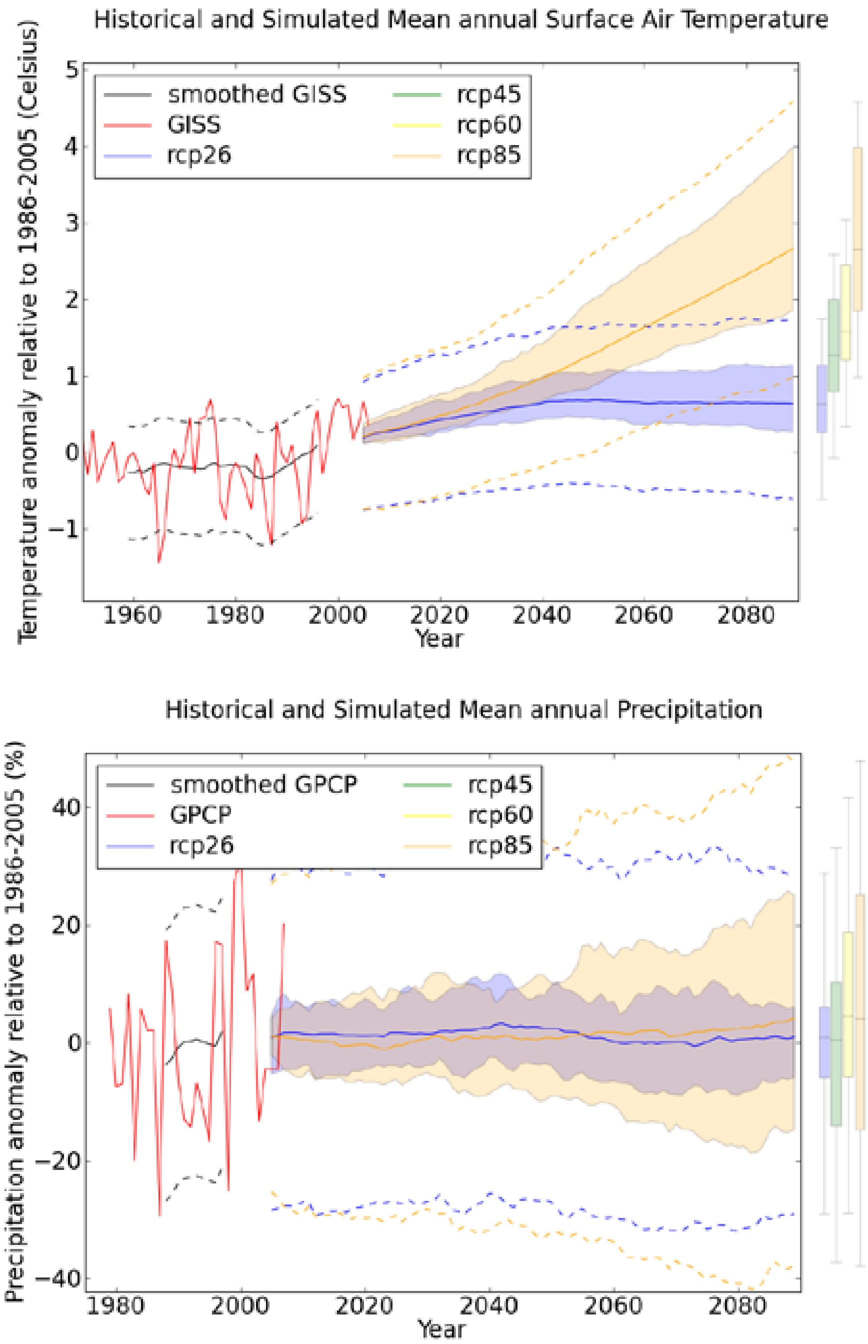


FIGURE 11. Historical and simulated mean annual surface air temperature (top) and precipitation (bottom) for Fiji. Reproduced from Pacific Climate Futures web site (https://www.pacificclimatefutures.net/en/climate-futures/future-climate/).

The future time series plots shown in Figure 11 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) interannual 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:

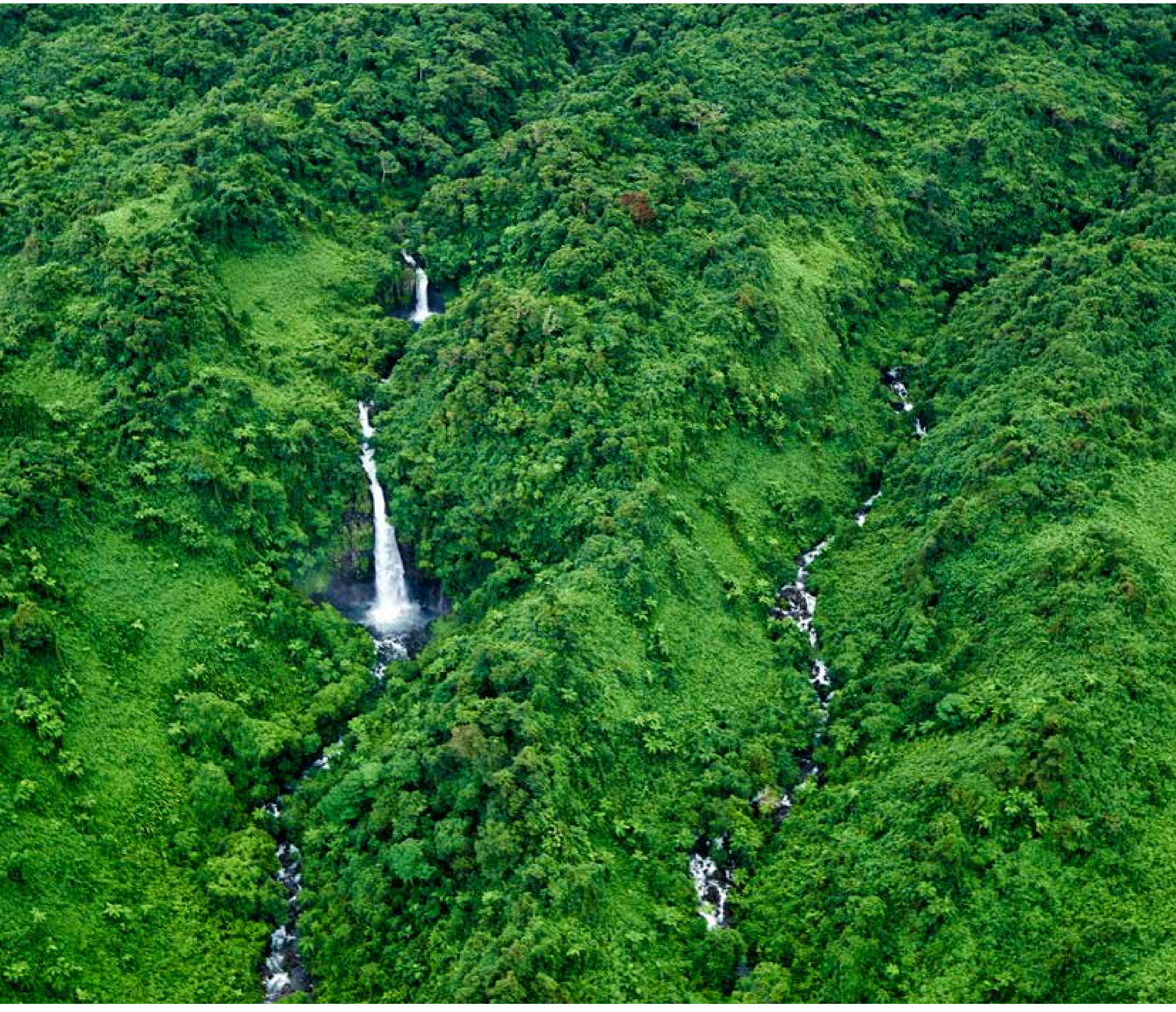
3.3.1 Current climate

- 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% 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%) 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 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).



Taveuni forest reserve. © Stuart Chape.

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. 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:

- terrestrial ecosystems;
- marine resources;
- freshwater resources;
- agricultural systems; and
- transportation and energy infrastructure.

4.1 TERRESTRIAL ECOSYSTEMS

Terrestrial ecosystems include complexities of land cover types in connected landscapes, and tend to include land uses such as agriculture and forestry, but are considered here in broader context. Specifically, the migration of how climate and human-caused changes affect the ability of the system to recover, or how they define a new trajectory of supply of ecosystem services.

TABLE 1. Summary of forces contributing to the vulnerable conditions for terrestrial ecosystems

Climate Forces	Additive Forces	Vulnerable Conditions
Rainfall frequency & intensity	Deforestation	Fragmented/ degraded forests
Drought	Land use change	Invasive species expansion
Windstorms	Large flood events	Erosion/ soil degradation
Air temperature	Imbalanced soil nutrients	Unstable supply of land products
Storm surge	Soil pollution/ chemical residue	
	Invasive species	
	Harvest	
	Land abandonment	

4.1.1 Land use/Land cover (LULC)

Several land cover maps have been made for Taveuni, each having varying utility for this project. A GIS coverage provided by the Wildlife Conservation Society (source unknown) correlates with the Ministry of Forestry coverage and a 2010 land-cover map provided by the Pacific Community's Geoscience Division (SPC-GSD) to provide a better understanding of cover types.

Use of high quality Landsat imagery (2016) along with the GIS data resources allowed for refinement of the extent of current forest cover conditions. Forest cover was divided into two categories: "rainforest" and "degraded rainforest". The primary difference was the observable contiguity of the forest canopy, where forest canopies that were generally uninterrupted were more likely to be in a non-degraded state, whereas fragmented forest or forest with large edges against deforested areas were described as degraded forest.

Most non-forested areas were either fallow from large deforestation events from the plantation era or are currently in small-scale cultivation from subsistence or commercial farming, including coconut plantations.

These areas were described as "dispersed agriculture" to reflect that the land area was under mixed use of agriculture, dwellings, mixed livestock and fallow areas. Grasslands were classified based on previously mapped commercial farm or pasture areas. Known mangrove areas of significant size were mapped as part of this study.

Land use/Land cover areas and distribution are presented in Table 2 and Figure 12.

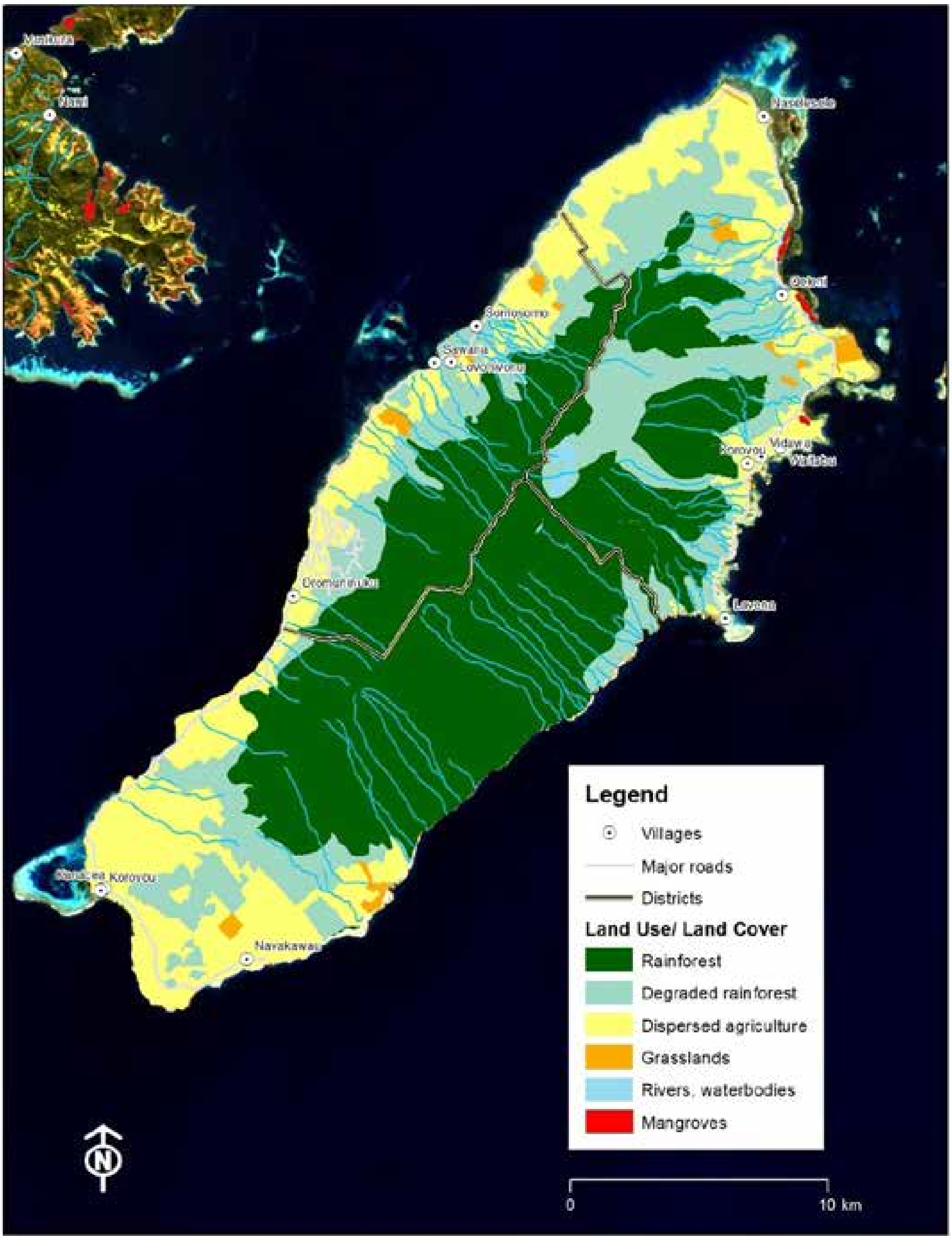


FIGURE 12. Land use/Land cover for Taveuni.

TABLE 2. Summary information of LULC categories and aggregated groupings

Land Use/Land Cover Type	Area (ha)	% of Area
Rainforest	20,972	48%
Degraded rainforest	10,835	25%
Dispersed agriculture	11,066	25%
Grasslands	543	1%
Rivers, waterbodies	126	<1%
Mangroves	59	0%
Total	**43,600**	

Note: Areas are estimated from GIS.

4.1.2 Reserve forests vulnerable to climate extremes

As summarised in the climate change overview section (Section 3.1), 2016 was a year with several record-breaking extremes for both maximum 24-hour rainfall (in February, April and December) and maximum temperature (in February and September), indicating some of the most extreme weather events documented over the past 60 years. Coupled with the size and destructive force of TC Winston, Taveuni has recently undergone large-scale stressors on its ecosystem and human environments.

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

A normalised difference vegetation index (NDVI) value was calculated from the multispectral Landsat imagery to assess an index of vegetation health. The NDVI is a ratio of the signal of the red spectrum and the near-infrared light that is calculated from the image, and is expressed on a scale of –1 to +1. In general terms, this yields a marker of vegetation health, measured as wavelengths of light absorbed and reflected by green and growing plants (i.e. photosynthetically active). High NDVI values (>0.6) correspond to dense vegetation at peak growth, while moderate values (0.2–0.5) may indicate sparse vegetation or senescing or damaged plants (nutrient poor crops, insect/ disease damage, physical damage, etc.). Low NDVI values (<0.1) generally indicate little or no vegetation.

Figure 13 displays the July 2016 NDVI analysis for Taveuni. There is considerable change in the NDVI values from healthy vegetation (dark green, index value ~0.8) to degraded conditions (yellow and red, <0.5), particularly for a large swathe of the upper forest reserve areas, and the centreline ridge into the leeward upper reaches. This may be a legacy effect of TC Winston, where the cyclone made direct landfall, although to date no field missions have confirmed the forest condition.

Anecdotal evidence has indicated there may be non-native species encroaching at upper elevations on the western side of the Taveuni ridgeline, mostly relegated to the small volcanic cone structures. Aerial oblique imaging conducted in 2017 appears to confirm large changes in forest structure in the peak areas with low NDVI values (see arrows in Figure 14), with low tree stem density and a prevalence of what appear to be vines. This would appear to be a significant change in tall evergreen or cloud forest types to a more degraded or open type of structure.

There is a need for an assessment of forest health, including a basic forest inventory of affected and non-affected areas to best understand the forest structure, composition and any degradation to function that may be under way. It is critical to determine the current condition and trajectory of forest health declines in order to determine the proper course of action to limit further, and perhaps permanent degradation.

The observed degradation response may be attributed to cyclone damage and decline or adaptation of late successional primary forest to a state of constant disturbance, favouring pioneer species. A complicating matter is that the deforestation and degradation in surrounding areas due to agricultural expansion, including access roads leading into the forest, will cause further threat of non-native species establishment and permanently convert the native forest to a state of permanent degradation. This would be a major blow to biodiversity for Taveuni and Fiji, as well as dramatically lowering the quality and quantity of forest cover of the country, affecting a wide range of ecosystem services.

Losses of primary forest cover to a fragmented state would greatly affect the role of Taveuni's forests in the water cycle, altering the influx of cloud-based moisture from cloud forests and epiphytes, and allowing for lower potentials of groundwater infiltration due to opening of the forest. Habitats supported by primary upland forest would be increasingly fragmented and could cause disruption in species success through loss of habitat.

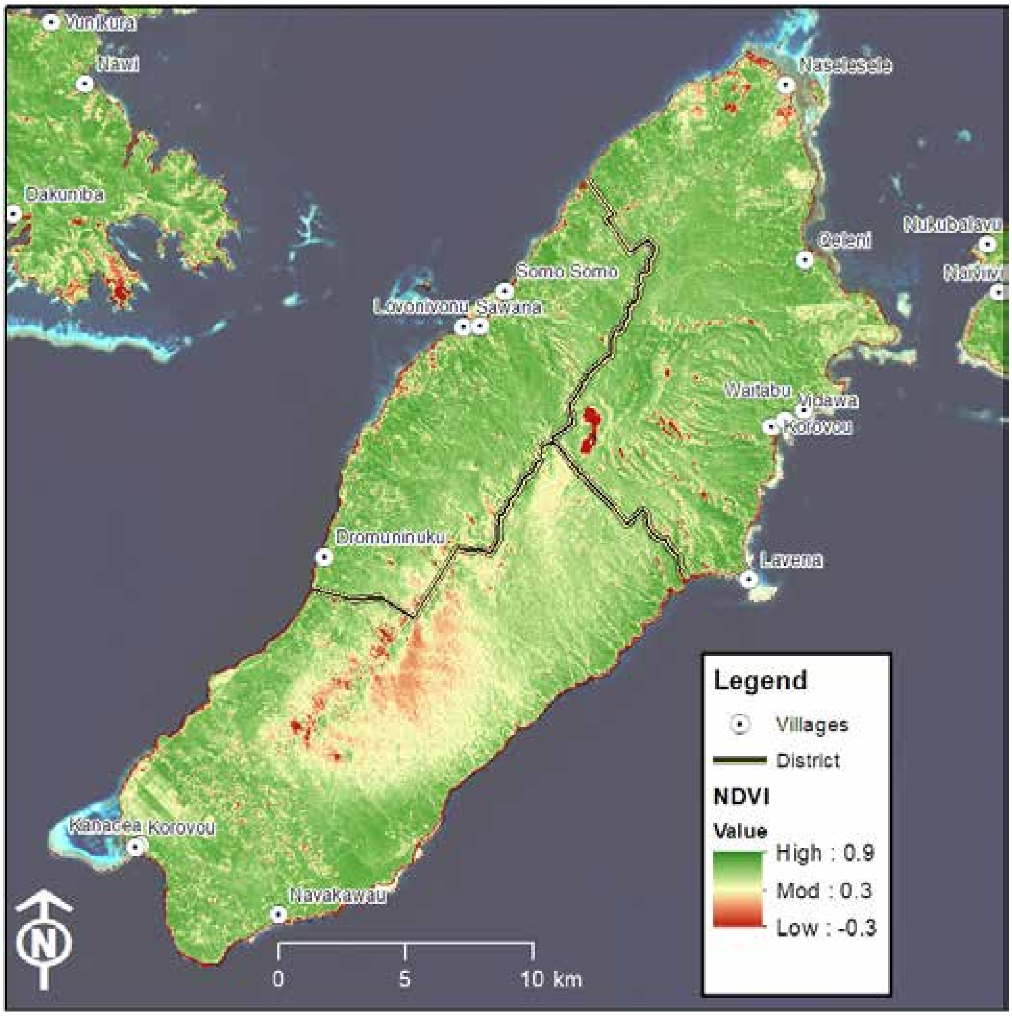


FIGURE 13. NDVI image calculated from July 2016, five months after TC Winston and at the height of a drought period. Green values indicate healthy vegetation; yellow is more sparse or senescing vegetation; and red values are bare soil or very sparse vegetation.

FIGURE 14. Left: Aerial view of forest degradation on high peaks of the central ridge of Taveuni (western side). Right: a normalised difference vegetation index (NDVI) map derived from 2016 Landsat 8-band imagery, indicating vegetation health (red = degraded or poor health; yellow = intermediate; green = high productivity). Arrows indicate reference locations surveyed. Note fragmented stands in left area corresponding with low NDVI values. See Section 5 for watershed boundary explanation for right image.

4.1.3 Wetland threats: Lake Tagimoucia

Lake Tagimoucia is formed from a volcanic crater at 800 m elevation in the upper reaches of the Wainikeli District, and is a popular tourist attraction. The environment is known for its biodiversity and the presence of rare plants, including the rare liana Tagimoucia that grows the national flower of Fiji, as well as sensitive amphibian species. As mentioned in the previous section, the Landsat image from July 2016 captured a time of extended drought.

Figure 15 shows Lake Tagimoucia in July 2016 (left) and with available imagery from January 1999 (right). There is striking evidence of the lake levels and wetland vegetation responses reduced to a small pond during the 2016 drought period. This emphasises threats to biodiversity in the wetland area, but there are also downstream effects of surface water flow to sensitive riparian habitats lower in the system.

FIGURE 15. Left: Landsat imagery of Lake Tagimoucia in 1996 during and after months of severe drought. Right: Same location, January 1999. Note brown area in left image is exposed soil from low lake levels.

Given the rich biodiversity, tourism interest, uniqueness and fragility of the site, interest has been expressed in including it in the Convention on Wetlands, an intergovernmental treaty initiated in 1971 and signed in Ramsar, Iran, with the goal of promoting conservation and sustainable use of wetlands. As a member country since 2006, Fiji has one Ramsar 615 ha site on Viti Levu (Upper Navua Conservation Area). The Lake Tagimoucia area (as delineated here in Figure 15) is approximately 300 ha in size, which would increase the effective wetland area for Fiji by 50%.

Mitigating extreme responses to extreme climates is a challenge. Conservation design to ensure forest health and sufficient buffer areas to protect key plant-water cycle processes around the lake will be critical, beginning with outreach and a firm understanding of the risks associated with climate and other pressures that may affect this ecosystem.

4.1.4 Widespread threats to ecosystem health

The pressure for agricultural productivity and lands on Taveuni, coupled with the historic land conversion from forest to agricultural lands (Section 2.3), has led to observable consequences, even outside considerations of extreme climate events. Changes to land use/land cover have spawned at least three principle vulnerabilities that amplify with climate change and even minor climate events. The following are known to occur throughout Taveuni and have cascading effects on other ecosystem-based resources.

Fragmented forests: Forest fragmentation results from direct land-use conversion, invasive species establishment that changes the fundamental forest dynamics (water use, reproductive success, shifts in structure, attenuation of rainfall and run-off, etc.), physical events (earthquakes, landslides, volcanic activity) and climate events (wind and windthrow, drought and deluge, storm surge and floods).

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.

Land management or tenure can likewise be a driver in forest fragmentation–land managers tend to manage for their confined space to meet specific objectives with little regard to the outside/neighbouring conditions, unless adversely affected. An increase in land ownership can therefore increase fragmentation, resulting in a landscape of smaller and less resilient or functional 'islands' of trees.

The three upland protected areas on Taveuni (Taveuni Forest Reserve, Ravilevu Nature Reserve and Bouma National Heritage Park (Figure 1) were established in part to stop fragmentation of remaining forest lands on the island. However, encroachment by agriculture and spread of invasive species continue to threaten these forests, along with climate-related forces as described above. The current push to merge these three contiguous areas into the Taveuni National Park may allow for better protection and restoration opportunities.

Conversion of forestland to agriculture across Taveuni, particularly in the northern and southern ends of the island, have fragmented the landscape to degraded forest and small-scale agricultural plots, increasing the exposure of native forest to disturbances (such as wind, fire, and invasive species spread) and decreased nutrient availability from intensive agriculture. In general, more forest edge results in more difficult conditions for natural expansion of forest into fallow agricultural areas.

Invasive species expansion: Current biosecurity programmes affecting international air travellers appear to be adequate, and there are also inspections of goods entering by cargo shipment into Fiji. However, there does not appear to be any robust programme of inter-island biosecurity, especially related to agricultural products and acquisition of seed and rootstock, within Fiji. Taveuni is an important agricultural producer, and there does not appear to be a systematic method for controlling soil movement from other islands (e.g. washing stations for transport vehicles), transfer of pests that affect food security (e.g. taro leaf blight), or for inspection of potential rootstocks used. Invasive species are widely considered to benefit from climate change circumstances in island environments, especially severe storm events that weaken standing forests and plantations and increase incident light for fast-growing species.

Invasive species expansion also occurs where abandoned farmlands remain accessible by vehicles. Deposits of seeds, as well as the use of fire to clear land, can have unwanted consequences such as the spread of invasive plant species.

Erosion/soil degradation: Increasing the overall vegetative cover to higher complexity (e.g. from grass to forest) has a direct effect on the soil profile and the fate and transport of eroded or degraded soils. Key strategies that can limit these vulnerabilities on the landscape include 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. Losses of topsoil degrade the ability of plants to grow, especially in tropical soils, and effectively lower the return on investment for future plantings. This is clearly observed with the reduction of productivity from intensive monocropping of dalo (Figure 4), where soil nutrient profiles are becoming degraded and labelled as 'infertile soils'.

Unstable wood and energy supply: Wood energy is common on Taveuni and serves as an additional driver of change in increasing ecosystem vulnerabilities. Use of wood derived from mangroves or forest edges increases fragmentation and can result in higher tree mortality with multiple entries. Traditional vanua for Taveuni have historically identified the saurusa (areas on the edge of village zones) for harvesting firewood; the area's intended purpose is to designate a convenient and constant supply of firewood. While firewood is not the most efficient or environmentally sustainable energy source, firewood collection remains a practice that can increase vulnerabilities to terrestrial ecosystems without proper planning and inputs. Planting of fast-growing nitrogen-fixing trees in community gardens for shade and soil amendment or planting trellises are strategies to ensure that firewood supply also provides other benefits, such as fixing soil nitrogen and improving other community garden crops.

4.2 MARINE RESOURCES

Generally, marine resources on Taveuni are declining and degrading due to the cumulative effects of intensive harvest and land-use practices. Table 3 outlines the forces contributing to the vulnerable conditions of the marine environment.

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

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

Coral reef health and extent: Coral reefs are vulnerable to local conditions on Taveuni, primarily due to overfishing and use and terrestrial run-off from sediment, wastewater, chemicals and other waste. Ocean warming and acidification from rising dissolved carbon dioxide (CO_2) concentrations are widely considered the greatest threat to coral reefs globally, and Taveuni is no exception. Coral reefs of Fiji are comparatively resilient to disturbance, 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 most developed reef system is in Somosomo Straits (Figure 6). Deeper patch reefs are less vulnerable to coral bleaching and human uses but night fishing and commercial poaching remain threats. The main reef systems are associated with Taveuni are described below.

Vuna Reef: This is an extensive and isolated mixed depth lagoon and reef flat. The extent and use of fishing in this area is not well documented, although local commercial diving operators have commented on the relatively good condition of the reef and fish populations. This is a common area for tourism. Its exposure to open ocean conditions leads to large changes in tidal movement; run-off from neighbouring farming activities is a source of sediment to the reef environment.

Naselesele-Qaleni Complex: A large system, predominantly serving as a subsistence fishing ground, as well as for commercial fishing. Night fishing has been observed along the outer reef. Proximity to the major road system, and sediment delivery from heavily deforested areas and steep, eroding canyons in the southern section increase threats to the reef area. This area sees heavy use by a range of communities that share in the ownership and use. Some wastewater plumes have been known to occur, yielding green algae; a filling station and small boat landings show signs of oil pollution.

Reef flats from Waitabu to Lavena: A series of lagoons and small reef flats, where a larger lagoon/reef flat at Lavena sources a small commercial fishery to supply other communities on Taveuni; given the habitat area and size of the catch, this area is under high fishing pressures and use by boat traffic. Waitabu has a developed history of local management toward conservation and ecotourism. Like Vuna Reef, this area is also within the prevailing path for storm events, including TC Winston in 2006.

Narrow patch reefs: island wide: Narrow patch reefs, extending 100–200 metres from the shoreline are present in all other areas, with the majority adjacent to the road network in Cakaudrove District. Use appears to be limited to access to deeper water for fishing. Proximity to the most populous villages, the major road system, and powerful creek networks are all sediment and pollution sources affecting reef patches.

Seagrass health and extent: Data on seagrass habitats are not available for Taveuni or its near-shore islands, but surveys, prior research, areal imagery and local interviews confirm the existence of a band of seagrass in several areas along the coast in an abundant condition. In particular, the areas extending from Naselesele almost to Qaleni appear to be in good condition in most places. 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. Below steep slopes with severe erosion and poor land use practices, sediment reduces light attenuation that can suffocate seagrass. Subsistence gleaning of invertebrate fish and invertebrates supports local communities, but increased and more deliberate harvest is being driven by increased tourism and off-island commercial operations.

Mangrove health and extent: Over the past few decades, Fiji has experienced an average rise in relative sea level of 2 mm per year. Mangroves act as a buffer to attenuate water quality pollution to seagrass and coral reef ecosystems from land-based activities (erosion, waste, and chemical pollution). Mangroves are at risk due to subsistence harvest for firewood, small diameter pole timber, and other uses. Reductions in mangrove size, distribution and health due to these factors greatly affect the ability of mangroves to provide the functions of attenuating run-off, particularly with decreasing patch sizes. Reduced patch sizes also subject standing mangroves to additional pressures from wind shear, storm surges, and other physical disturbances.

Mangroves provide key nursery areas for fish and habitats for marine life, and also function as a subsistence fishing ground for a variety of invertebrates. Reductions in mangrove health, size and distribution are directly related to the ability of subsistence fishers to harvest finfish and shellfish.

There are no large complexes of mangroves on Taveuni. A recent mapping effort of coastal features was conducted in July 2017 by the Water Institute of the Gulf and SPREP to characterise the coastline for coastal erosion potential, with a focus on modelling wave attenuation in Naselesele and Somosomo (Figure 16). Overall, there were 4,800 m of mangrove detected in 12 patches, representing ~6% of the measured coastline (8.6 km). The major mangrove features begin at Naselesele and extend southwards to the north of Qaleni; the mangroves in this area are relatively narrow; the major road in some areas is limiting the potential expansion landward, though topography in this area would not allow for any significant development of complexes.

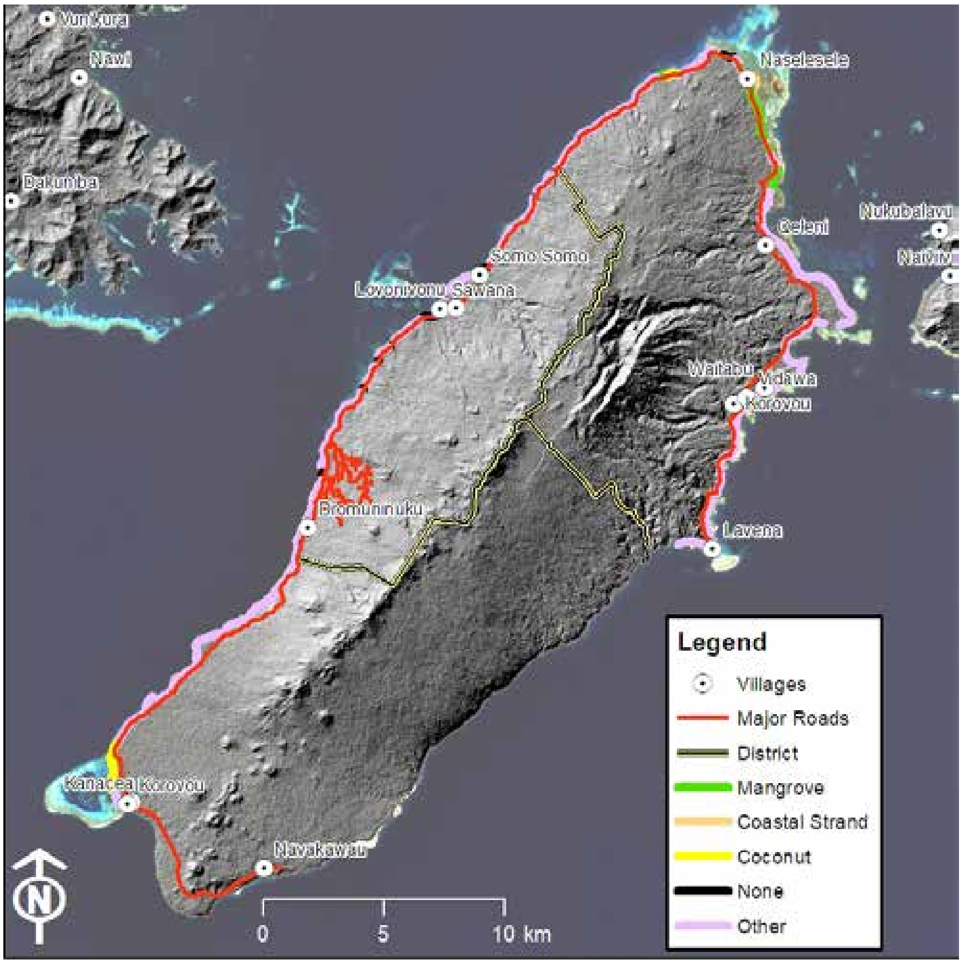


FIGURE 16. Coastal survey of major vegetation types for the majority of Taveuni island. Source: Water Institute of the Gulf, unpublished.

Smaller patches at the mouths of some rivers between Qaleni and Lavena are also present. These are estuarine mangroves that may have enhancement opportunity. An additional mangrove patch on the leeward side to the north of Vuna Lagoon is an important site for mitigating pollution flow from heavily farmed areas reliant on chemical fertilisers.

Inadequate fish and coral reef populations: Climate change can be expected to amplify existing local threats to coral reefs, mangroves, seagrasses and intertidal flats in Taveuni, resulting in declines in the quality and area of all habitats of important food resources. Input from local communities on Taveuni suggest that coral cover will continue to decline; reef fish size, abundance and availability of targeted species will decline; and ecosystem-wide changes in community structure will threaten the integrity and resilience of nearshore reefs. Coastal fisheries for reef fish and invertebrates are projected to show progressive declines in productivity, due to both the direct effects (overfishing from local and commercial operations) and the indirect effects of climate change (changes to fish habitats). Since coral reef fish and invertebrates are a main source of protein for most communities around the island, as stocks continue to decline from over-harvesting, basic needs of communities will likely not be met in the long term.

Reef fish populations inside marine protected areas (Figure 17) may render these locations less vulnerable, but poaching and heavy harvest pressures from outside commercial operations has been widely reported by locals. Interviews with local Taveuni residents suggest that fishing is curbed only within the Waitabu MPA. As climate changes, storm intensity in Fiji is expected to increase. 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. In Bua, Cakaudrove, Lomaiviti, Tailevu, Ra and Ba, most qoliqoli owners were split over the decision to open these areas for the purpose of food source and income-generation after TC Winston. While communities have the right to open or close these areas, the Ministry of Fisheries is recommending they consult first with them in an effort to keep protected areas intact for the fast recovery of coastal resources.

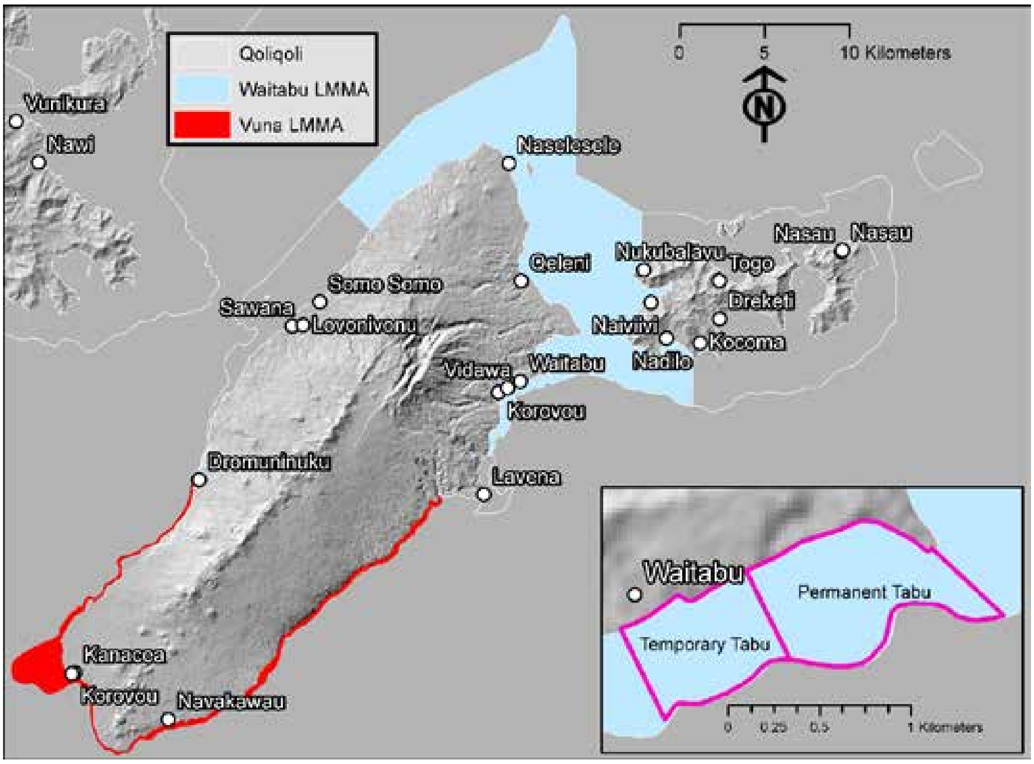


FIGURE 17. Locally managed marine areas/marine protected areas in Taveuni.

Coastal erosion: The effects of sea-level rise are likely to be experienced along sections of low-lying coastline in Taveuni, with increased inundation, flooding and salt-water intrusion putting road infrastructure at risk (Figure 18). A large proportion of the coastline along the western, northern and southern edges of the island appears to be at risk. Severe coastal erosion is occurring around portions of Taveuni. Areas to the southeast of Naselesele, in the vicinity of Somosomo and northwest of Kanacea appear to be particularly vulnerable to flooding and erosion. Very severe erosion at Vunitarawau near Qeleni has displaced mangrove coastal vegetation and threatens road infrastructure. Sand is accreting in places where active erosion is occurring, potentially smothering seagrass beds. In areas where inland migration or retreat of mangroves, seagrass and shorelines can occur unobstructed (such as in south-east), coastal erosion effects are projected to be less. Enhancement of existing mangroves from Qeleni to Naselesele is a critical step identified in coastal protection. A coastal erosion study by the Water Institute of the Gulf is under way to identify key options in both Naselesele and vulnerable areas near Somosomo.

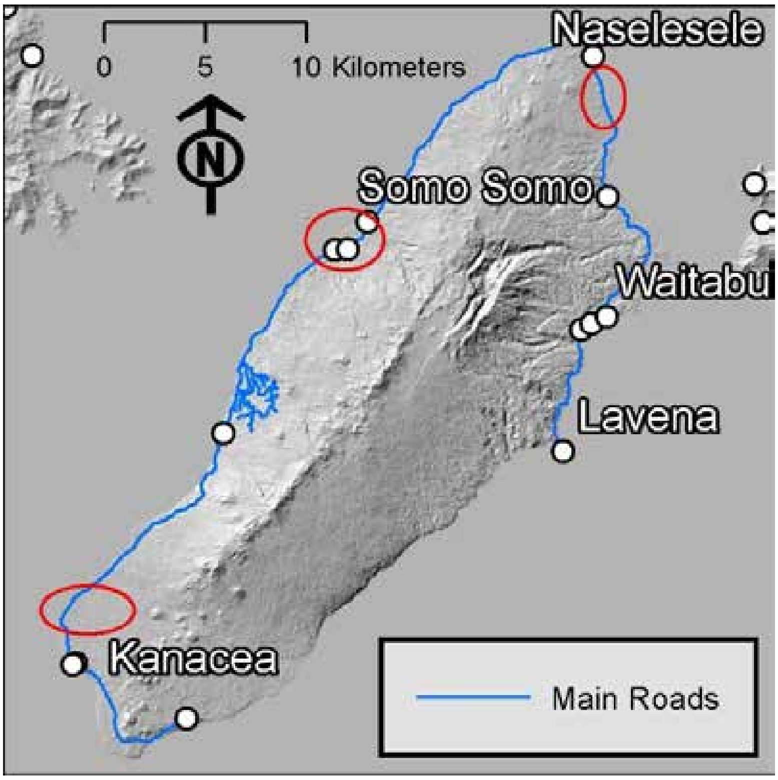


FIGURE 18. Main roads showing areas of likely flooding (red).

4.3 FRESHWATER RESOURCES

Taveuni has abundant freshwater resources, variably distributed, both spatially and temporally. Drought and extreme rainfall events are common, yet drought has the greater effect on water resources. Surface water is particularly vulnerable due to lack of storage, creating dependence on precipitation that is well-distributed in space and time. Current climate patterns and the additive forces shown in Table 4 likely 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	Existing ground/surface water trends in use	Groundwater supply
Sea-level flux	Population trends	Surface water supply
Rainfall magnitude	Terrestrial run-off pollution (erosion, mines, sanitation)	Pollution attenuation capacity
Air temperature regime	Wetland and riparian degradation and loss	Floodplain vulnerability
Drought frequency, duration, intensity	Gravel extraction	Aquatic habitat and species
	Delivery infrastructure	Community use/ Livelihood of aquatic use
	Irrigation use and trends	Recreation and tourism
	River/ stream re-engineering	

Groundwater supply: Groundwater supply on Taveuni is abundant and relatively resistant to current and likely future climate conditions. Groundwater occurs primarily in geologic formations that are at a high enough elevation above sea level to be resilient to sea-level rise. Little is known about the rate or sustainability of groundwater extraction; however, current withdrawal rates are likely sustainable (though unknown) over the medium term. Part of the reason for this is that up to the present time the relatively abundant and well-distributed rainfall patterns have favoured surface water use. If surface water becomes less reliable, there may be increasing demand for groundwater.

Annual rainfall levels are predicted to remain largely unchanged into the future (Figure 10). Given the long subsurface pathways, it is unlikely that groundwater recharge will be significantly changed by predicted climate change. One exception might be from higher evapotranspiration rates associated with predicted increases in annual air temperatures. This, coupled with losses of forests at high elevations, may contribute to lower rates of groundwater infiltration due to lower cloud water interception, soil heating, evaporative loss, and run-off.

Interviews with water resource managers indicate that one of the primary concerns with groundwater is the adequacy of the physical plant and water distribution systems on Taveuni. Well-casing had in some cases failed and redevelopment of groundwater wells was needed. Failed or failing water systems prevented the distribution of water across the island in some cases. This was the case in 2016 when rotating blackouts of water delivery was experienced as infrastructure could not service demand.

Surface water supply: Surface water sources supply most water for domestic and agricultural uses on Taveuni and depend on a relatively constant supply of rainfall. Taveuni is steep, and stream systems are short and respond rapidly to rainfall events (see Figure 9). Most surface systems use storage tanks; however, these are generally too small to buffer long drought periods. The Naselesele and Vuna communities have few surface water sources and are reliant on springs that are sensitive to drought conditions. Despite high rainfall in certain areas, there appears to very little by way of rain catchment, especially on Taveuni, where tourism demand and increasing drought regularly exceeds available water for the hotels and communities.

Pollution attenuation capacity: Freshwater pollution on Taveuni occurs primarily from naturally high erosion rates, exacerbated by land management practices. 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 the vulnerability to freshwater resources downstream, as well as the marine environment. Management of the riparian zones is one way to mitigate for non-point source pollutants, with forest buffer areas that allow for filtering and moderating sediment flow. Figure 19 displays the land cover with 30 m riparian buffer zones extended from known streams. Vulnerable areas are in degraded forestlands and grassland/historic coconut plantations under 150 m in elevation.

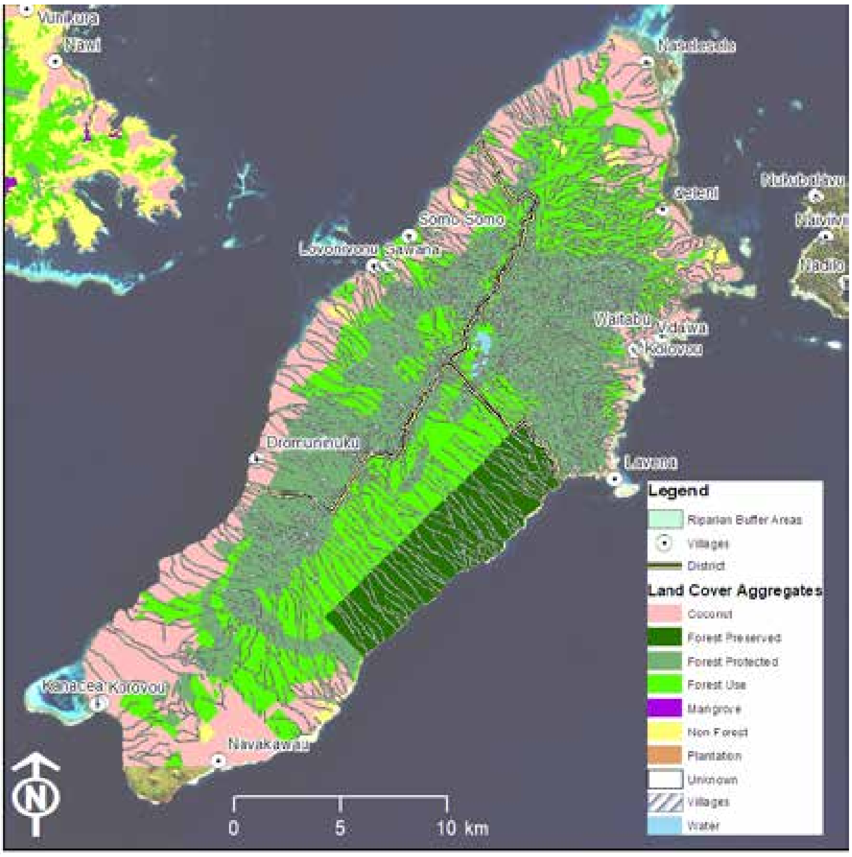


FIGURE 19. Taveuni land use and land cover with riparian buffer areas. Riparian areas in non-forested areas are less likely to attenuate pollution to the marine environment.

Floodplain vulnerability: Taveuni is steep and streams occupy narrow corridors with little floodplain development. Although 'floodplains' are rare, flooding occurs in developed areas near streams, associated with major storm events. Given projected increases in more extreme rainfall events and sea-level rise, it is likely that floods will increase. Increased sediment loads (from land use) and run-off efficiency (from drainage systems) will amplify flooding problems. Few options exist on Taveuni for wetland mitigation to minimise flooding issues other than development of mangrove areas and protection of waterfall pools and stream systems below these pools to avoid degradation and erosion that may compromise their attenuation capacity.

Aquatic habitat and species risk: Streams on Taveuni are generally steep and intermittent, and most catchments are long and narrow, running from ridgetop to the sea (Figure 20). The largest stream systems on the island are Somosomo Creek in the north-west of Taveuni, Tavoro Creek, and the Waibula River on the eastern side of the island. The Somosomo catchment is heavily farmed with agricultural plots, and there is little erosion control or stream buffers. Little evidence of stream protection measures were seen on site visits, and it is likely that aquatic species and habitats will experience degradation with intensified agriculture, particularly from chemical fertiliser, herbicides and sediment delivery.

FIGURE 20. Major streams on Taveuni.

The principal climate change-related effects on freshwater habitats and species on Taveuni include potential increases in flood-related disturbance, increased periods of low or no stream flow, and warmer overall water temperatures. These effects will favour some species at the expense of others, with a likely shift in community composition. Saltwater intrusion and inland extension of brackish waters are unlikely to be a significant factor on Taveuni, given the steep relief. Additive forces, however, will probably continue to pose the greatest risks; increased sedimentation and other pollutants, physical habitat destruction, loss of riparian buffers and channel complexity, and continued barriers to upstream migration are all disturbance vectors that cause harm to aquatic species and habitat.

Livelihood: Taveuni's rivers and streams 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; all of which are important to livelihoods and a consistent source of local protein. Since freshwater ecosystems are vulnerable to climate change, the cultural traditions and food security of local communities may also be at risk. There also may be 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 intestinal bacteria and parasites from infected food and water). The extent of these vulnerabilities is largely unknown.

Recreation and tourism: Freshwater resources play a supporting role as key destinations for tourists on Taveuni, particularly on the north-eastern coastlines and mountain areas, and are locally critical for some small communities scattered across the island. The Waibula River, south of Qeleni, is a popular destination for tourists from Taveuni and the islands of Qamea and Laucala. Threats to healthy river systems and the associated freshwater amenities will likely increase vulnerabilities and have unintended negative consequences for Taveuni tourism. Taveuni competes with other similar ecotourism destinations, advertising pristine freshwater streams and waterfalls as a primary attraction. The vulnerabilities described above will likely have an impact on recreation and tourism.

4.4 AGRICULTURAL SYSTEMS

Agricultural resources are critical to Taveuni's food security and the economy of the country, yet 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. Changes in climate patterns can affect crop suitability and disease or pest vulnerability. Changes in precipitation patterns–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 for their products and their required inputs, both of which are affected by other producers and supply chains.

Agriculture 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 the leading additive force affecting change. Nevertheless, increasing diversity of income sources by maximising land efficiencies and minimising impacts is a key mechanism to strengthen the role of agriculture in providing sustained services.

TABLE 5. Forces affecting agricultural vulnerabilities

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

Household revenue and food dependence: Many households in Taveuni rely on agricultural production for subsistence and income. Agricultural productivity has been in decline due largely to intensive, monocrop farming practices, and without appropriate adaptation strategies, agriculture in Taveuni will fail to meet income needs, as well as the ability of families to improve infrastructure and resilience to climate extremes (drinking water, shelter, storm resilient crops, etc.).

Distribution networks of local food production on Taveuni (and across Fiji) are important to build resilience to natural disasters, as evidenced by TC Winston in 2016. Local caches of seed stock and 'cyclone resistant' storage for potted plants are needed so that community gardens can be rapidly deployed following a disaster event, especially as communities are often isolated due to infrastructure failure (short term). A well-distributed food production system builds resilience to often localised storm damage.

Eroding soils: Soil erosion is a central issue for Taveuni, due to steep slopes, high rainfall, and soil characteristics that combine to create a naturally erosive condition. Coconut plantations occupy much of the lower-gradient lands at the southern and northern ends of the island, and dalo and other annual crops have pushed further upslope over the past 20 years. Marginal agricultural operations are often unable to apply the best management practices needed to minimize soil erosion. Uncertainties with respect to land tenure limit long-term investment in soil conservation.

Soil Infertility: The same climate and additive forces affecting eroding soils are also impacting 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, because farmers cannot be certain they will maintain tenure to benefit from scarce resource investments. Diversification of crops to include nitrogen fixing plants, use of green manure, and building of a soil organic matter profile are mechanisms to slow the current and widespread trajectory of soil infertility on Taveuni.

4.5 TRANSPORTATION AND ENERGY INFRASTRUCTURE

Transportation and energy infrastructure are vulnerable to storm events, particularly as sea levels rise on Taveuni (Figure 18). The principal road runs around the island and is already experiencing erosion and flooding, being vulnerable to climate extremes and other additive forces (Figure 18). Taveuni's separation by sea from the major commercial, industrial and governmental service centres of Viti Levu makes it particularly vulnerable during disaster response and recovery periods. It can also exacerbate the effects of a disaster and increase the time it takes to recover from energy and fuel shortages or infrastructure failures. This was seen after TC Winston.

TABLE 6. 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	

Transportation infrastructure: Roads are vulnerable to storm events, including flooding and erosion. Roads on Taveuni vary in condition from well-maintained in the Somosomo area and north to Naselesele (Figure 18) but require frequent maintenance in other areas. Access to the interior is limited, and roads are steep and often impassable, even in dry conditions. Bridges are low-lying and often get flooded or damaged during high flow. Storm effects are amplified in coastal areas by sea-level rise.

Disaster response capability: Areas of low-lying roads susceptible to flooding, landslide-prone areas with the potential to block roads, limited air-service, and a dependence on limited ferry services to other islands, combined with increased severity and general unpredictability of storm events, leaves Taveuni vulnerable to major storm events and recovery can (and frequently does) take months or even years.

Community connectivity/geographic separation: The natural separation of Taveuni from the main islands of Fiji reduces the internal redundancies and fail-safes, including multiple sources (e.g. energy supply, water supply) and requires more reliant local systems.

Power grids: Apart from the Somosomo area, Taveuni lacks a central power grid, and relies on distributed disconnected power sources that are subject to shut-down during periods when fuel delivery is not possible. Furthermore, most power is generated from petroleum, which increase dependence on international sources and require maintenance. Storm event disruption can be long, and systems easily disrupted for a given size storm event if resilience is low. Alternatives in areas with constant and developed water sources (e.g. Lavena) can benefit from a review of micro-hydro power plants or other technologies that are less reliant on regular maintenance and repair.

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. 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). Establishing a framework to link land uses and land-use changes with the environmental processes (and downstream consequences) can be done by identifying watershed (or catchment) boundaries across Taveuni. These watershed boundaries would require appropriate scaling to be potentially managed by communities, groups of communities, or councils to achieve their primary environmental values through time.

An existing and coarse delineation of watersheds is available from government sources, but there was a need to delineate effective watershed boundaries that correspond with historic ownerships and logical divides in physical characteristics (geomorphology, rainfall regimes, prevalent wind patterns, etc.). Using available digital elevation models (DEM) and known stream cover layers, a suite of watershed boundaries was identified at varying scales and presented to communities of stakeholders across Taveuni.

Watershed boundaries are nested and therefore can be aggregated or disaggregated according to the primary (human-identified) objectives. Maps of potential watershed boundaries were produced for community workshops to identify the appropriate boundaries that fit known or existing socio-political or geographic boundaries (e.g. districts, historic landmarks or features, etc.). Community focus groups selected boundaries to meet the need for watershed units. There were high degrees of consensus, both within and across boundaries chosen, with little to no overlap. A total of 11 watersheds were identified as part of this exercise (Figure 21).

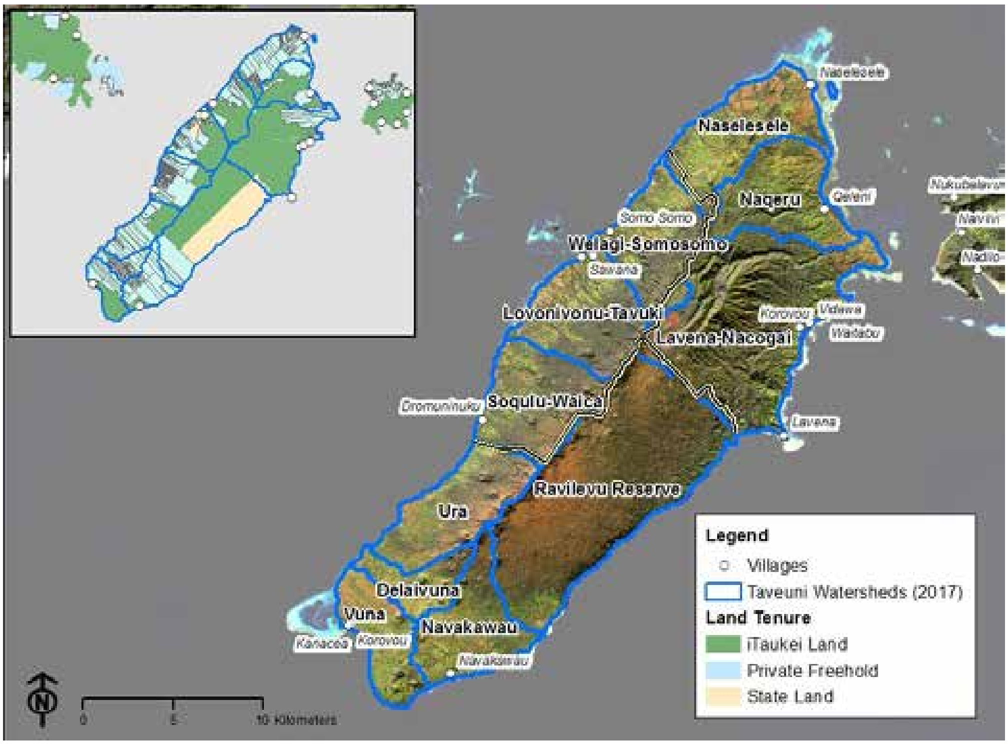


FIGURE 21. Watershed map for Taveuni, made through GIS analysis and community involvement.

5.2 HISTORICAL CONNECTIONS WITH THE LANDSCAPE

Workshop activities were guided, with traditional leaders to identify traditional uses of the landscape and determine what the historical guidelines, or 'rules', were for managing natural resources. The objective was to identify common language and traditional practices that may be lost or muted, but can help to formulate a new, 21st century view of landscape management that is fundamentally Fijian.

Emergent from community workshops was the concept of tua, or those land areas that provide specific goods and services to the community. Tua are naturally situated in a ridge-to-reef framework and offer a potential resource for defining landscape management and development of EbA activities for future phases of the PEBACC project, as well as others.

Table 7 outlines the description and importance of each tua, which are mapped in Figure 22. These are analogous to a traditional ecosystem service framework and are naturally structured to provide conservation guidelines. While these are not in site-specific detail, nor strictly adhered to, they are helpful in the development of EbA options for linking historic land-use rules and responsibilities of stewardship with developing a 21st century adaptation of a 'desired future condition' among all stakeholders in connected landscapes.

TABLE 7. Definition of traditional tua, including description and ecosystem services provided for each. Tua follow a complex gradient based on social, elevational and topographical considerations. Source: Vanua of Taveuni – PEBACC Workshop 2016

Tua	Description – What grows there, what is its purpose?	Importance – What is provided by this area?
Waitui	Deep sea	Food, income, air, wind, storms
Cakau	Reef	Food, fish, protection from storms, nursery area, tourism (diving) income
Sawana	From reef to beach, intertidal area	Food, fishing grounds
Matavura	Coastal strand – boat mooring at night, mangroves	Protection, filtration (protects reef), buffers reef from run-off, access to the sea, gateway to the sea, tourism, family area
Koro	Above the wave zone, location of villages	House and home, dwellings, community, schools, church, commerce, rest and relaxation
Saurusa	Empty space between villages, gardens, forest providing plants, villages may grow into these areas, expansion	Burial areas, expansion, food and nourishment, firewood, construction material, light timber production, material for thatching
Voavoa	Formerly teitei -- fallow areas, agricultural area, market, farms, rotational farming, can change position with teitei	Needed to maintain the teitei in rotations
Teitei	Organised farming, currently cultivated, can change position with voavoa (rotating ~7–10 years)	Food for village and commerce, sustainability
Tokaitua	Intermediate ridge tops	Hunting (pigs, chickens)
Qakilo	Inter-valleys, side streams located within	Protection from landslides, wind, hunting, erosion protection, water infiltration, spring water
Veikauloa	Deep forest, mid-slope forest, can be rain-forest, big trees, water source	Rain interception, tourism (hiking, bird watching)
Veikaulalai	Cloud forest – Ridgetop mist catcher	Cloud water interception, source of water, chiefly location

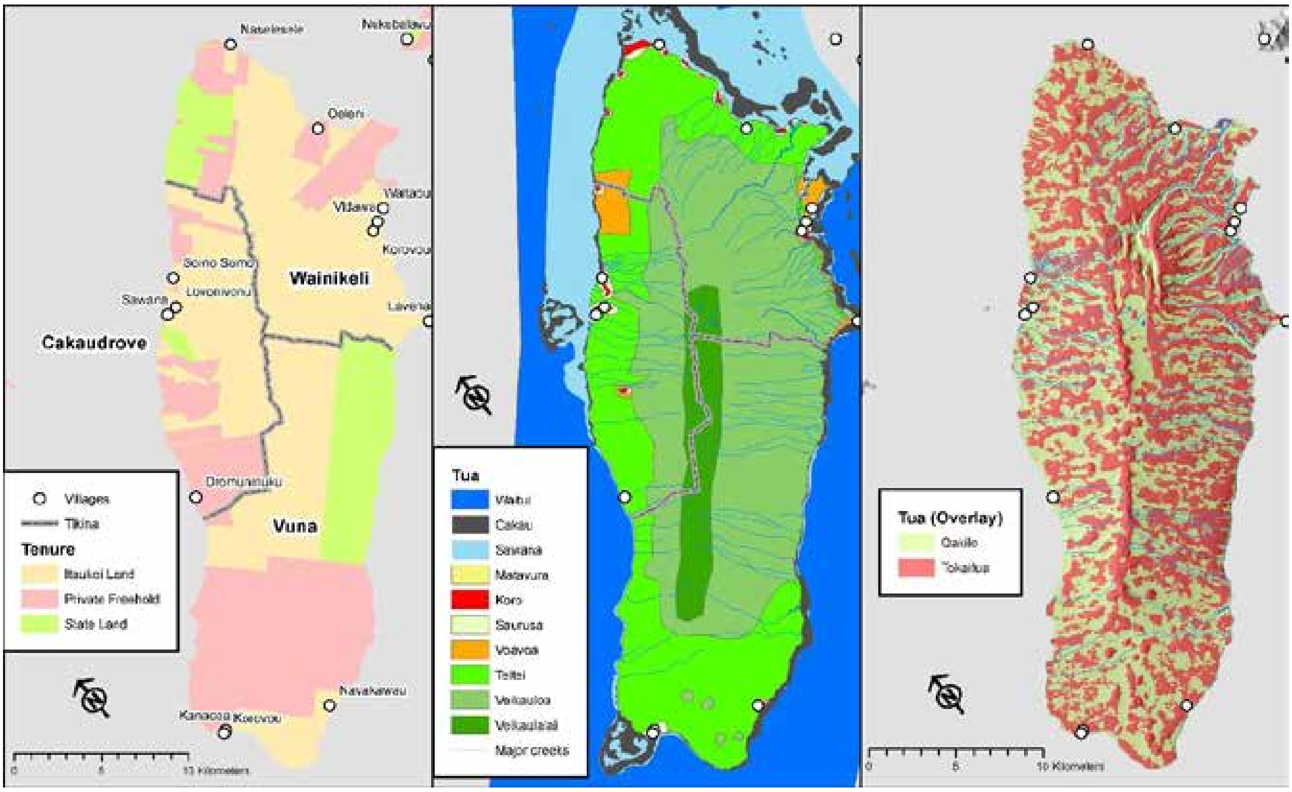


FIGURE 22. Taveuni island, showing land tenure (left), principal tua (centre), and additional tua overlay units (right).

5.3 ECOSYSTEM-BASED ADAPTATION AT WATERSHED SCALES

A final outcome of the ESRAM workshop activities to identify connected landscapes was the synthesis of historic practices with the current realities and challenges to determine the best way to move forward to address vulnerable conditions. From a series of workshops and meetings, communities within the watersheds developed stakeholder groups to identify and evaluate priority issues affecting their watersheds and livelihoods.

Overall, groups identified the need to expand stakeholder bases and conduct outreach to identify key vulnerabilities affecting their livelihoods. Watershed groups prepared a list of core values to manage for in each watershed. Key activities to explore during the PEBACC Phase 2 Options Assessment are listed, along with watershed size and stakeholder information in Table 8.

An island-wide summary of key activities to explore for developing EbA options (consolidated from Table 8) for the 43,662 hectares – 122 mataqali with landownership of 54% iTaukei, 33% freehold lands and 13% state lands – includes:

- identifying a system for watershed groups to regularly convene;
- providing training opportunities specific to meeting goals; and
- developing EbA maps and priority areas to include all watersheds (PEBACC Phase 2).

TABLE 8. Summary of watershed characteristics, land tenure/ownership and key activities and values identified by each watershed group as part of the ESRAM workshop meetings

District	Watershed	Area (ha)	% of island	Number of mataqali	ITaukei land	Private freehold	State land	Key Activities/ Values Identified
Wainikeli	Lavena-Nacogai	8,259	19%	33	83%	15%	2%	▪ Enhanced agriculture/agroforestry ▪ Native forest restoration/planting ▪ Mitigate beach erosion ▪ Mitigate flooding/riparian planting ▪ Sustainable power source (e.g. micro-hydro) ▪ Coral reef enhancement
	Naqeru	3,138	7%	22	95%	5%	0%	▪ Rehabilitate expired lease lands ▪ Agroforestry/high value plantations for income ▪ Mitigate flooding/riparian planting ▪ Mangrove expansion/enhancement ▪ Address coastal erosion concerns ▪ Ecotourism in upland forest
	Naselesele	3,503	8%	24	21%	36%	43%	▪ Water conservation and access ▪ Ecotourism site on lagoon and freshwater pond ▪ Improvement of marine habitat/ sustainable fisheries ▪ Increase tree cover through agroforestry, mixed plantation and native species ▪ Work with neighbouring areas to minimise deforestation in upper elevations
Cakaudrove	Welagi-Somosomo	2,957	7%	42	84%	16%	0%	▪ Reforest and protection around natural spring sites ▪ Riparian planting ▪ Increase native forest through native forest/ plantation management ▪ Improved outreach with watershed stakeholders ▪ Expand agroforestry in mid-elevation/ developed areas
	Lovonivonu-Tavuki	3,374	8%	23	70%	24%	6%	▪ Flood mitigation/riparian planting near towns ▪ Restoration of native forest/plantations in upland areas ▪ Monitor invasive species in upland native forest ▪ Extend outreach to all stakeholders
	Soqulu-Waica	3,275	8%	7	35%	63%	2%	▪ Conduct stakeholder outreach to improve involvement with communities ▪ Engage landowners to increase forest cover and riparian plantings

District	Watershed	Area (ha)	% of island	Number of mataqali	ITaukei land	Private freehold	State land	Key Activities/ Values Identified
Vuna	Ura	3,154	7%	3	39%	61%	0%	▪ Develop agroforestry/plantation options in lower elevations in former copra lands ▪ Increase native forest via out-planting of existing fragments ▪ Participate in native forest health monitoring ▪ Participate with neighbouring watersheds in upper elevation reforestation activities
	Delaivuna	1,355	3%	2	0%	91%	9%	▪ Diversify agricultural systems to counter declining yields ▪ Increase soil productivity ▪ Increase water holding capacity of the landscape (reforest, riparian plantings, etc.)
	Vuna	2,093	5%	28	54%	45%	0%	▪ Reforest with high-value native trees in upper elevations ▪ Increase forest cover on degraded lands ▪ Agroforestry and agricultural enhancement ▪ Establishment and improvement of water source ▪ Mangrove and coastline enhancement ▪ Marine management and coral enhancement
	Navakawau	2,842	7%	4	10%	90%	0%	▪ Rehabilitate iTaukei lands with high-value agroforestry or plantation options ▪ Diversify plantings to yield high-value hardwoods ▪ Develop sustainable watershed management plan for leases and land use between iTaukei and private landowners
Vuna (Govt)	Ravilevu Reserve	9,712	22%	6	43%	17%	39%	▪ Engage government as watershed coordinators ▪ Outreach to mataqali and private lands ▪ Conduct study and mapping of forest health concerns ▪ Engage neighbouring landowners for forest restoration solutions to increase ecosystem services
IIsland-wide summary		43,662	100%	122	54%	33%	13%	▪ Identify a system for watershed groups to regularly convene ▪ Provide training opportunities specific to meeting goals ▪ Develop EbA maps and priority areas for all watersheds (PEBACC Phase 2)

Note: Area and land ownership, especially the number of Mataqali, is approximate as it was derived from available GIS coverages.

Children washing and bathing in the river, Somosomo village, Taveuni Island.

6. NEXT STEPS: DEVELOP EBA OPTIONS

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

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

- Manage for connected landscapes using emergent watershed groups.
- Develop activities that build on strengths in the community, supplementing training to add to existing knowledge, rather than making drastic changes.
- Consider EbA interventions that increase the diversity of choices – these include diversity of crops, timing or locations of fishing, and different income sources that pay long-term dividends rather than short-term gains.
- Consider different scales of EbA implementation and the strengths and weaknesses of each – examples include large-scale EbA interventions in a single area or many, smaller activities distributed across Taveuni.
- Extend outreach to include industry (tourism, aquaculture, nurserymen, plantation managers, non-timber forest products, etc.) in addressing gaps in understanding to strengthen capacity and provide new business opportunities – actions that revert current degradation activities to ecosystem restoration and enhancement.

Provincial office, Somosomo village, Taveuni Island.

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