EVALUATING ECOSYSTEM-BASED ADAPTATION FOR DISASTER RISK REDUCTION IN FIJI

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EXECUTIVE SUMMARY

Overview

Natural disasters such as hurricanes, cyclones, and tropical depressions cause average annual direct losses of US$284 million in the Pacific. With a combined population of fewer than 10 million people, annual losses are the highest in the world on a per-capita basis. Extreme weather events such as heavy rainfall are closely linked to climate change, suggesting that Pacific Island nations face increasing risk of disasters such as flooding and landslides. Proactive management through infrastructure development, social solutions, and/or ecosystem-based adaptation can mitigate these risks. However, there are a paucity of data pertaining to the costs, effectiveness, and feasibility of most management options.

In the wake of two major flood events and a cyclone occurring between January and December 2012, we conducted a state-of-the-science assessment of disaster risk reduction for flooding in the Ba and Penang River catchments in Viti Levu, Fiji to identify the most cost-effective management options for communities and households (Figure E1). The analysis accounted for the biophysical and socioeconomic impacts of flooding, the costs, benefits, and feasibility of management, and the potential impacts of climate change.

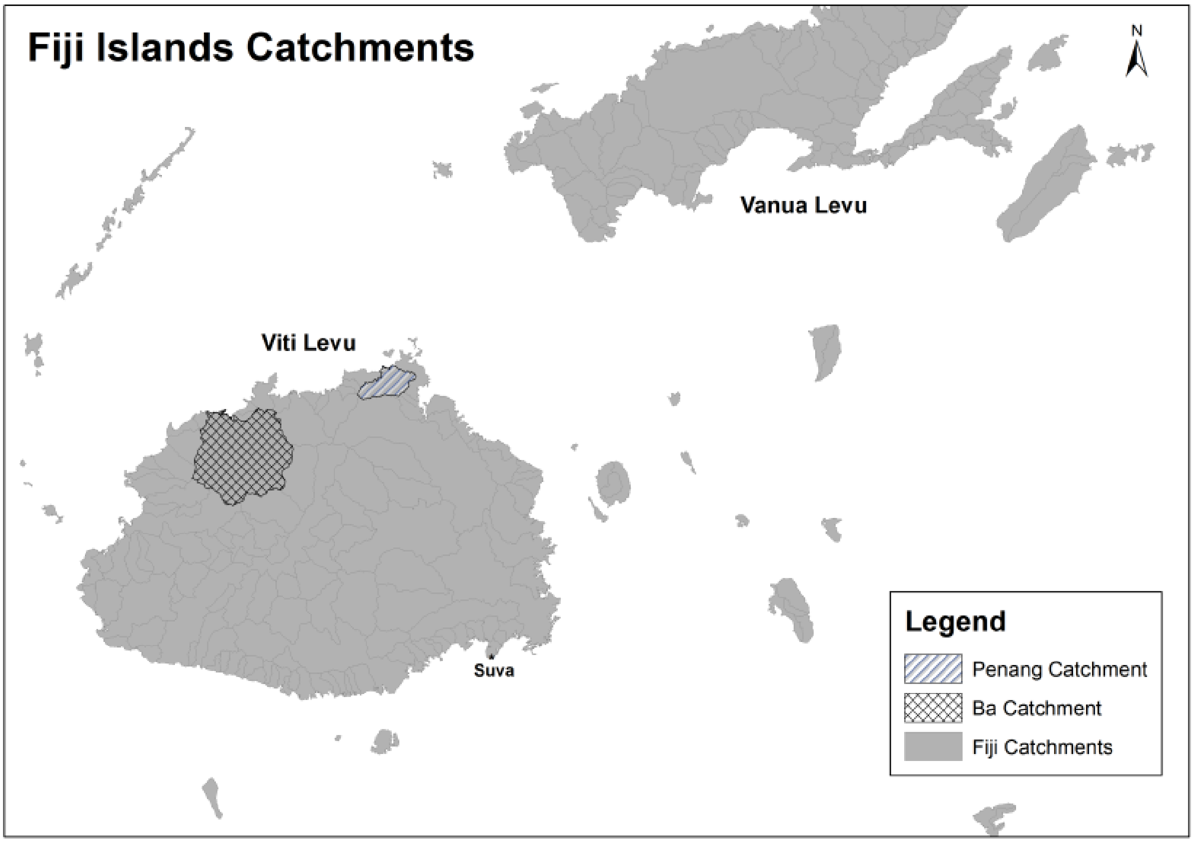


Figure E1. **Fiji Islands, including study sites**

Study Approach

The foundation of this study is an extensive socioeconomic survey that quantifies the direct and indirect impacts of flooding in the Ba River and Penang River catchments. We then develop hydrological models of the two river catchments to forecast future flood damages and to evaluate the effect of infrastructure development and ecosystem-based adaptation on future flood damage. Next, we employ secondary data and GIS to incorporate likely impacts from climate change. Finally, we conduct a comprehensive cost-benefit analysis to systematically assess adaptation options.

Impacts

Fiji's single worst natural disaster occurred in 1931, when a hurricane led to the highest recorded flood in the Ba River catchment. History nearly repeated itself in 2009, when a severe monsoonal trough caused significant damage, loss of life, and widespread flooding, particularly in Ba town. In January 2012, however, a flood of similar magnitude followed a tropical rain depression, leading to widespread flooding of both the Ba River and the Penang River. In March of that same year, severe rains cause additional flooding throughout the two catchments. Cyclone Evan struck the same areas in December 2012, causing additional damage and exacerbating the challenges of recovery.

Based on a survey of 369 households in 36 communities spread across the two catchments, we combine hydrological modelling of the Ba and Penang rivers with GIS to estimate that the January 2012 flood caused FJ$36.4 and FJ$12.2 in damages for the Ba River and Penang River catchments, respectively, while the March 2012 flood caused FJ$24.1 and FJ$8.4 in damages for the Ba River and Penang River catchments, respectively.

Crop damages were especially pronounced, accounting for well over 80% of the total damages recorded for both floods as well as for Cyclone Evan (Figure E2). Direct damage to housing and durables – although by no means negligible – was modest in comparison. Losses to livestock were also modest in comparison to crop losses.

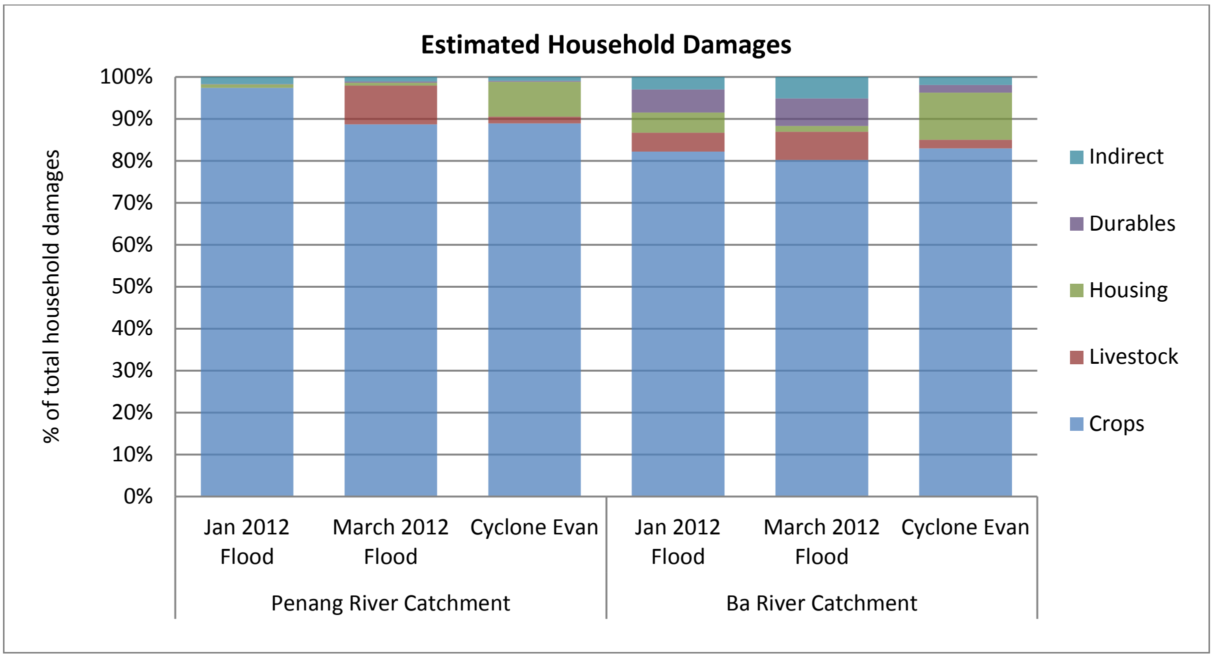


Figure E2. **Estimated damages to households, as percent of total damage**

Climate Change and Disaster Risk

Climate change projections for Fiji suggest that extreme rainfall will increase in frequency, particularly in the area comprising the Ba and Penang River catchments. Hence, we use the range of projected shifts in heavy rainfall return periods to construct 'moderate' and 'severe' climate-change scenarios in order to estimate future damages from flooding relative to 'current' climate.

Flooding events can be expressed in return periods. For the moderate scenario, we assume that each event shifts one return interval; analogously, for the severe scenario, we assume a shift of two return intervals. That is, the January flood that was considered a 1-in-50 year event under the current climate scenario is assumed to become a 1-in-20 year event under the moderate scenario and a 1-in-10 year event under the severe scenario. Similarly, the March 2012 flood is estimated to shift from a 1-in-20 year flood under the current climate scenario to become a 1-in-10 year flood and a 1-in-5 year flood under the moderate and severe climate-change scenarios, respectively.

Annual losses from flooding will increase accordingly. A summary of the estimated impacts of climate change on various flood return periods is listed in Table E1. We estimate that annual losses will increase by about 90% with moderate climate change and by nearly 275% with severe climate change.

Table E1. **Estimated damages to Ba and Penang River catchments from flooding (million FJD)**

Climate	1-in-5	1-in-10	1-in-20	1-in-50	1-in-100	Expected Annual
			Ba River Catchment			
Current	$5.6	$11.2	$22.3	$38.3	$76.5	$4.9
Moderate	$11.2	$22.3	$38.3	$76.5	$153.0	$9.4
Severe	$22.3	$38.3	$76.5	$153.0	$306.0	$18.2
			Penang River Catchment			
Current	$2.1	$4.2	$8.5	$13.1	$26.2	$1.8
Moderate	$4.2	$8.5	$13.1	$26.2	$52.4	$3.4
Severe	$8.5	$13.1	$26.2	$52.4	$104.7	$6.4

Adaptation

Adaptation to climate change may include 'hard approaches', 'soft approaches', and 'ecosystem-based adaptation', or EbA. Hard approaches employ infrastructure or technology in an effort to limit the damages caused by natural disasters. Examples include physical structures such as sea walls and embankments as well as activities such as channel dredging. Soft approaches are behavioural, focusing on limiting exposure through early warning systems, education, and effective planning. In contrast, EbA relies on natural or biological systems to mitigate natural disaster risks and to safeguard essential ecosystem services.

Box 1: Overview of EbA

Definition: Adaptation that integrates ecosystem services and biodiversity into a strategy to limit the adverse impacts of climate change.

Examples: afforestation, riparian planting, floodplain planting, alternative cropping systems, wetland restoration, integrated water resource management

Co-Benefits: In addition to protection from climate change impacts, EbA provides benefits such as maintenance and enhancement of ecosystem services (e.g., habitat provision, erosion control) that are crucial for livelihoods and human well-being, such as clean water and food. EbA can also contribute to the mitigation of climate change by reducing emissions from ecosystem loss and degradation and by enhancing carbon sequestration. EbA approaches are typically more flexible approaches than hard infrastructure projects.

Economics: EbA approaches are often highly cost-effective. For example, Naumann et al. (2011, p. 3) compared EbA approaches with hard infrastructure approaches for the potential to reduce climate change impacts across Europe and conclude that 'the majority of projects using ecosystem-based approaches can be considered as beneficial from an economic point of view…[In addition,] ecosystem-based approaches are likely to be more cost-effective than traditional engineered approaches…' Similarly, Rao et al. (2012, p. 13) suggest that EbA strategies are often 'orders of magnitude cheaper than engineering options…'

Options for the Ba and Penang River Catchments

Evidence from our socioeconomic surveys shows that hard approaches and soft approaches are the most common methods of adaptation in communities living near the Ba and Penang rivers (Table E2). For example, 44% of respondents reported reinforcing buildings and 33% reported requesting government assistance to adapt to climate change. In contrast, just 3% had planted trees to mitigate the effects of climate change.

In our analysis, we focus on EbA that may reduce damages stemming from flooding in particular. For EbA, these mitigation options include planting riparian buffers, afforesting the upper catchment, and planting floodplain vegetation. For hard approaches, these mitigation options include reinforcing riverbanks, dredging rivers, and raising houses. We also evaluate an integrated approach to adaptation that includes both EbA and hard options to assess the robustness of our findings.

Table E2. Current Adaptation Strategies in Communities Surveyed, Ba and Penang River Catchments, Fiji

Adaptation Option	% Communities
Reinforce buildings	44%
Request government assistance	33%
Designate evacuation centre	19%
Change cropping practices/varieties	17%
Dredge river	**14%**
Raise buildings	**11%**
Relocate buildings	8%
Store crops/food supply	8%
Save money for disaster response	8%
Plant mangroves	3%
Plant trees	**3%**
Construct diversion channel	3%
Plant riparian buffers along waterways	**0%**
Protect reef	0%
Create fire break, fire bans	0%
Change forestry practice/harvest ages	0%
Plant native vegetation in floodplains	**0%**
Improve village drainage system	0%
Construct sea wall	0%

Cost-Benefit Analysis

Cost-benefit analysis (CBA) is a systematic process of identifying, valuing, and comparing costs and benefits of a project in order to make concrete recommendations. Specifically, CBA is used to determine the extent to which the benefits of a given project outweigh the costs and to compare the relative merits of alternative projects in order to identify a preferred approach.

Bridge over the Penang River

We consider the costs and benefits of the adaptation approaches identified above under three climate change scenarios – current, moderate, and severe. The CBA assumes a project life of 100 years, and net present values (NPV) are calculated using a standard discount rate of 8%. Results are summarised in Table E3. In terms of NPV, the larger the value, the greater the net benefits the option provides. As for the benefit-cost ratio (BCR), the larger the ratio, the greater the amount of monetised benefit that are provided for each dollar spent on the intervention.

Table E3. Cost-benefit Analysis of Adaptation to Flood Risk in Ba and Penang River Catchments

Option	Ba River Catchment Total NPV *(FJ$ million)*	Ba River Catchment BCR	Penang River Catchment Total NPV *(FJ$ million)*	Penang River Catchment BCR
Current Climate Change				
Riparian buffers	12.6	2.8	5.0	6.8
Upland afforestation	19.5	1.2	8.6	1.5
Floodplain vegetation	(4.8)	0.8	1.6	1.4
Riverbank reinforcement	(83.2)	0.3	(17.5)	0.4
Raising houses	(13.5)	0.0	(4.6)	0.0
Dredging the river	(22.3)	0.6	3.9	1.6
Mixed Intervention	(3.3)	1.0	6.1	1.4
Moderate Climate Change				
Riparian buffers	26.8	4.9	9.7	12.3
Upland afforestation	47.8	1.4	18.1	2.1
Floodplain vegetation	6.6	1.3	5.4	2.3
Riverbank reinforcement	(54.9)	0.5	(8.0)	0.7
Raising houses	(13.1)	0.1	(4.6)	0.0
Dredging the river	6.0	1.1	13.4	2.9
Mixed Intervention	39.1	1.5	20.3	2.4
Severe Climate Change				
Riparian buffers	53.8	8.7	18.5	22.5
Upland afforestation	101.8	1.8	35.7	3.1
Floodplain vegetation	28.2	2.3	12.4	4.1
Riverbank reinforcement	(0.8)	1.0	9.5	1.3
Raising houses	(12.3)	0.1	(4.6)	0.0
Dredging the river	60.1	2.1	31.0	5.5
Mixed Intervention	88.8	2.1	42.6	4.0

Notes: NPV is the 'Net Present Value', which reports the discounted stream of future benefits less the discounted stream of future costs over the life of the project (i.e., monetary benefits for every dollar spent). BCR is the 'Benefit-Cost Ratio', which indicates the efficiency of spending on a particular form of adaptation. In the full report, we further consider differing levels of effectiveness for each option.

Recommendations

Although planting along streams and riverbanks does not provide the highest level of protection from flooding, the low cost of implementation coupled with the ecosystem services such as carbon sequestration, non-timber forest products, and habitat provision means that riparian planting has the highest impact per dollar spent on mitigation, i.e., it is most efficient.

Upland afforestation provides the greatest benefits overall because trees not only reduce the damages from flooding but also produce large quantities of monetised ecosystem services such as fruits, firewood, and carbon sequestration. Afforestation can also provide benefits that were not monetised in this study, including habitat provision and erosion control. However, the cost of planting and monitoring large areas is relatively high, rendering upland afforestation less efficient than riparian planting.

The benefits of planting native vegetation exceed the costs when climate change is expected to be moderate or severe, and the opportunity costs to planting in areas previously used for agriculture are modest. However, planting native vegetation in floodplains is neither as efficient as riparian buffers nor as effective as upland afforestation, so should be considered only as part of a mixed adaptation strategy.

The benefits of river dredging exceed the costs under the moderate and extreme climate-change scenarios. However, the repeated cost of dredging the river at least once every ten years is high relative to the benefits, particularly in the Ba River catchment. In the Penang River catchment, river dredging is more efficient than afforestation and floodplain planting, although it trails behind riparian buffers in terms of efficiency. Importantly, dredging does not reduce the flood risk in communities in the upper catchment, i.e., the benefits of dredging accrue exclusively downstream, which may or may not be desirable.

Neither reinforcing riverbanks nor raising houses is economically viable. In fact, under most scenarios, the costs of these activities greatly exceed their benefits.

A mixed intervention that incorporates both hard approaches and EbA is effective under most scenarios, indicating that it may be preferable to many approaches. This would particularly be the case if this approach incorporated a number of 'single-focused' options with positive NPVs (e.g., riparian planting, afforestation, and dredging). Nevertheless, we note that the cost of hard approaches can be high, and hence the efficiency of mixed interventions is lower than that of some EbA by themselves.

Team members practice survey enumeration on tablet computers.

1 INTRODUCTION

Natural disasters cause average annual direct losses of US$284 million in the Pacific. With a combined population of fewer than 10 million people (World Bank, 2012), annual losses are the highest in the world on a per-capita basis (World Bank, 2012). As such, the World Conference on Disaster Reduction recently acknowledged that small island states such as those in the Pacific require concerted research attention due to their high levels of exposure to hydrometeorological hazards such as hurricanes, cyclones, and tropical depressions (Hay, 2009; PCRAFI, 2011).

1.1 Climate-related natural disasters in Fiji

Three of the worst natural disasters in Fijian history stem directly from cyclones. In late February 1931 a slow moving hurricane struck the main island of Viti Levu, causing estimated 1-in-250 year floods in the north-western province of Ba (McGree *et al.*, 2010). At least 126 people were killed in the Ba River catchment, with a further 99 killed elsewhere in Fiji (Yeo and Blong, 2010). More recently, Hurricane Kina caused nine fatalities and resulted in approximately FJ$188 million in damage in 1993 (World Bank, 2000), and Cyclone Ami caused 17 fatalities and resulted in FJ$104 million in damage in 2003 (NDMO, 2003).

However, parts of Fiji are extremely vulnerable to flooding even without cyclonic activity. For example, a persistent monsoon trough triggered record rainfall over five days in January 2009 (FMS, 2009). Severe flooding of the Nadi, Ba, and Sigagtoka rivers ensued (Ambroz, 200 9), with floodwaters rising to an estimated 2.5-3m at the Rarawai mill near the Ba Township, eclipsing all previous flood records bar that of 1931 (McGree *et al.*, 2010). 11 lives were lost during the floods and 11,458 people were forced to seek shelter in evacuation centres (Ambroz, 2009; McGree *et al.*, 2010). Public utilities were disrupted for more than a fortnight, and the government declared a 30-day state of natural disaster. In the immediate aftermath, the total costs were estimated at FJ$113 million by the Fijian government (Ambroz, 2009). This figure was later revised up to FJ$175 million (Mcgree *et al.*, 2010).

As with the floods of 1931, damage from the 2009 floods was concentrated in Ba province. Sugarcane crops were badly damaged by the floodwaters, and a number of small bridges used to transport sugarcane were destroyed (McGree *et al.*, 2010). The main road was badly damaged on each side of the Ba bridge. Ambroz (2009) reports that total losses to private households – including structural damage and lost assets – reached FJ$56 million in Ba and that losses to businesses totalled FJ$31 million, primarily in the form of lost earnings.

The western and northern divisions of Viti Levu were flooded twice more in early 2012. The first flood took place between 21 January and 12 February, when a broad tropical depression brought heavy and persistent rainfall to the area (WPRO, 2012). Over 400mm of rainfall was recorded, prompting flooding throughout Nadi and Ba (WPRO, 2012; Asian Scientist, 2012). A state of emergency was declared as 1,300 people sought shelter in evacuation centres (Molan, 2012; WPRO, 2012). Flooding and landslides killed 11 people, and early damage estimates stood close to FJ$60 million (WPRO, 2012; UN News Centre, 2012) as many homes were damaged and crops were washed away (Asian Scientist, 2012; Molan, 2012).

Two months later, another tropical depression caused heavy rainfall in the northern and western divisions of Viti Levu, which led to flooding in Ba, Lautoka, Tavua, and Rakiraki (Simmons and Mele, 2013). Some 15,000 people were temporarily displaced (UN Country Team in Fiji, 2012; Simmons and Mele, 2013). Four people were killed during the floods and a state of natural disaster was called for western parts of Viti Levu (UN Country Team in Fiji, 2012). Damages were estimated at more than FJ$70 million (UN Country Team in Fiji, 2012).

Tropical Cyclone Evan was the third major natural disaster to affect northern and western Viti Levu in 2012. With wind speeds of 210Km/h, Cyclone Evan was a Category 4 storm, among the strongest to hit Fiji in recent memory (SPC and SOPAC, 2013). Early warning systems increased preparedness, and, as a result, no lives were lost (SPC and SOPAC, 2013). However, disruption and damage were widespread: some 11,000 to 14,000 people were displaced by the December 2012 storm and the total economic value of the disaster is estimated at FJ$194.9 million (NDMO, 2012, in Simmons and Mele, 2013; SPC and SOPAC, 2013). Private houses were also badly affected, with 8,497 damaged and 2,094 completely destroyed (SPC and SOPAC, 2013). In addition, agriculture was badly affected, with up to FJ$33.6 million in losses and damages (Simmons and Mele, 2013).

Between flooding and cyclones, the total estimated damage from weather-related natural disasters in 2012 reached FJ$325 million (approximately 4.3% of GDP), prompting Fiji's Reserve Bank to reduce estimated growth rates (Simmons and Mele, 2013). Moreover, because these damages were highly concentrated, the three disasters took an acute toll in both human and economic terms.

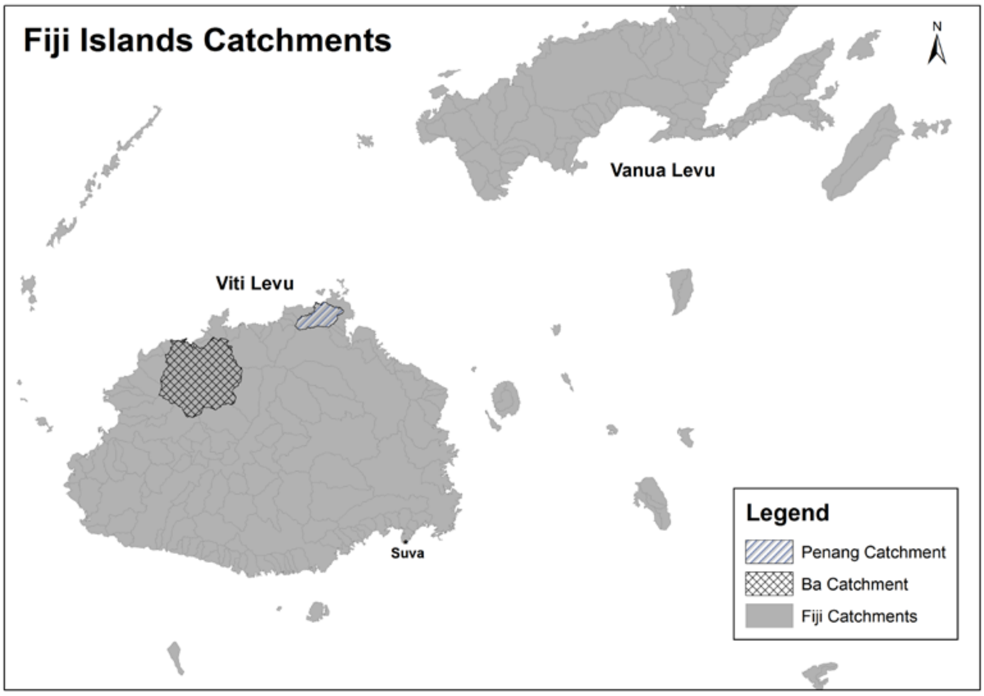


Figure 1. Fiji Islands, including study sites

1.2 Changing risk profiles globally under climate change

Over the last 70-odd years, the number of recorded disasters globally increased almost monotonically (Figure 2), with disproportionately high increases in the incidence of flooding. While part of the observed increase in number stems from increased exposure as human settlements have expanded, Munang *et al.* (2013) note that the increased incidence of natural disasters has coincided with an increase in temperature, which is widely considered to be anthropogenic in nature (e.g., Preston *et al.*, 2006). As such, the frequency of climate-related disasters is likely to continue to increase.

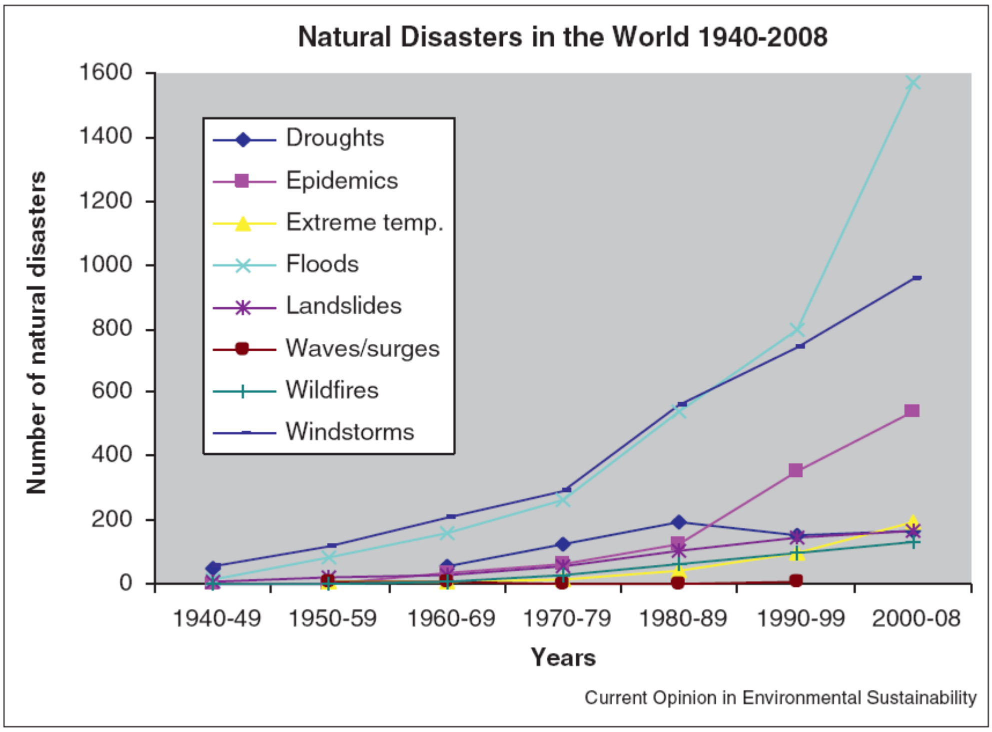


Figure 2. Observations of natural disasters globally between 1940 and 2008. Source: Munang et al. (2013).

1.3 Changing risk profiles in Fiji under climate change

While patterns in natural hazards related to climate change are observable on a global basis, changes in climate on a regional scale depend highly on atmospheric patterns and oceanic circulation (Bates *et al.*, 2008) , making it difficult to isolate trends in natural hazard frequency over the historical record. Nevertheless, Australian Bureau of Meteorology and CSIRO (2011) observe that temperatures in the South Pacific have increased by 0.6°C in the last hundred years, and ADB (2011) finds that events such as storm surges, floods, and droughts have increased in the Pacific in recent decades. Figure 3 plots flood height against time for Fiji's Ba River, demonstrating a strong increasing trend (Yeo et al., 2007; Yeo, pers. comm, 22 July 2013). Thus, climactic trends in the Pacific appear to follow those observed more widely.

To anticipate future trends, PICCAP (2005) developed risk projections for Fiji using two General Circulation Models (GCMs) within the Special Report on Emissions Scenarios. While the A2 scenario is considered to be extreme, the B2 scenario is considered to be 'mid-range'. Under this mid-range scenario, PICCAP projects that:

- average temperature will increase by 0.5°C by 2025, by 0.9°C by 2050, and by 1.6°C by 2100;
- annual rainfall will increase by 3.3% by 2025, by 5.7% by 2050, and by 9.7% by 2100;
- sea level will rise by 11cm by 2025, by 23cm by 2050, and by 50cm by 2100; and
- maximum wind gusts will increase by 3.4% by 2025, by 6.8% by 2050, and by 13.4% by 2100.

Taken together, these projections indicate that climate change will lead to higher incidence of natural disasters, including flooding, landslides, and coastal erosion. It is also expected that agricultural productivity will decline (Preston et al., 2006), with stronger winds expected to damage crops including sugar, banana, and coconuts and flooding expected to damage root crops such as taro and cassava.

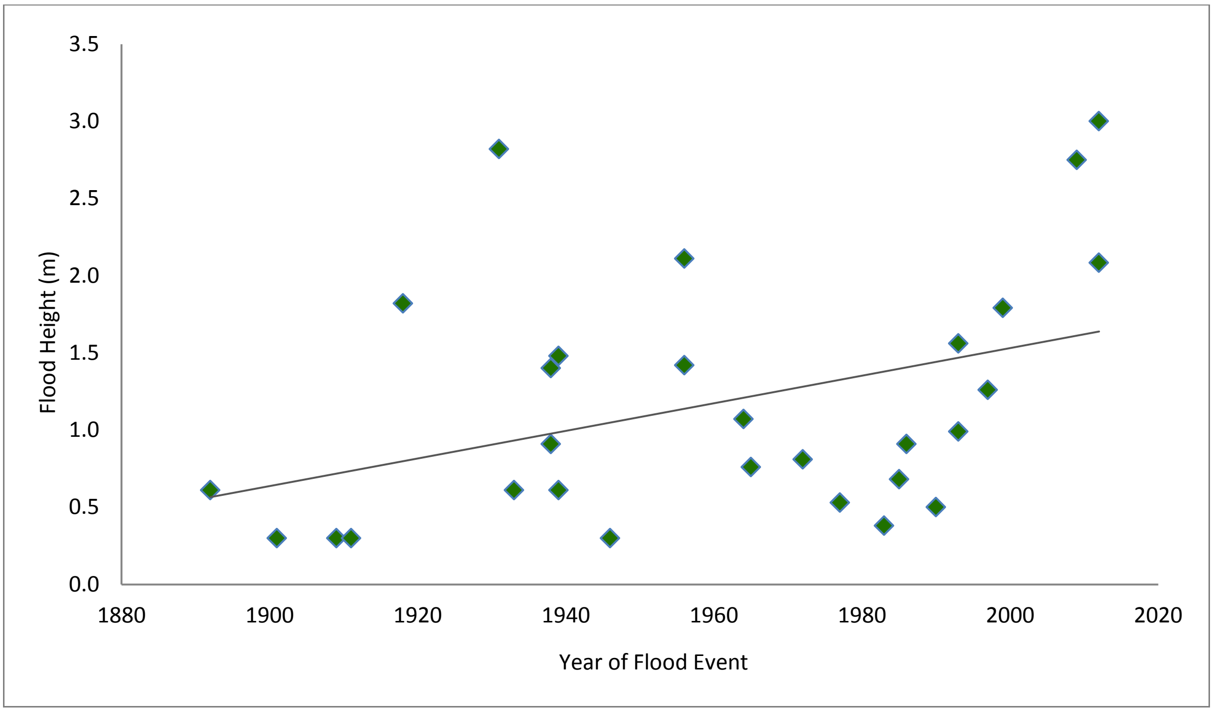


Figure 3. **Flood height of the Ba River over time, with trend line**

Hay (2006, in Hay, 2009) modelled future changes in the return period for heavy precipitation events in Nadi and concludes that a 400mm 24-hour rainfall total had a 190-year return period between 1946 and 1965, while such rainfall would likely have a 25-year return period between 2086 and 2100. PCRAFI (2011) estimates that Fiji has a 50% chance of incurring losses greater than FJ$750 million and casualties of more than 1,200 people over the next 50 years. Moreover, annual maximum daily precipitation amounts that currently occur with a 1-in-20-year probability will occur with a 1-in-5 to 1-in-10-year probability by the end of this century (IPCC, 2012),

Appendix 1 provides a more thorough account using a broad and representative eight GCMs and reports on the relative agreement of modelled projections. For temperature and precipitation, the results are consistent with those presented above, unequivocally pointing to increases. However, the models show more divergence for cyclone risk and flooding. For example, the number of cyclones is likely to decline while their intensity and destructiveness will increase (Preston *et al.*, 2006; Solomon *et al*., 2007; Yeo *et al.*, 2007; Australian Bureau of Meteorology and CSIRO, 2011; Rao *et al.*, 2012). To wit, PCRAFI (2011) estimates that a 1-in-100 year tropical cyclone would cause damage equivalent to 28% of Fiji's GDP. Similarly, although the results are not unequivocal, flooding is expected to increase substantially in at least some catchments (Preston *et al.*, 2006; Hay, 2009; Rao *et al.*, 2012; IPCC, 2012).

1.4 Changing risk profiles due to human activity and development

Human activities and development influence the disaster-risk profile in at least three important ways. First, human alterations to natural systems can change how these systems behave, which may either reduce or exacerbate the risk of natural disasters. Second, the expansion and development of infrastructure in risk-prone areas increases exposure to disaster risk. Third, socioeconomic development may either foster or hamper resilience. Indeed, these influences may be more important than the physical drivers of risk (IPCC, 2012).

1.4.1 Increases in exposure

Exposure describes the presence of people; their livelihoods; their possessions; and their social, cultural and environmental amenities in relation to risk (IPCC, 2012). As populations grow and infrastructure develops and expands, exposure increases. Increases in exposure over time have been the major driver of increased loss and damage from climate-related disasters (IPCC, 2012).

For example, exposure is increased by poor planning or poor enforcement of zoning ordinances. In Ba Township, the Town Planning Act stipulates that houses must be built a minimum of 5.0m above mean sea level. However, floodwaters can be expected to exceed this height every four to five years, on average (Yeo *et al.*, 2007), and a flood the size of that from 1931 would inundate compliant houses with almost 3m of water.

Elsewhere in Fiji, tourism-driven development of coastal areas has increased exposure to coastal flooding, sea-level rise, and tsunamis (SPREP, 2011). Hence, IPCC (2012) suggests that increases in exposure will continue to be the dominant driver of future increases in climate-related disaster risk.

1.4.2 Human alterations to natural systems

Risk stemming from natural disasters is influenced by human alterations and land-use changes. For example, attempts to constrain waterways may increase erosion susceptibility and sedimentation while exacerbating flooding if an engineered channel overflows (Rao *et al.*, 2012). Catchment deforestation and the expansion of urban areas are also generally found to increase flood risk and channel sedimentation (Bates *et al.*, 2008). Philpott *et al.* (2008) find that landslide risk increases as agricultural intensity increases and vegetation complexity decreases.

Some studies suggest that flood risk has increased as a result of land alteration in Fiji. For example, Ambroz (2009) surveyed stakeholder perceptions about the causes of the January 2009 flooding in Ba province. A number of respondents suggested that siltation of the Ba River due to unsustainable agricultural practices in the catchment had increased the risk of flooding. While these explanations are consistent with the findings outlined above, Yeo *et al.* (2007) found no statistically significant correlation between channel sedimentation and flood frequency or between land use change and flood frequency in the Ba River catchment. The extent to which land-use changes have increased the disaster risk profile in Fiji thus remains unclear.

1.5 Social resilience

The risk profiles of communities is further influenced by 'social resilience', which Chapin *et al.* (2009, in SPREP, 2011, p.9) define as the capacity of a social system 'to absorb a spectrum of shocks or perturbations and to sustain and develop its fundamental function, structure, identity and feedbacks through either recovery or reorganization in a new context'. Social resilience is, therefore, an internal condition of households or communities.

Social and economic changes have acted to both increase and decrease social resilience. Over time, many traditional means of ensuring social resilience have been abandoned. For example, while Pacific Island settlements were traditionally located on secure land away from coastal or riverine hazards, the population is now disproportionately coastal (Russell *et al.*, 2012). In addition, crop diversity has diminished and adaptable crops like taro and yams have been displaced in some areas by the more vulnerable cassava (Russell *et al.*, 2012).

While the abandonment of traditional resilience strategies has some negative consequences, the gradual process of socioeconomic development may have increased overall social resilience in the Pacific. Fiji is a middle-income country, and while it faces challenges relating to isolation and limited natural resources, these are often less acute than in other Pacific nations (Van Beukering *et al.*, 2007; Russell *et al.*, 2012). Nevertheless, development in Fiji is still hampered by unstable governance, poor infrastructure, international political tensions, and ineffective environmental and economic policy (e.g., Preston *et al.*, 2006). According to AusAid (2006), these conditions threaten economic growth in Fiji and in turn may reduce resilience as risk from natural disasters grows.

Social resilience is influenced by power structures within societies. Russell *et al.* (2012) note that less hierarchical communities are generally more socially resilient because their members feel more community responsibility. In Fiji, society is structured around kin-based hierarchies decided by age, seniority of decent, and gender (Takasaki, 2009). While these hierarchies create power inequalities within Fijian society, they also foster interdependence. For example, in an investigation of the allocation of disaster relief funding in Fiji, Takasaki (2009) found that local elites distributed relief funding evenly and refrained from capturing larger benefits for themselves. Therefore, while hierarchical societies are generally less socially resilient than egalitarian ones, this may not be the case in kin-based Fijian communities.

While it appears that power inequalities have little impact on social resilience in Fijian communities, it is likely that economic inequalities do. Specifically, more than 30% of Fiji's rural population lives below the national poverty line (Van Beukering *et al.*, 2007), and unlike urban populations, the rural population is more reliant on natural resources (and therefore more exposed to natural disasters).

Crossing on a tributary of the Ba River.

2 ADAPTATION STRATEGIES FOR REDUCING DISASTER RISK

Parry *et al*. (2007, P.6) defines climate change adaptation as ‘adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.’ Adaptation can be characterised as ‘hard approaches’, ‘soft approaches’, and ecosystem-based adaptation (EbA) approaches (Jones *et al.*, 2012). Hard approaches use infrastructure or technology in an effort to limit the damages caused by natural disasters. Examples include structures such as sea walls, embankments, and dredging of channels. Soft approaches are generally behavioural, focusing on limiting exposure through disaster warnings, education, and effective planning. EbA uses natural or biological systems to mitigate natural disaster risks and safeguard essential ecosystem services. The three approaches are discussed in turn.

Hard approaches

Hard approaches such as sea walls and flood levies may provide effective defence against climate-related loss and damage (Rao *et al.*, 2012) and have dominated climate-related disaster risk reduction to date (Jones *et al.*, 2012). In Fiji, for example, river dredging is seen as the most appropriate flood reduction measure by both stakeholders and policy makers (e.g., Yeo, 1997, in Yeo, 2007; Ambroz, 2009; Chaudhary, 2012), and the government has identified river dredging as one of four flood rehabilitation priorities[1] (UN Country Team in Fiji, 2012).

Unfortunately, hard approaches are often expensive (Jones *et al.*, 2012). In Fiji, for example, initial cost estimates of the government’s four flood rehabilitation priorities suggest that river dredging is roughly 100 times more expensive than the other three strategies combined (UN Country Team in Fiji, 2012). In addition, hard approaches may have short lifecycles and often require costly maintenance (Jones *et al.*, 2012).

Furthermore, engineered structures such as levies and sea walls are designed to contain disasters of given magnitudes, and once their fail points are exceeded, the damage is often catastrophic. A popular example of this tipping point is the levees surrounding New Orleans which, when overwhelmed, held floodwaters in, increasing the duration of flooding (Jones *et al.*, 2012). Such inflexibility poses a particular challenge when adapting to changing climatic conditions, and SPREP (2011) argues that hard adaptation approaches become less appropriate in the face of greater uncertainty.

2.1 Soft approaches

Soft approaches to adaptation are often less expensive and more flexible than hard approaches (Hallegatte, 2010). Soft approaches work to either reduce exposure (e.g., by prohibiting development in high-risk areas or through early warning systems), spread disaster risk over time and space (e.g., by insuring infrastructure, assets, and crops), or increase community resilience (e.g., by education) (Jones et al., 2012). The flexibility of soft approaches represents a substantial advantage over hard infrastructure (Wilby and Dessai, 2010), for as Hallegatte (2010, p.) points out ‘an insurance scheme can be adjusted every year, unlike a water reservoir.’ Flexible soft approaches can also reduce the chance of costly maladaptation.

2.2 Ecosystem-based adaptation

EbA is defined by the Convention on Biological Diversity as ‘Adaptation that integrates the use of biodiversity and ecosystem services into an overall strategy to help people adapt to the adverse impacts of climate change’ (CBD, in SPREP, 2011). By this definition, the focus of EbA is to benefit people, with ecosystem protection and rehabilitation being means to that end (SPREP, 2011). These approaches are gaining attention due to a number of advantages they have over both hard and soft adaptation approaches.

EbA approaches provide highly flexible alternatives to hard infrastructure projects (UNEP, 2013). As Jones *et al.* (2012, p.506) point out, ecosystems are often ‘inherently plastic’ and, under suitable conditions, have the ability to respond to change and to reorganise. The potential benefits of EbA approaches are particularly large in developing countries given the importance of natural capital for individual livelihoods and the broader economy (SPREP, 2011).

[1] The other three priorities were 1) Distribution of seedlings for export crops and vetinary drugs; 2) Distribution of seedlings for food security; and 3) River Dredging and infrastructure development/rehabilitation.

In contrast, soft approaches are generally unable to provide the same level of protection against natural disasters as hard approaches or EbA. For example, early warning systems are imperfect and may threaten lives and assets if their accuracy is overstated or their assessments are inaccurate (Hallegatte, 2010). Furthermore, while insurance provides some protection against material losses, it does not reduce the risk to human life during natural disasters. Because of these limitations, soft approaches are, at best, only part of effective disaster-risk reduction.

A rapidly growing body of literature suggests that EbA approaches are also highly cost-effective (Jones *et al.*, 2012). Naumann *et al.* (2011, p. 3) compared EbA approaches with hard infrastructure approaches for the potential to reduce climate change impacts across Europe and concluded that 'the majority of projects using ecosystem-based approaches can be considered as beneficial from an economic point of view…[however] ecosystem-based approaches are likely to be more cost-effective than traditional engineered approaches…' Rao *et al.* (2012, p. 13) suggest that EbA strategies are often 'orders of magnitude cheaper than engineering options…'[2]

When implemented using best practice, EbA also has procedural benefits. According to UNEP (2013), EbA provides opportunities for collaboration between sectors, involvement of local stakeholders, and integration of traditional knowledge into adaptation planning. EbA may also reduce the risk of maladaptation by achieving a broader range of social, environmental, and resilience-related objectives than targeted infrastructure projects (UNEP, 2013).

2.2.1 EbA strategies for reducing flood risk

As noted in Section 1.2, the incidence of flooding has increased dramatically worldwide over the past 100 years. As described in Section 1.3, this trend is expected to continue for Fiji and is expected to result in more frequent catastrophic damages. Hence, we focus primarily on EbA strategies for reducing flood risk. Specifically, we describe the processes and co-benefits of reducing headwater flow by preserving or re-planting upland forests; using riverine and riparian vegetation to slow the flood pulse and reduce flood peaks; and reducing flood peaks by conserving or planting floodplain vegetation.

2.2.2 Upland forests

Preserving or re-planting upland forests reduces flash flooding, delays peak flows, decreases erosion, and reduces sediment loads (Rao *et al.*, 2012). Vegetation increases flow resistance and infiltration, meaning that peak flows are both smaller and delayed. For example, Jakeman *et al.* (2005) point out that forested catchments release both smaller annual discharge and smaller proportions of discharge occurring as quick flow. Upland forests also moderate soil moisture levels and dry the soil at depth through transpiration (Sidle, 2008). Furthermore, vegetation root structures stabilise the soil mantle and reduce landslide risk and erosion (Sidle, 2008). In Fiji, intact headwater forests have been found to limit erosion, channel sedimentation, and flooding in Lami Town near Suva (Rao *et al.*, 2012). Preservation of these upland forests or replanting forests in cleared areas may therefore provide an effective way to reduce flood risk in Fiji.

2.2.3 Riverine and riparian vegetation

Similar to preserving upland vegetation, planting or preserving vegetation along river banks can reduce and delay peak flow while reducing channel erosion and siltation (SPREP, 2011; Rao *et al.*, 2012). As Anderson (2005) notes, vegetation in or near waterways increases flow resistance, delaying and attenuating flood peaks. Increased resistance does, however, increase flood height in the upper tributaries, such that there exists a trade-off between flooded area in the lower catchment and higher water levels in the headwaters (Anderson, 2005). The implications of redistributing floodwaters must therefore be considered when planning to replant riparian zones.

2.2.4 Floodplain re-vegetation

Preserving or replanting vegetation on floodplains may further delay and attenuate flood peaks, particularly when implemented alongside riparian planting. For example, Pithart (2008) compared hydrographs from segments of the Luznice floodplain with differing degrees of forestation. He found that the 12km-long undeveloped section of the floodplain delayed the peaks of large floods by up to two days and reduced peak discharge by between 10% and 20%. The benefits for downstream communities are clear; however, increased costs for those who live or farm on the floodplains are often

[2] For example, Hillen (2008, in Jones *et al.*, 2012) found that the annual cost of maintaining a sea dyke in Vietnam was FJ$287.50 per hectare protected compared to only FJ$7.50 per hectare protected for maintaining mangrove forests. Das and Vincent (2009) assessed the influence of mangrove depth on death toll in Orissa during the Indian super-cyclone of 1999. They found that in pure economic terms, based on implied wage differentials from the death toll alone, replanting mangroves is a cost-effective risk reduction strategy.

considerable, a particular problem in the Pacific because floodplains are densely populated and used for agricultural production (SPREP, 2011). Particular challenges may arise where floodplain re-vegetation effectively forces the relocation of floodplain residents, who may have cultural and/or spiritual ties to their land (Adger *et al.*, 2013).

2.2.5 EbA co-benefits

EbA strategies to mitigating disaster risk often carry important co-benefits, including ecological resilience and other gains. We discuss these in turn.

2.2.6 Ecological resilience

EbA strategies to mitigating disaster risk may promote 'ecological resilience'[3], i.e., 'the amount of disturbance a system can withstand before it changes to a new set of reinforcing systems of structures' (SPREP, 2011, p.9).[4] For example, restrictions to limit trawling in fisheries can prevent habitat destruction to promote habitat heterogeneity and thus fish population and species diversity (Bernhardt and Leslie, 2013). EbA approaches to managing disaster risk can often be seen as 'no regrets' strategies (Preston *et al.*, 2006) because they emphasize addressing *existing* climate vulnerability and are therefore likely to provide benefits regardless of how climate changes in the future (Preston *et al.*, 2006). For example, afforestation may reduce damage stemming from high winds as well as reducing and delaying peak flows of floodwaters. This approach is both consistent with the principles of disaster-risk management and desirable given the uncertainty inherent in climate projections (IPCC, 2012; ADPC, 2013).

Human development may undermine ecological resilience (Russell *et al.*, 2012). For example, ecosystems in the Pacific are degraded due to reductions in biodiversity, changes in land management, and fragmentation of ecosystems (Buncle *et al.*, 2013). Such degradation undermines the provision of ecosystem services and reduces the ability of ecosystems to buffer against natural disasters. Indeed, Munang *et al.* (2013) find that up to 60% of ecosystem services are already degraded or depleted, reducing the resilience of human communities and increasing both physical and socioeconomic vulnerability (Thornton, 2012).

Unlike hard infrastructure, however, ecosystems are capable of adapting to changing conditions. While the adaptive capacity of some ecosystems (such as coral reefs) may be outstripped if the projected rates of climate change eventuate, other ecosystems are more resilient. For example, Gilman *et al.* (2007) note that mangrove forests in the Pacific are capable of inland migration at rates substantially higher than those of projected sea-level rise.

2.2.7 Other benefits

The strategies for EbA described above variously help to sequester carbon; protect biodiversity; provide cultural, recreational, and tourism amenities; and provide opportunities for agroforestry (SPREP, 2011; Thornton, 2012; Jones *et al.*, 2012; UNEP, 2013). These approaches also protect and enhance ecosystem services relating to flow regulation, water purification, land stabilisation, and provision of fuel wood and fodder (Rao *et al.*, 2012; Thornton, 2012).

The value of such co-benefits stemming from EbA projects can be considerable. For example, Dubgaard (2004) found that restoration of a wetland on the Skjern River in Denmark would avoid FJ$2.3 million in flood mitigation costs and provide FJ$84.6 million in co-benefits such as biodiversity protection and recreational opportunities. In Fiji, Aalbersberg *et al.* (2005) calculated that the ecological spill-over benefits of locally managed marine areas in Ucunivanua, Kumi, and Votua helped to increase weekly household income by 43% on average between 2000 and 2003.

[3] Human development may undermine ecological resilience via biodiversity loss, changes in land management systems, and fragmentation (Buncle *et al.*, 2013; Russell *et al.*, 2012). However, climate change may also contribute to eroding ecological resilience; according to Parry *et al.* (2007, p. 213), 'The resilience of many ecosystems is likely to be exceeded by 2100 by an unprecedented combination of change in climate, associated disturbances (e.g., flooding, drought, wildfire, insects, ocean acidification), and other global change drivers (e.g., land-use change, pollution, over-exploitation of resources)'. Regardless of the source, Munang *et al.* (2013) find that up to 60% of ecosystem services are already degraded, reducing the resilience of human communities.

[4] In contrast, 'engineering resilience' is 'the rate at which a system returns to a single steady state following a disturbance' (SPREP, 2011, p.9). Engineering resilience makes assumptions about future risk to design systems that have high redundancy and are therefore unlikely to fail (SPREP, 2011).

2.2.8 Uncertainty in EbA

Uncertainty represents a significant challenge in mitigating climate-related disaster risk via EbA.

Specifically, uncertainty with regard to climate change reduces the value proposition of investment of any kind. Unlike hard adaptation, however, it may be more difficult to generalise successes across locales due to ecological and environmental idiosyncrasies. For example, different plant species are likely to have different abilities to attenuate flood waves (Anderson, 2005; SPERP, 2011). Similarly, the nature of ecosystem services provided by a given species may depend critically on climate (Komiyama, 2008). For this reason, hard adaptation may be preferable to EbA, at least in the absence of rigorous sensitivity analysis.

Political uncertainty may also undermine the relative attractiveness of EbA to mitigating the risks of climate change. Specifically, EbA approaches often disproportionately deliver benefits over long timeframes as ecosystems become established and mature. In contrast, decision making is often political in nature and, as such, tends to be biased in favour of short-term benefits (UNEP, 2013).

2.2.9 EbA in the Pacific

Despite an emerging understanding of the potential of EbA in addressing climate-related risk worldwide, there has been limited application of EbA in the Pacific. According to Lal (2011) and SPREP (2011), social and economic conditions in at-risk communities are not well understood and decision makers are often sceptical of the ability of ecosystem-based approaches to reduce disaster risk. Moreover, under conditions of scarcity, decision makers often allocate funds to high-profile post-disaster response measures rather than prevention strategies (Benson and Twigg, 2004).

Without additional evidence on the effectiveness and costs of EbA relative to traditional infrastructure projects, Pacific decision makers may allocate resources sub-optimally when planning for climate-related disasters in the region (UNEP, 2013; Jones *et al.*, 2012). Hence, there is a need to rigorously evaluate the costs and benefits of EbA vis-à-vis hard adaptation, explicitly accounting for social and economic vulnerability, resilience, geography, and uncertainty in climate-related disaster risk.

Indo-Fijian house in the lower Ba River Catchment

3 STUDY SITES

3.1 Ba River catchment

Located in the north-western part of Viti Levu, Ba is the second largest province in Fiji by area and the largest by population, with 231,762 residents according to the 2007 census (Fiji Bureau of Statistics, 2012b). Two-thirds of the province residents are of Indo-Fijian ethnicity and are largely descended from indentured labourers brought to Fiji to work on colonial sugar cane plantations between 1879 and 1916. The remaining one-third of the population is comprised of *iTaukei*, i.e., indigenous Fijians. Sugar production, timber harvesting, and fishing are important commercial activities, although the population is largely rural and generally poor: Narsey (2008) reports a 34% poverty rate in Ba Province. 45,879 people are estimated to live within the boundaries of the catchment, most of them in Ba Town and downstream, where flooding is a particular risk.

'Ba' is also the name given to a district, a tikina (an administrative area comprising several towns and/or villages), a prominent town, and a river. The Ba River runs from its headwaters in the central mountainous parts of Viti Levu north through Ba Town, spilling into the Pacific near the village of Nailaga. The Ba River is subject to frequent flooding, with flooding recorded in 1871, 1892, 1918, 1931, 1938, 1939, 1956, 1964, 1965, 1972, 1986, 1993, 1997, 1999, 2009, and 2012 (McGree et al. 2010). As noted earlier, several of these floods have been catastrophic, leading to significant loss of crops, property, and life. Dredging commenced in late 2012 as a tool to alleviate flooding in the future (e.g., Malo, 2012).

The Ba River catchment is approximately 94,950 ha in size. Land use is dominated by talasiga (open grassland), which comprises about 38% of the total area, followed by native forests (29%). Other important land uses include agriculture (17%), forest plantations (5%), disturbed forest (5%), and development (2%). An overview of land use in the catchment is displayed in Figure 4.

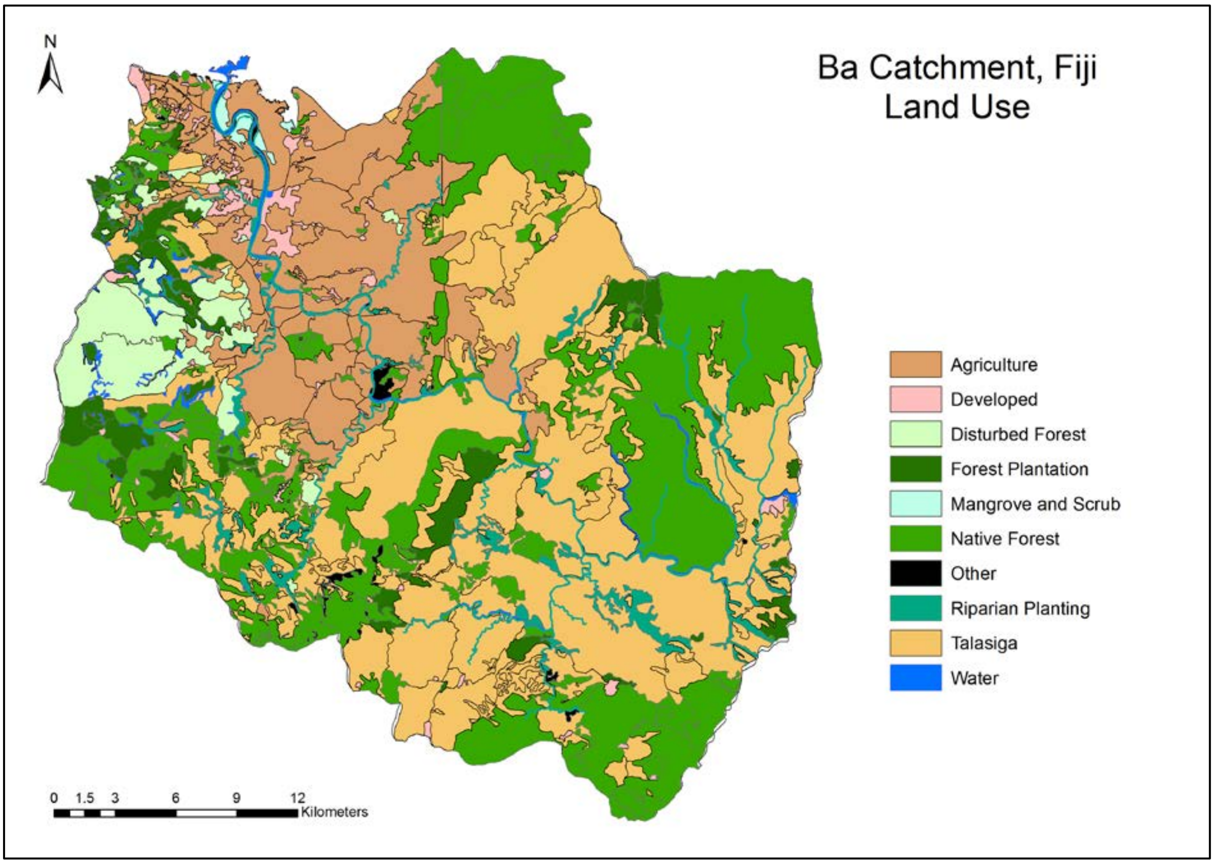


Figure 4. **Ba River catchment, Fiji**

3.2 Penang River catchment

Bordering Ba Province on the east, Ra Province is comparatively small, with just 29,464 residents at the time of the 2007 census. Approximately 15% of the population lives in Rakiraki Town, its only urban settlement, with the remaining 85% living in scattered rural settlements and villages. Nearly 70% of the population is ethnically *iTaukei* and just over 30% is of Indo-Fijian ethnicity census (Fiji Bureau of Statistics, 2012b). Sugar production is the main economic activity, although tourism and cattle rearing are also locally important industries. Narsey (2008) reports that 53% of the population of Ra Province earns less than the poverty line, suggesting that this population is especially vulnerable in the face of disasters.

The Penang River (alternatively, the Rakiraki River) flows approximately 1 kilometre outside Rakiraki Town. It is known to have flooded in 1914, 1939, 1956, 1972, 1986, 1999, 2004, 2009, 2012, and 2014. Although the Penang River is considerably smaller than the Ba River, significant flooding and forced evacuations in recent years have prompted the Rakiraki provincial administrator to call for proposals to divert the river and/or to relocate Rakiraki Town (Fiji Ministry of Information, 2012).

The Penang River catchment is about 10,250 ha in size. Land use is dominated by talasiga (open grassland), which comprises about 45% of the total area, and sugarcane/agriculture (43%). Other land uses include forests (10%), and developments (2%). An overview of land use in the catchment is displayed in Figure 5.

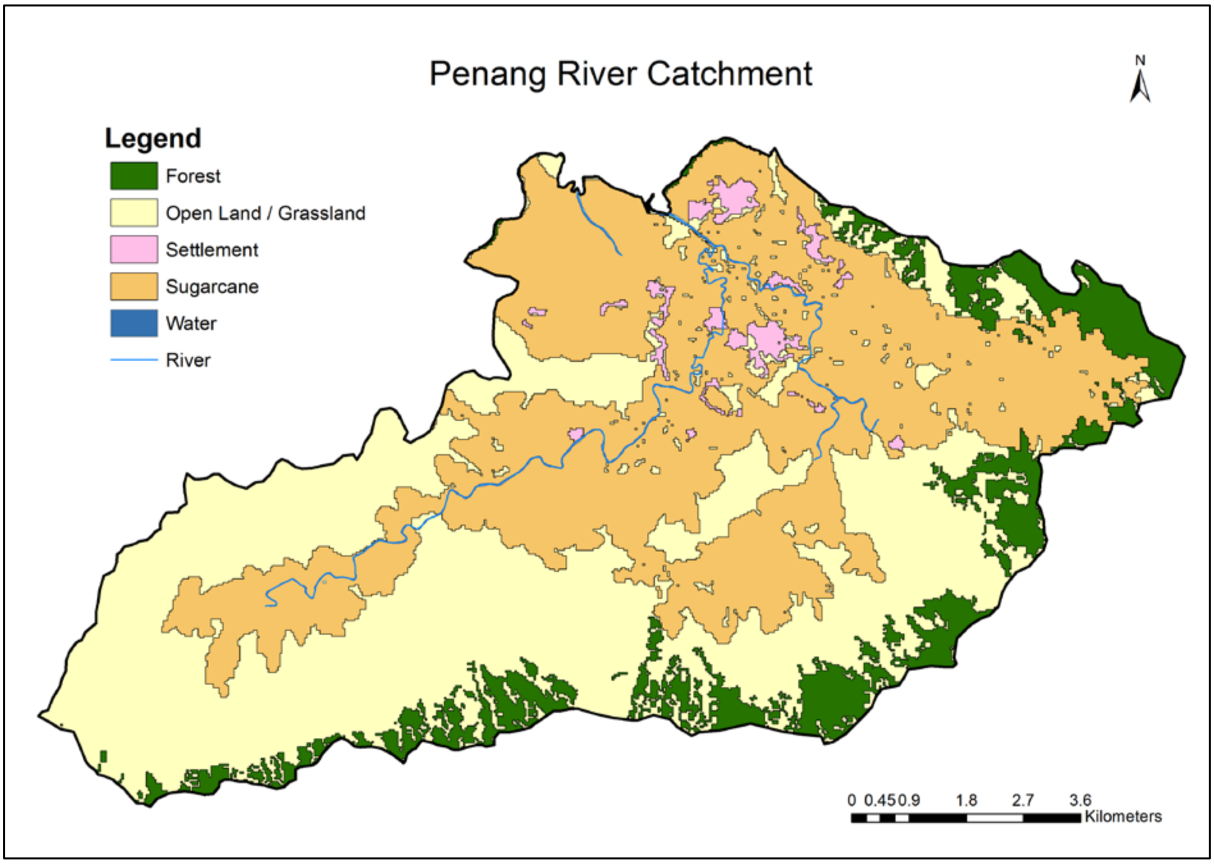


Figure 5. **Penang River catchment, Fiji**

4 CBA METHODOLOGY AND ITS APPLICATION

Cost-Benefit Analysis (CBA) is defined by Buncle *et al.* (2013, p.*v*) as 'A systematic process for assessing, calculating and comparing the advantages (benefits) and disadvantages (costs) of an activity…[including] those costs and benefits that cannot be quantified in monetary terms but are nonetheless valued by society…'. This approach organises and compares complex trade-offs with the aim of finding strategies that maximise public welfare (Mechler, 2005). In contrast to other evaluation methods such as multi-criteria analysis, CBA is noted for its methodological tractability, transparency, and wide adoption among governments and makers of environmental policy (Pearce, Atkinson, and Mourato, 2006). CBA is also noted for its simplicity: In the words of Goulder and Kennedy (2009, p.1), 'Perhaps the most important basis for supporting a policy that would protect otherwise threatened ecosystem services is evidence that society gains more value from such protections than it gives up.'

4.1 Methods

To inform the comprehensive CBA, we undertook a detailed suite of social, economic, and physical surveys. In addition, we developed the first detailed hydrological models of the Ba River and the Penang River. These methods are discussed in turn prior to providing a detailed account of the CBA methodology.

4.1.1 Survey sample

To collect data on the income, exposure to disaster risk, and resilience in the Ba River catchment, we divided the catchment into three distinct areas (Figure 6):

- the upper catchment, from the ridge line through Navala;
- the middle catchment, just downstream of Navala to just upstream of the Rarawai Sugar Mill; and
- the lower catchment, from the Rarawai Sugar Mill upstream from Ba Town through the river mouth near Nailaga

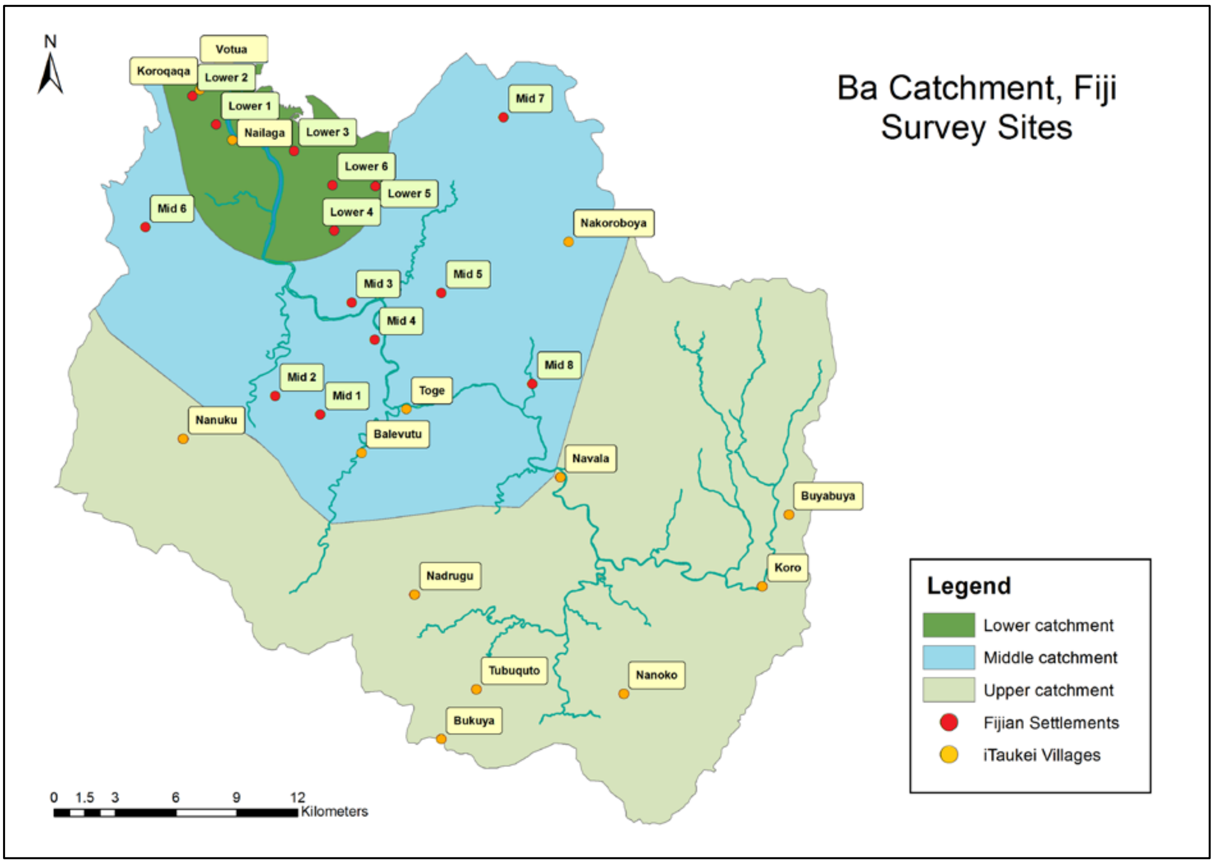


Figure 6. Ba River catchment survey sites

To ensure broad geographic coverage, approximately one-third of the sample was drawn from each part of the catchment. Within each part of the catchment, we further stratified the sample by ethnicity to ensure that our sample is representative of Fiji's population. We drew villages (officially recognized entities that are exclusively *iTaukei*) and settlements (informal clusters of houses that are largely Indo-Fijian) based on a probability sample. Prior to the start of the survey, enumerators visited each village/settlement (hereafter, 'community') to *sevusevu* and to explain the purpose of the research in broad terms, and to set appointments with 12 heads of households drawn at random from community rosters; in settlements in which fewer than 12 households resided, nearby settlements were added, again based on a probability sample.

In this way, 14 villages (58% of all registered villages in the catchment) and 14 settlements[5] were included in the survey. In each community, a separate survey was administered to a community leader who was familiar with local finances and infrastructure. In villages, this questionnaire was invariably answered by the village headman; in settlements, a respected elder was identified to respond to this questionnaire. In addition, separate surveys pertaining to *mataqali* (i.e., clan) land and assets were administered to a representative sample of mataqali leaders in each village. Thus, 28 community leaders and 41 *mataqali* leaders were surveyed throughout the Ba River catchment. In addition, 96 households were surveyed in the upper Ba River catchment, all of them *iTaukei*. In the middle Ba River catchment, 102 households were surveyed, 47% *iTaukei* and 53% Indo-Fijian. In the lower Ba River catchment, 97 households were surveyed, 38% *iTaukei* and 62% Indo-Fijian (Table 1).

Table 1. **Survey sample by location and ethnicity**

	iTaukei	Indo-Fijian	Total
Ba lower	37	60	97
Ba middle	48	54	102
Ba upper	96	0	96
Penang	36	38	74
Total	**217**	**152**	**369**

The Penang River is smaller than the Ba River in terms of length, volume, elevation drop, and at-risk population. Hence, we stratified this sample only by ethnicity. The 74 households that participated in the survey (49% *iTaukei* and 51% Indo-Fijian) were drawn from three villages and five settlements (Figure 7). Eight community leaders and 12 *mataqali* leaders were also surveyed. As with the Ba River catchment, all communities were visited prior to enumeration and any settlement comprising fewer than 12 households was augmented by surveys in new settlements.


(L) Houses in an *iTaukei* village in the Penang River catchment
(R) Curious child in a flood-prone village in the Penang River catchment

[5] Most settlements are not officially recognized, so the percentage of settlements included in the survey is difficult to ascertain. However, the 2007 census registered 3932 rural Indo-Fijian households in the Ba River catchment; the settlements in which we surveyed encompass 1780 households, indicating that 32% of rural Indo-Fijian households are covered by the sample.

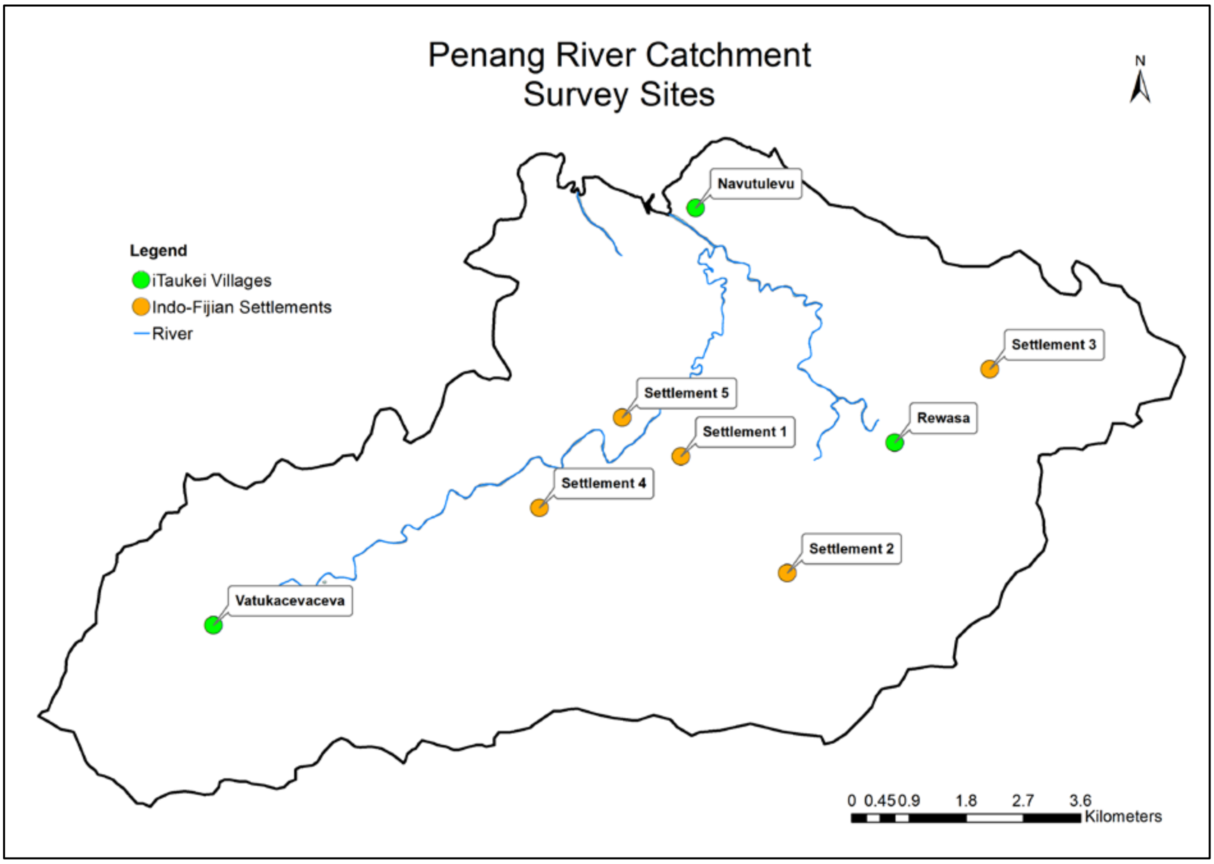


Figure 7. Penang River catchment survey sites

The survey results were aggregated to estimate population-level impacts using GIS and 2007 census data that are presented at the level of sub-district enumeration areas. The population by survey site was estimated by creating boundaries that were equidistant from adjacent sites (i.e., Voroni polygons). The 2007 census data were then intersected with the polygons containing survey sites to partition the population. Using an area-weighted sum approach, the population within each census polygon was allocated to each survey site polygon based on an even distribution across each of the enumeration areas. This method resulted in an average population of 209 iTaukei and 484 Indo-Fijian households per study site area in the Ba River catchment and an average population of 280 iTaukei and 212 Indo-Fijian households per study site area in the Penang River catchment. Details on the population and number of households surveyed for each community are listed in Table 2.

Table 2. Communities and households surveyed in Ba River and Penang River catchments

Community	Primary Ethnicity	HH in Community	# HH Surveyed
Ba River Catchment			
Ba Lower 1	Indo-Fijian	180	13
Ba Lower 2	Indo-Fijian	60	12
Ba Lower 3	Indo-Fijian	35	12
Ba Lower 4	Indo-Fijian	200	12
Ba Lower 5	Indo-Fijian	120	6
Ba Lower 6	Indo-Fijian	100	6
Ba Mid 1	Indo-Fijian	65	8
Ba Mid 2	Indo-Fijian	90	4
Ba Mid 3	Indo-Fijian	210	13
Ba Mid 4	Indo-Fijian	200	12

Community	Primary Ethnicity	HH in Community	# HH Surveyed
Ba Mid 5	Indo-Fijian	180	8
Ba Mid 6	Indo-Fijian	75	6
Ba Mid 7	Indo-Fijian	65	10
Ba Mid 8	Indo-Fijian	200	5
Balevutu	iTaukei	305	12
Bukuya	iTaukei	664	12
Buyabuya	iTaukei	167	12
Koro	iTaukei	128	12
Koroqaqa	iTaukei	122	12
Nadrugu	iTaukei	128	12
Nailaga	iTaukei	885	12
Nakoroboya	iTaukei	162	12
Nanoko	iTaukei	319	12
Nanuku	iTaukei	98	12
Navala	iTaukei	526	12
Toge	iTaukei	95	12
Tubuquto	iTaukei	206	12
Votua	iTaukei	691	12
Penang River Catchment			
Navutulevu	iTaukei	378	12
Ra 1	Indo-Fijian	220	12
Ra 2	Indo-Fijian	52	6
Ra 3	Indo-Fijian	375	6
Ra 4	Indo-Fijian	87	6
Ra 5	Indo-Fijian	348	8
Rewasa	iTaukei	348	12
Vatukacevaceva	iTaukei	114	12

4.1.2 Survey content

The community leaders' survey (Appendix 2) recorded data on community demographics and the value of financial accounts and community assets such as schools, places of worship, halls, dispensaries, canteens/co-ops, lodges, roads, improved footpaths, bridges, vehicles, water storage systems, power lines, generators, communal land, docks, seawalls, boats, monuments, cemeteries, tools, and other durable goods on 1 January 2012. Respondents were then asked to indicate which assets were damaged and the actual or estimated costs of repair for the January 2012 floods, the March 2012 floods, and the December 2012 cyclone, Evan. Finally, community leaders were asked to discuss the causes of natural disasters and to identify possible responses. This survey took 45 minutes to complete, on average.

The *mataqali* leaders' survey (Appendix 3) covered *mataqali* assets such as crops, livestock, forestry, equipment, and leased land. For each asset, respondents were asked to discuss the extent and value of damage incurred as a result of the three major natural disasters of 2012. This survey took 30 minutes to complete, on average.

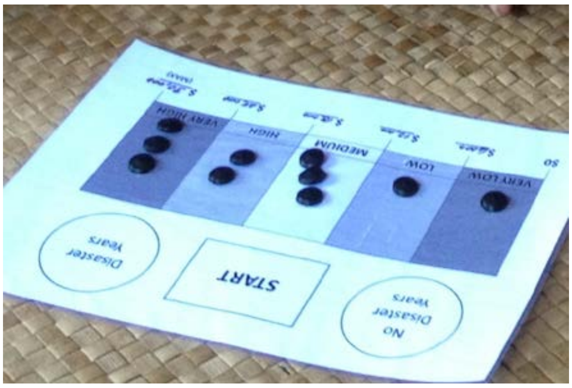
Approximately 95% of randomly selected household heads kept their appointments with the survey enumerators. In most of the remaining cases, the household head delegated a household member to respond to the survey on his or her behalf. In the eight cases where neither the household head nor a delegate was available at the scheduled time, alternate households were identified in the same communities to serve as replacements. In villages, FJ$30 was donated to the village fund for each survey completed; in settlements, FJ$30 was paid directly to the respondent to acknowledge the time and effort required to participate in the survey.

The household survey (Appendix 4) consisted of questions on demographics, education, and health; cropping, livestock, fishing, and forestry; labour income, remittances, durable goods, and housing; and time allocation. Enumeration on tablet computers enabled very complex logic[6], and up to 2,740 data points were collected for each household. The tablets also facilitated flexibility, making the questionnaire available in the language preferred by the respondent.[7] On average, the survey took 103 minutes to complete.

The survey also included several novel elements pertaining to the social and economic impacts of natural disasters. First, respondents were asked to reflect on environmental challenges ranging from flooding and cyclones to expiring land leases and invasive species, noting which had adversely affected them in recent years and whether the problem had increased, decreased, or stayed the same over the preceding decade. Respondents were also asked to identify and rank the three most significant environmental challenges facing the community.

Second, respondents were asked a series of detailed questions regarding the three major natural disasters of 2012. Specifically, respondents were asked:

- whether they had received warning of each disaster (and how);
- whether they evacuated (and for how long);
- whether there was damage to housing and durable goods (and how much);
- whether they lost electricity or the ability to travel to work (and for how long);
- whether they spent money on food or temporary shelter (and how much);
- whether they lost wages (and how much);
- whether they incurred expenses protecting their homes from disasters and/or cleaning up after them (and the value thereof); and
- whether the disaster caused injury or sickness (and the details thereof).



(L) Exercise to ascertain expected losses to disasters over the next 20 years.
(R) Self-administered question regarding community resilience.

Third, respondents were asked a series of questions regarding expectations of losses due to future disasters. These questions were designed in consortium with two graduate students at the University of California, Davis, who hypothesize that previous exposure to natural disasters will increase expectations of future loss (e.g., Botzen, Aerts, and van der Bergh 2009). Specifically, respondents were asked to estimate the cost of rebuilding and/or replacing all losses during q year of the worst imaginable disasters. They were then asked to estimate the number of years in the next 20 in which they expected to be affected by natural disasters. Finally, respondents were asked to evaluate the probabilities associated with losses of various amounts, i.e., losses of up to 20% of the maximum imaginable, losses up between 20% and 40% of the maximum imaginable, etc. These questions were enumerated as a game to increase interactions during the survey and to minimise the computational burden on survey respondents.

Finally, respondents were asked to reflect on resilience of the communities in which they live. For example, respondents were asked the extent to which they agreed with statements such as ‘The community is able to identify new ways to solve problems’, ‘People in this community share a common vision’, ‘People in this community work together to solve problems’,

[6] For example, general data were collected on up to 34 different crops, but detailed production data were only collected for the five crops that were considered to be most important by each household. Similarly, the survey collected different types of information for different fish species depending on habitat and seasonality.

[7] Electronic enumeration also facilitates quality assurance while the enumerators are in the field and eliminates data-entry error.

‘Women are involved in making important decisions in the community’, ‘The community has the skills and knowledge to limit the damage from natural disasters’, and ‘The people of this community have control over our future’. Most surveys ask respondents to respond to such statements on a five-point Likert scale with the following responses: ‘strongly disagree’, ‘disagree’, ‘neutral’, ‘agree’, and ‘strongly agree’. However, electronic enumeration enabled the question to be answered via a slider, allowing for 201 gradients instead of just five. In this way, respondents could articulate differences the extent to which they agree or disagree with the statements. In addition, these responses were entered by the respondents themselves, enabling them to respond without concern of neighbours’ opinions (Tourangeau and Smith, 1996). After three fixed statements to allow for learning, statements were asked in a random order to eliminate concerns about order effect, i.e., biases based on the order in which questions were asked (Krosnick and Alwin, 1987). Finally, some statements read in the affirmative while others read in the negative (e.g., ‘People in this community do not share a common vision’) to reduce concerns of yea-saying, i.e., the tendency to repeat answers in lengthy questionnaires (Blamey, Bennet, and Morrison 1999).

As part of the CDKN project, a framework for adaptive capacity/resilience was developed based on earlier work performed for AusAID (Warrick *et al.,* submitted for publication). The statements above were developed to reflect the components of this framework.

4.1.3 Survey validation, enumeration, and quality assurance

All three survey questionnaires were tested in neighbouring catchments to ensure that the questions were understandable, that response categories were appropriate, and that the surveys were of appropriate length. In total, three community leaders, three *mataqali* leaders, and 29 household heads participated in survey testing.

The surveys were undertaken by four staff member and 11 post-graduate students from the University of the South Pacific and one staff member from Landcare Research. All staff members had extensive experience collecting socioeconomic surveys prior to these surveys, as did four of the students. However, the household survey is the first in Fiji to use electronic enumeration, so all participants attended an intensive, three-day training on survey enumeration in a Fijian community prior to the survey beginning. By the end of the training, each enumerator had become comfortable with using tablet computers for survey enumeration, and new enumerators gained confidence in survey administration through practice with experienced enumerators.

Because this was the first household survey in Fiji to be enumerated electronically, the training also focused on computer-assisted data collection. Specifically, enumerators were trained in the use of the Clutec mQuest survey software on the Android operating system using Samsung Galaxy 10.1 tablets. Participants of the training learned first how to use the tablets, and then how to teach respondents to use the tablets to enter sensitive information, e.g., responses to questions pertaining to community resilience. In addition, two USP staff members were trained in basic hardware support and one staff member was trained in electronic data management and quality assurance using mQuest and Microsoft Excel. By assessing data quality at the end of enumeration each evening, mistakes were corrected before enumerators had moved to new villages, a massive improvement in efficiency and accuracy relative to previous surveys. In addition, the staff member in charge of assuring data quality provided extensive and timely feedback to enumerators and team leaders based on each day's results, dramatically increasing capacity in the process.

The surveys were conducted over a four-week period in February and March 2013. Each household survey was electronically validated in the field using programs that automatically identified outliers in the data based on prior responses. Households for which questionable responses had been reported were re-contacted the following day and corrections were made where necessary.

4.1.4 Hydrological model

To model the flooding extent for both the Ba and Penang River catchments, we used the US Army Corps of Engineers Hydrologic Engineering Center’s River Analysis System or HEC-RAS (Brunner 2010). In addition, we visualised and developed the data needed for HEC-RAS using ESRI’s ArcGIS and the US Army Corps of Engineers’ HEC-GeoRAS extension to facilitate the transfer of information between ArcGIS and HEC-RAS.

Using the river centrelines, land use map, and a 25m digital elevation model (DEM) for the catchment (PACRIS 2013; John Lowry, pers comm, 20 Sept 2013), we developed all of the ancillary data required to run HEC-RAS for the two catchments. The 25m resolution of the DEM was sufficient to undertake this analysis once the river channel and the depth of the river was cut into the DEM. Using information from Acrement and Schneider (1984), Aldridge and Garrett (1973), Schneider et al. (1977), and Hicks and Mason (1991), we estimated the Manning's N value for each land use type. Manning's N is a surface roughness coefficient used to estimate the amount of friction that is required to be overcome to enable water to flow over the surface. The Manning's N values used are outlined in Table 3.

Indo-Fijian house in the Penang River catchment.

iTaukei house in the Penang River catchment.

Table 3: Manning's N Values used within the hydrological modelling of the Ba and Penang River catchments

Land Use Type	Manning's N Value	Land Use Type	Manning's N Value
Upland Closed Rain Forest	0.18	Rock Outcrops	0.10
Upland Rain Forest	0.18	Thorn Scrub	0.10
Bamboo	0.17	Healthy Talasiga	0.09
Upland Open Rain Forest	0.17	Remnant Lowland Rain Forest	0.09
Broadleaf Dry Transition Forest	0.16	Agriculture (large scale)	0.08
Lowland Open Rain Forest	0.16	Disturbed Upland Rain Forest	0.08
Lowland Rain Forest	0.15	Talasiga	0.08
Upland Dry Forest	0.14	Anthropogenic Landscapes	0.06
Mixed Dry Forest	0.13	Disturbed Talasiga (Fire Scar)	0.06
Plantation and Production Forest	0.13	Village/Settlement	0.06
Softwood Plantation	0.13	Urban/Suburban/Developed	0.05
Disturbed Lowland Rain Forest	0.12	Landslide	0.04
Mangrove Forest and Scrub	0.12	Marginal Floodplain	0.04
Riparian Vegetation	0.11	Streambed	0.04
Dry Semi-Evergreen Thickets	0.10	River Channel	0.03
Other Landscapes	0.10		

Using HEC-GeoRAS, we exported the data for use within the HEC-RAS model. Within HEC-RAS, we ran a steady-flow analysis across each catchment. In the absence of detailed flow values at the mouth of the river, estimated values were used and then increased or decreased to calibrate the model to a normal flow level throughout the catchment. After calibration, we ran the model at a variety of increasing flow levels and compared the resulting flood inundation levels with the estimated levels sourced through the survey. Once the flood inundation levels match the survey results, the flood extent was generated for further analysis and use.

4.1.5 CBA tool

The approach to CBA presented in this report is based on the *Cost-Benefit Analysis for Natural Resource Management in the Pacific* (Buncle *et al*., 2013) manual that was developed with support from this project. Specifically, the surveys described above informed our analysis by providing detailed data on exposure to and damages resulting from natural disasters in 2012, common practices for mitigating damage, and the associated costs of mitigation. The hydrological model was then used to predict total damage in other flooding events based on household averages derived from the survey.

Costs that are avoided as a result of adaptation – whether direct (e.g., physical damage to homes) or indirect (e.g., the value of wages lost because flooding prevented people from travelling to work) – are considered to be benefits of adaptation. The costs that accrue in an effort to mitigate damage stemming from natural disasters (e.g., the costs of river dredging and of afforestation) are considered to be the costs of adaptation.

Because costs accrue over the duration of a project, we calculate the present value (PV) of current and future costs by discounting future costs at the real rate of interest, i.e., the opportunity cost of money. We assume a project length of 100 years and a discount rate of 8%, which is the median discount rate used for long-term environmental management projects in the Pacific (Lal and Holland, 2010). Results were also calculated with 4% and 12% discount rate to better understand the robustness of our calculations (see discussion on sensitivity below). Prices, units, and the PV of benefits were calculated similarly.

Recurring costs such as extraction and monitoring are assumed to accrue at the end of each of the 100 years in the life of the management intervention. Capital costs, by contrast, are assumed to accrue only during the initial period. Information about the number of physical units of inputs under each form of adaptation (e.g., the density of trees used in afforestation) is derived from the scientific literature, survey responses, and expert knowledge. Costs associated with each option are derived from official sources (e.g., the Fiji Ministry of Fisheries and Forest for the cost of seedlings). Total monetised costs are estimated by multiplying the unit costs incurred in each year by the number of physical units.

Finally, we calculate the net present value (NPV) of each management option by subtracting the PV of costs from the PV of benefits. We also calculate the benefit-cost ratio (i.e., the ratio of the present value of benefits to the present value of costs, BCR), which describes the relative efficiency of each management option.

4.1.6 Adaptation strategies considered

In this study, we consider several options for disaster risk reduction from flooding in the Ba and Penang River catchments. The EbA options include planting riparian buffers, afforesting the upper catchment, and planting floodplain vegetation. The hard infrastructure options include reinforce riverbanks, river dredging, and raising houses. There is also a mixed intervention approach that includes a mix of EbA and hard options.

A summary of the key assumptions for each of these adaptation options is listed in Table 4. The 'do nothing' approach represents the baseline or status quo against which the costs and benefits of other management options are measured. The mixed Intervention approach included a variety of the adaptation options considered for this study, including reinforcing riverbanks, dredging, upland afforestation, riparian buffers, and planting floodplain vegetation. For simplicity, we assumed that 25% of area treated under the single set of options would be carried out under the mixed approach, (e.g., about 8,900 ha of afforestation and 323 ha of riparian planting, (Table 5). In this case, most of the EbA interventions were carried out in the upper and middle portion of the catchment, while the hard approaches were assumed to be implemented in the lower catchment near Ba Town, Rakiraki Town, and the river mouths. Importantly, this integrated approach is assumed to be highly effective relative to individual options.

Table 4. Summary of adaptation options evaluated in cost-benefit analysis

Option	Ba River Catchment	Penang River Catchment
Do nothing	Assumes status quo of limited interventions undertaken prior to 2012 floods	Assumes status quo of limited interventions undertaken prior to 2012 floods
Plant riparian buffers	Plant 30m buffer of native vegetation along all stream-banks (1,291 ha)	Plant 30m buffer of native vegetation along all stream-banks (138 ha)
Afforest upper catchment	Plant native trees on all talasiga (open grassland) in upper catchment (35,626 ha)	Plant native trees on all of talasiga (open grassland) in catchment (4,645 ha)
Plant floodplain vegetation	Plant native vegetation on 10% of cropland in catchment flood plain (total 1,631 ha)	Plant native vegetation on 10% of cropland in catchment flood plain (437 ha)
Reinforce riverbanks	Construct levies and other 'hard' infrastructure along stream-bank of lower and mid-reaches of river (115.3 km)	Construct levies and other 'hard' infrastructure along stream-bank of lower reaches of river (28.8 km)
River dredging	Dredge lower portion of the Ba River (3,845,000 m3)	Dredge lower portion of the Penang River (500,000 m3)
Raising houses	Elevate living area of 3,000 vulnerable houses in catchment	Elevate living area of 1,000 vulnerable houses in catchment
Mixed interventions	Mix of options undertaken in various parts of the catchment (see Table 5)	Mix of options undertaken in various parts of the catchment (see Table 5)

Table 5. Summary of mixed approach options evaluated in cost-benefit analysis

Option	Ba River Catchment	Penang River Catchment
Plant riparian buffers	Plant 30m buffer of native vegetation along 323 ha of stream-banks	Plant 30m buffer of native vegetation along 35 ha of stream-banks
Afforest upper catchment	Plant native trees on 8,907 ha of talasiga in upper catchment	Plant native trees on 1,161 ha of talasiga in upper catchment
Plant floodplain vegetation	Plant native vegetation on 408 ha of cropland in catchment flood plain	Plant native vegetation on 109 ha of cropland in catchment flood plain
Reinforce riverbanks	Construct levies and other 'hard' infrastructure along 28.8 km of stream-banks in lower reaches of Penang	Construct levies and other 'hard' infrastructure along 7.2 km of stream-banks in lower reaches of Penang
River dredging	Dredge 961,250 m3 from lower portion of the Ba River	Dredge 125,000 m3 from lower portion of the Penang River

4.1.7 Climate change scenarios

Projecting changes in flood frequency and severity is problematic because observational records of floods are often short, sparse, and confounded by influences such as channel constriction and land use change (IPCC, 2012). Catchments are highly idiosyncratic geographic features; therefore, the relationship between climate and flood risk often needs to be assessed on a case-by-case basis (IPCC, 2012). Based on physical reasoning, there is medium confidence that flooding will increase in areas like Fiji, where the incidence of heavy rainfall is expected to increase (Rao et al., 2012; IPCC, 2012). In the absence of detailed data and hydrological modelling in the region, however, the specifics and magnitude of these changes remain uncertain.

We use the range of projected shifts in extreme heavy rainfall return periods discussed in Section 1.3 and Appendix 1 to construct two climate change scenarios to estimate the likely range of future damages from flooding in the Ba and Penang River catchments relative to 'current' climate. The 'moderate' scenario follows projections similar what may occur under the SRES B2 or relative concentration pathway (RCP) 6.0 scenarios, while the 'severe' scenario follows projected changes under the SRES A2 or RCP 8.5 scenario.

Events can be expressed in return periods and/or flood exceedence probability curves. For the moderate scenario, we assume that each event under the moderate climate regime shifts one return interval while the severe scenario assumes a shift of two return intervals. That is, the January flood that was considered to be a 1-in-50 event under the current climate is assumed to be a 1-in-20 event under the moderate scenario and a 1-in-10 event under the severe scenario. The same method applies to the March 2012 flood, which was estimated to be a 1-in-20 year flood but which could become a 1-in-10 or 1-in-5 year flood under the moderate and severe climate change scenarios, respectively.

4.2 Empirical findings

In this section, we provide a detailed analysis of the empirical findings from our comprehensive surveys and from our hydrological modelling. First, we discuss demographics and income to provide insight into the vulnerability of the at-risk populations. Second, we describe the incidence and severity of disasters to affect the surveyed households in historical context. We then describe the damages caused by the three major natural disasters that affected the Ba River and Penang River catchments and present flood exceedence probability curves for present and future flooding. Next, we describe perceived exposure to risk and expectations of future damages based on survey evidence, putting those figures into context based on modelling evidence. Finally, we briefly discuss community resilience in the Ba River catchment vis-avis community resilience in the Penang River catchment.

4.2.1 Survey results

4.2.1.1 Demographics and income

Table 6 and Table 7 show the average age of respondents to the household survey, their genders, the maximum education obtained by any household member, household income for the 12 months immediately preceding the survey, and total household wealth, averaged across each surveyed community in the Ba and Penang River catchments, respectively. The household income reported here is the net income from cropping, livestock, timber and non-timber forest products (NFTP), fishing, wage labour, rental of housing and capital, and government transfers, after expenses. Wealth includes the self-reported value of housing, durable goods, and livestock.

Except for a handful of cases in which a surrogate had been nominated, the household survey was administered to self-identified heads of households. The average age of survey respondents is 51 and 90% of survey respondents are male, consistent with headship patterns in Fiji over the last 50 years (Panapasa, 1997). The maximum number of grade levels completed is nearly monotonic with age, with each successive generation obtaining more education than the one that preceded it. Thus, the average number of grade levels completed is 11.5, higher in households comprising multiple generations and lower in those in which the household head does not reside with his or her children.

The most recent official data on household income comes from the Household Income and Expenditure Survey, which was conducted by the Fiji Bureau of Statistics in 2009 (Fiji Bureau of Statistics, 2009a). According to these figures, average household income for rural Fiji as a whole was FJ$ 11,608. For Fiji's Western Division (which includes the Ba and Penang River catchments) as a whole, average rural household income was FJ$ 9960. The average household incomes by community based on our survey results are FJ$ 7849 in the Ba River catchment and FJ$10,133 in the Penang River catchment. Given that growth of GDP fluctuated between -1% and 2% between 2009 and 2013 (World Bank, 2014), that these households were exposed to three major natural disasters during the year, and that 25% of Fiji's poor live in Ba Province (Narsey, 2009), our income figures are consistent with the official figures. Nevertheless, average income in sampled communities demonstrates a high level of variation: five of the sampled *iTaukei* villages report average household incomes below FJ$ 5,000 while three report average household incomes above FJ$ 10,000. Income heterogeneity across *iTaukei* villages is largely driven by production of *Piper methysticum*, i.e., kava, (*yaqona* in Fijian). This cash crop plays an important ceremonial role throughout the Pacific; it is slow growing, so producers bear considerable risk in the four or more years of growth between harvest (Davis and Brown 1999), but incomes of between FJ$ 5400 and FJ$ 18,000 per acre have been recorded (Murray 2000).[8]

Table 6. **Summary statistics, Ba River catchment**

BA Community	Age *(years)*	Male *(share)*	Max Education *(years)*	Total Income *(FJ$)*	Total Wealth *(FJ$)*
Ba Lower 1	49.38	0.85	12.31	7,713	50,513
Ba Lower 2	50.17	0.92	11.17	6,495	26,304
Ba Lower 3	51.00	0.67	11.50	8,373	50,813
Ba Lower 4	50.67	0.92	11.67	7,295	39,360
Ba Lower 5	54.83	0.67	12.00	10,155	57,277
Ba Lower 6	54.50	1.00	12.00	11,262	36,288
Ba Mid 1	50.25	0.88	9.88	4,293	26,905
Ba Mid 2	48.00	0.75	11.75	8,028	41,811
Ba Mid 3	49.31	0.85	11.92	8,878	46,116
Ba Mid 4	55.67	0.83	11.42	8,757	28,810
Ba Mid 5	54.88	1.00	12.50	6,196	27,196
Ba Mid 6	50.83	1.00	9.67	11,950	58,151
Ba Mid 7	55.50	0.90	11.30	11,766	22,815
Ba Mid 8	51.40	1.00	12.40	8,983	64,866
Balevutu	56.00	0.75	12.75	4,744	12,606
Bukuya	49.25	0.92	11.92	4,893	17,611
Buyabuya	49.00	1.00	10.92	6,355	12,226
Koro	48.55	0.91	11.36	16,407	18,597
Koroqaqa	48.42	1.00	11.67	6,494	11,365
Nadrugu	50.92	0.75	9.75	8,113	14,045
Nailaga	55.42	0.67	12.58	4,240	27,265
Nakoroboya	47.92	1.00	9.17	5,407	10,522
Nanoko	50.33	1.00	11.50	4,655	21,941
Nanuku	59.67	0.92	10.92	8,174	16,490
Navala	48.08	1.00	10.58	16,397	8,810
Toge	55.42	0.75	10.50	4,695	13,908
Tubuquto	50.17	1.00	10.92	6,193	16,732
Votua	53.33	0.75	10.83	7,340	18,536
Total	**51.69**	**0.88**	**11.29**	**7,849**	**26,136**

[8] Sizable kava harvests in both Koro and Navala lead to average incomes of more than double those in other *iTaukei* villages.

Table 7. Summary statistics, Penang River catchment

Penang Community	Age *(years)*	Male *(share)*	Max Education *(years)*	Total Income *(FJ$)*	Total Wealth *(FJ$)*
Navutulevu	47.58	1.00	12.25	10,317	19,933
Ra 1	53.83	1.00	12.00	10,513	43,017
Ra 2	38.17	1.00	12.17	14,316	39,628
Ra 3	54.17	0.83	10.83	7,399	34,603
Ra 4	53.00	1.00	12.17	15,619	73,900
Ra 5	45.75	1.00	12.75	14,332	49,798
Rewasa	58.00	0.83	10.67	6,050	17,679
Vatukacevaceva	51.25	0.83	11.08	7,385	16,209
Total	**50.89**	**0.93**	**11.69**	**10,133**	**33,098**

Wealth is not reported in any publically available official documents, but the fact that the demographic and income profiles of our sample so closely matches those reported in both the peer-reviewed literature and official documents suggests that our estimates of wealth will be similarly reliable. We calculate wealth as the stated replacement value of the physical house, vehicles and any other durable assets, jewellery, and bank accounts. The average wealth among households in surveyed communities in the Ba River catchment is FJ$ 26,366, or 3.3 times annual income. The average wealth among households in surveyed communities in the Penang River catchment is FJ$ 33,098, also 3.3 times annual income.

The average income among surveyed households does not differ by ethnicity in the Ba River catchment, although surveyed households in largely Indo-Fijian settlements have higher incomes than surveyed households in *iTaukei* villages in the Penang River catchment (statistically significant at the 5% level using a two-sided *t* test). Narsey (2012) notes that Indo-Fijian households are larger than *iTaukei* households, on average, and that ethnic differences in income at the household level invariably disappear when calculating per-capita income. That being said, Narsey (2012) also reports that Indo-Fijian households tend to be wealthier than *iTaukei* households because *iTaukei* households support more non-working adults than Indo-Fijian households. In addition, rural *iTaukei* households donate or give away 9% of their annual incomes, on average, while rural Indo-Fijian households donate or give away just 1% of their annual incomes (Narsey, 2012). In our sample, the average wealth of households in settlements and *iTaukei* villages in the Ba River catchment are FJ$ 41,712 and FJ$ 16,327, respectively. The average wealth of households in settlements and *iTaukei* villages in the Penang River catchment are FJ$ 47,457 and FJ$ 17,941, respectively. These differences in wealth by community (and, by extension, ethnicity) are statistically significant at the 1% level.

4.2.1.2 Incidence and severity of disasters

Survey respondents were asked whether they had been affected by a variety of natural disasters and ailments ‘in recent years’, including storm surge, declining fish stocks, coastal erosion, coral bleaching, cyclones, heavy rains, flooding, drought, soil erosion, landslides/slips, lack of drinking water, fire, animal/crop disease, and human disease. Respondents were also asked whether they had been affected by invasive species and whether they had faced (or will face) the prospect of un-renewed land leases. [9] Respondents who reported being affected by a given type of disaster were also asked whether the problems associated with each disaster have become better, gotten worse, or remained unchanged.

Table 8 and Table 9 rank the significance of each type disaster. Table 10 and Table 11 show the incidence and trend for 15 different disasters, averaged at the community level, for the Ba and Penang River catchments, respectively. Specifically, the number indicates the share of surveyed households in each community that have been adversely affected by each type of disaster. Dashes indicate that none of the surveyed households were adversely affected by that particular type of disaster. Green and red shading indicate that the severity of disasters has diminished and increased over time, respectively. No shading indicates that the trend remains unchanged. Figures shown in the final row are weighted by the number of observations in each community.

[9] Expiring land leases are a major concern among Indo-Fijian households because *iTaukei* own 87% of the land in Fiji, because the majority of the Indo-Fijians population are tenants of indigenous landowners, and because at least 27,750 leases (the vast majority of them to Indo-Fijian households) were not renewed when they expired between 1999 and 2004 (Narayan, 2008); as such, expiring land leases are classified as ‘potential disasters’ for at least part of the surveyed population.

Between 58% and 100% of survey respondents in all 36 communities had been adversely affected by cyclones in recent years. Heavy rains also adversely affected individuals in all surveyed communities, although fewer respondents reported being personally affected by heavy rains than by cyclones in 23 of the 26 communities; the adverse impacts of heavy rains are more widespread in the Penang River catchment than in the Ba River catchment. Flooding and drought were also widely reported, affecting individuals in 35 communities each. The overall incidence of being adversely affected by flooding is similar to that of being adversely affected by heavy rains, although the incidence within individual communities sometimes differs radically. For example, 100% of the households in the second settlement in the middle Ba River catchment were adversely affected by heavy rains while none of them were affected by flooding; in contrast, only 25% of the surveyed households in Votua were adversely affected by heavy rains while 100% were affected by flooding. Nearly half of survey respondents had been adversely affected by drought while approximately one-quarter were adversely affected by lack of drinking water and/or soil erosion. Survey respondents also report being adversely affected by storm surge, declining fish stocks, coastal erosion, landslides/slips, fire, animal/crop disease, human disease, and invasive species, albeit in smaller numbers. No survey respondent reported being adversely affected by coral bleaching (omitted).

Among those who report being adversely affected, a majority of respondents in 19 communities reported that cyclones have come worse over the preceding decade; respondents only reported that cyclones had become better, on average, in one community in the Ba River catchment. Drought and shortages of drinking water had reportedly become worse in 22 and 19 surveyed communities, respectively, with three communities reporting that droughts had become better and two reporting that problems associated with a lack of drinking water had improved. Flooding reportedly became worse in 13 surveyed communities, improved in one community, and stayed the same in the remaining 21 communities in which at least one respondent reported being adversely affected.

In both the Ba River and Penang River catchments, survey respondents identified flooding as the single most significant challenge facing their communities (Table 8 and Table 9). Thus, while cyclones are the most common natural disaster (Table 10 and Table 11), this finding suggests that the risk associated with flooding events is more severe. Regardless, while more survey respondents were adversely affected by cyclones than by flooding, cyclones were selected as the second most significant challenge in the Ba River catchment and the third most significant challenge in the Penang River catchment, after heavy rains. Flooding, cyclones, and heavy rains consistently appear among the top three most significant challenges facing communities, with droughts being a distant fourth. Soil erosion, lack of drinking water, and/or landslips and landslides were identified as being among the top three challenges for at least 10% of survey respondents in the Ba River catchment. In the Penang River catchment, expiring land leases are the next most important challenge after drought.

Table 8. **Rankings of most significant disasters affecting households in the Ba River catchment**

Challenge	1st	2nd	3rd	Top 3
Cyclones	0.245	0.344	0.254	0.722
Flooding	0.282	0.170	0.107	0.505
Heavy rains	0.119	0.185	0.239	0.447
Drought	0.065	0.124	0.181	0.298
Soil erosion	0.044	0.039	0.088	0.139
Lack of drinking water	0.095	0.035	-	0.125
Landslips and landslides	0.020	0.058	0.044	0.102
Expiring land leases	0.061	0.012	0.010	0.078
Human disease	0.041	0.015	0.015	0.064
Invasive species	0.010	0.012	0.024	0.037
Fire	0.014	0.008	0.015	0.031
Declining fish and seafood stock	0.003	-	0.015	0.014
Coastal erosion	-	-	0.005	0.003
Animal/crop disease	-	-	0.005	0.003

Note: Each number reflects the share of surveyed households that reported a given disaster as being the first, second, or third biggest challenge facing their communities. Dashes indicate that no households selected that disaster in that order. The final column shows the share of households that reported a given disaster is being among the top three most significant challenges facing their communities.

Table 9. Rankings of most significant disasters affecting households in the Penang River catchment

Challenge	1st	2nd	3rd	Top 3
Cyclones	0.208	0.235	0.362	0.649
Heavy rains	0.278	0.279	0.170	0.635
Flooding	0.361	0.206	0.149	0.635
Drought	0.028	0.162	0.128	0.257
Expiring land leases	0.042	0.015	0.064	0.095
Declining fish and seafood stock	-	0.044	0.021	0.054
Soil erosion	0.014	0.029	0.021	0.054
Human disease	0.014	-	0.043	0.041
Invasive species	0.014	0.015	0.021	0.041
Lack of drinking water	0.028	-	-	0.027
Fire	0.014	0.015	-	0.027
Landslips and landslides	-	-	0.021	0.014

Note: Each number reflects the share of surveyed households that reported a given disaster as being the first, second, or third biggest challenge facing their communities. Dashes indicate that no households selected that disaster in that order. The final column shows the share of households that reported a given disaster is being among the top three most significant challenges facing their communities.

iTaukei house in the Ba River catchment. Note that the house sits on stilts due to previous exposure to flooding.

Table 10. Incidence and trend of disasters in communities in the Ba River catchment

Community	storm surge	declining fish stocks	coastal erosion	cyclones	heavy rains	flooding	drought	soil erosion	Land-slides/ slips	lack of drinking water	fire	animal/ crop disease	human disease	expiring land leases	invasive species
Ba Lower 1	0.23	0.46	0.23	0.92	1.00	0.85	0.69	0.31	0.15	0.46	0.08	0.08	0.23	0.31	-
Ba Lower 2	-	0.08	-	0.75	0.75	1.00	0.58	-	0.08	0.50	0.08	0.08	0.42	0.50	0.08
Ba Lower 3	0.08	-	-	0.75	0.50	0.67	0.67	0.08	-	0.42	0.08	-	0.17	-	0.08
Ba Lower 4	0.08	-	0.08	1.00	0.75	0.50	0.58	0.25	0.08	0.33	-	0.08	0.25	0.25	0.08
Ba Lower 5	-	-	-	0.67	1.00	0.33	1.00	0.33	0.17	0.33	0.17	0.33	0.33	1.00	0.33
Ba Lower 6	-	-	-	0.83	0.67	0.33	0.83	0.17	0.17	-	-	-	0.17	0.33	0.17
Ba Mid 1	-	-	-	0.63	0.50	0.13	0.75	0.13	0.25	0.75	-	0.13	0.38	0.63	0.13
Ba Mid 2	-	-	-	1.00	1.00	-	0.75	0.25	0.25	0.75	0.50	-	-	-	-
Ba Mid 3	-	-	-	0.85	0.85	0.77	0.77	0.38	0.15	0.38	0.08	-	0.15	0.15	0.15
Ba Mid 4	0.08	-	-	0.83	0.58	0.92	0.75	0.25	-	1.00	0.08	-	0.25	0.17	0.17
Ba Mid 5	-	-	-	1.00	0.88	0.88	0.75	0.13	-	0.50	-	-	0.13	0.38	0.13
Ba Mid 6	-	-	-	1.00	1.00	0.83	0.83	0.50	0.67	0.33	-	0.17	0.17	0.17	0.17
Ba Mid 7	-	-	-	0.60	0.80	0.70	0.80	0.20	0.10	-	0.20	0.20	0.10	0.10	0.10
Ba Mid 8	-	-	-	0.60	0.40	0.40	0.80	0.40	0.40	0.80	-	-	0.20	-	-
Balevutu	-	-	-	0.83	0.67	0.42	0.50	0.25	0.08	0.17	0.17	0.08	0.17	0.08	-
Bukuya	-	-	-	0.83	0.33	0.17	0.33	0.17	0.17	0.17	0.25	-	-	-	0.08
Buyabuya	-	-	-	1.00	0.25	0.08	0.17	0.33	0.08	0.25	-	-	-	-	-
Koro	-	-	-	0.83	0.58	0.08	0.42	0.33	0.08	0.08	0.25	-	-	-	-
Koroqaqa	-	0.17	-	0.58	0.17	0.75	0.25	-	0.08	-	0.25	-	-	0.08	-
Nadrugu	-	-	-	0.92	0.67	0.08	0.42	0.33	0.42	0.17	0.08	-	-	-	0.08
Nailaga	-	0.17	-	0.58	0.33	1.00	0.08	0.33	0.08	-	-	-	-	-	-
Nakoroboya	-	-	-	0.83	0.50	0.17	0.17	0.33	0.42	0.08	0.08	-	0.25	-	-
Nanoko	-	-	-	0.92	0.33	0.25	0.42	0.17	0.25	0.50	0.17	-	0.50	-	-
Nanuku	-	-	0.08	0.83	0.75	0.58	0.08	0.33	0.25	-	0.25	-	-	-	-
Navala	-	-	-	0.92	0.42	0.83	0.17	0.42	0.25	0.33	0.08	-	-	-	-
Toge	-	-	-	0.83	0.50	1.00	-	0.42	0.25	0.17	-	-	-	-	-
Tubuquto	-	-	-	0.75	0.75	0.25	0.25	0.25	0.33	0.33	-	-	-	-	0.08
Votua	-	-	0.08	0.58	0.25	1.00	0.08	0.08	-	-	-	-	-	-	-
Total	**0.02**	**0.04**	**0.02**	**0.81**	**0.59**	**0.56**	**0.45**	**0.25**	**0.17**	**0.29**	**0.10**	**0.03**	**0.13**	**0.13**	**0.06**

Note: The number indicates the share of surveyed households in each community that have been affected by each type of disaster ‘in recent years’. Dashes indicate that none of the surveyed households were affected by that particular type of disaster. Green and red shading indicate that the severity of disasters has diminished and increased, respectively. No shading indicates that the severity has not changed.

Table 11. Incidence and trend of disasters in communities in the Penang River catchment

Community	Storm surge	Declining fish stocks	Coastal erosion	Cyclones	Heavy rains	Flooding	Drought	Soil erosion	Landslides/ slides	Lack of drinking water	Fire	Animal/ crop disease	Human disease	Expiring land leases	Invasive species
Navutulevu	-	0.25	-	0.92	0.67	0.75	0.25	-	-	0.08	0.08	-	-	0.08	-
Ra 1	-	-	-	0.67	0.92	0.92	0.50	0.33	0.25	0.25	0.17	-	0.33	0.17	0.08
Ra 2	-	-	-	0.50	0.83	0.83	1.00	0.33	0.33	0.33	0.17	-	0.33	0.33	0.17
Ra 3	-	-	-	1.00	0.67	0.83	0.67	0.67	0.17	0.50	-	-	0.33	0.33	0.17
Ra 4	-	-	-	0.67	0.83	1.00	0.67	0.17	0.17	0.67	-	-	0.33	0.33	0.17
Ra 5	-	-	-	0.63	0.88	0.63	0.50	0.50	0.13	0.38	0.38	0.25	0.13	0.13	0.13
Rewasa	-	-	-	0.83	0.67	0.67	0.25	-	-	0.17	-	-	-	-	-
Vatukacevaceva	-	0.08	-	0.75	0.67	0.42	0.50	0.25	0.08	-	0.17	-	-	-	-
Total	**-**	**0.05**	**-**	**0.76**	**0.76**	**0.73**	**0.49**	**0.24**	**0.12**	**0.24**	**0.12**	**0.03**	**0.15**	**0.14**	**0.07**

Note: The number indicates the share of surveyed households in each community that have been affected by each type of disaster 'in recent years'. Dashes indicate that none of the surveyed households were affected by that particular type of disaster. Green and red shading indicate that the severity of disasters has diminished and increased, respectively. No shading indicates that the severity has not changed.

4.2.1.3 Adaptation options

The community survey collected information on what adaptation options were currently undertaken, as well as suggestions for interventions that could be implemented in the future. As discussed in Section 2, the options can be roughly categorised as hard, soft, and ecosystem-based. A summary of the various adaptation measures currently being implemented in the study sites are listed in Table 12. The responses indicate that reinforcing buildings (44%) and requesting assistance (33%) are the most prevalent options, followed by several other hard and soft approaches. Only 3% of study sites have currently done any EbA options, through planting trees and mangroves.

Table 12. Current Adaptation Options

Adaption Option	Approach	% Villages
Reinforce buildings	Hard	44%
Request government assistance	Soft	33%
Designate evacuation centre	Soft	19%
Change cropping practices/varieties	Soft	17%
Dredge river	Hard	14%
Raise buildings	Hard	11%
Relocate buildings	Hard	8%
Store crops/food supply	Soft	8%
Save money for disaster response	Soft	8%
Plant mangroves	EbA	3%
Plant trees	EbA	3%
Construct diversion channel	Hard	3%
Plant riparian buffers along waterways	EbA	0%
Protect reef	EbA	0%
Create fire break, fire bans	Hard	0%
Change forestry practice/harvest ages	EbA	0%
Plant native vegetation in floodplains	EbA	0%
Improve village drainage system	Hard	0%
Construct sea wall	Hard	0%
Reinforce stream and river banks	Hard	0%
Develop evacuation plan/committee	Soft	0%

Table 13 presents a summary of the proposed (unprompted) adaptation measures by focus groups who participated in the community-level survey. In this case, the EbA option of planting trees was the most proposed option by 36% of the focus groups. This was followed by the soft option of raising awareness about the measures that could be taken to reduce disaster risks (25%) and the hard option of improving local drainage. The ‘other’ category included a mix of responses, including ‘have faith in God’ and ‘work together as a community to resolve conflict and support each other’.

Table 13. Proposed Adaptation Options

Adaption Option	Approach	% Villages
Plant Trees	EbA	36%
Raise Awareness/Educate	Soft	25%
Improve Drainage	Hard	18%
Dredge River	Hard	11%
Stop Burning	EbA	11%
Relocate Houses	Hard	7%
Change Harvest Practices	EbA	7%
Change River Structure	Hard	7%
Other	n/a	21%

These findings suggest that there are limited adaptation options currently being implemented in the two catchments. Thus, the damages estimated in this study could be considered high relative to a catchment with similar socio-economic and biophysical characteristics where more formal adaptation measures have been done. The proposed adaptation responses suggest that communities would be open to supporting the option of implementing EbA interventions.

4.2.2 Flooding and cyclones in 2012

Tropical cyclones may develop when six primary conditions exist, namely: warm sea temperatures; atmospheric instability; high humidity in the troposphere; sufficient Coriolis force; a pre-existing low-level focus or disturbance; and low vertical wind shear (Gray, 1979). Many of these phenomena are well understood, and recent developments in 'track forecasting' allow meteorologists to predict the movement and speed of cyclones with increasing levels of precision up to five days in advance. Computer modelling has led to similar advances in accurately predicting flooding, yet these systems depend on extremely detailed topological detail that is often unavailable in developing countries such as Fiji.

Thus, it is unsurprising that 37% of survey respondents were first made aware of pending flooding in January 2012 via storm clouds, high humidity, and rising waters (Figure 8). Approximately 54% of survey respondents were first alerted to the flooding via radio, television, and/or Internet sources; the median affected community was alerted 6.5 hours prior to the floods arriving. Approximately 9% of survey respondents were notified about the January floods via other means, including friends, text messages from mobile phone providers, and indicators based on traditional ecological knowledge.[10] Notification regarding the March floods was more formal, with over 90% of survey respondents first learning of the floods via radio (most common), television, or the Internet (Figure 9). In contrast, over 90% of survey respondents were made aware of Cyclone Evan via official news sources on radio, television, and/or the Internet (Figure 10). The median community was aware of Cyclone Evan 42 hours prior to its arrival.

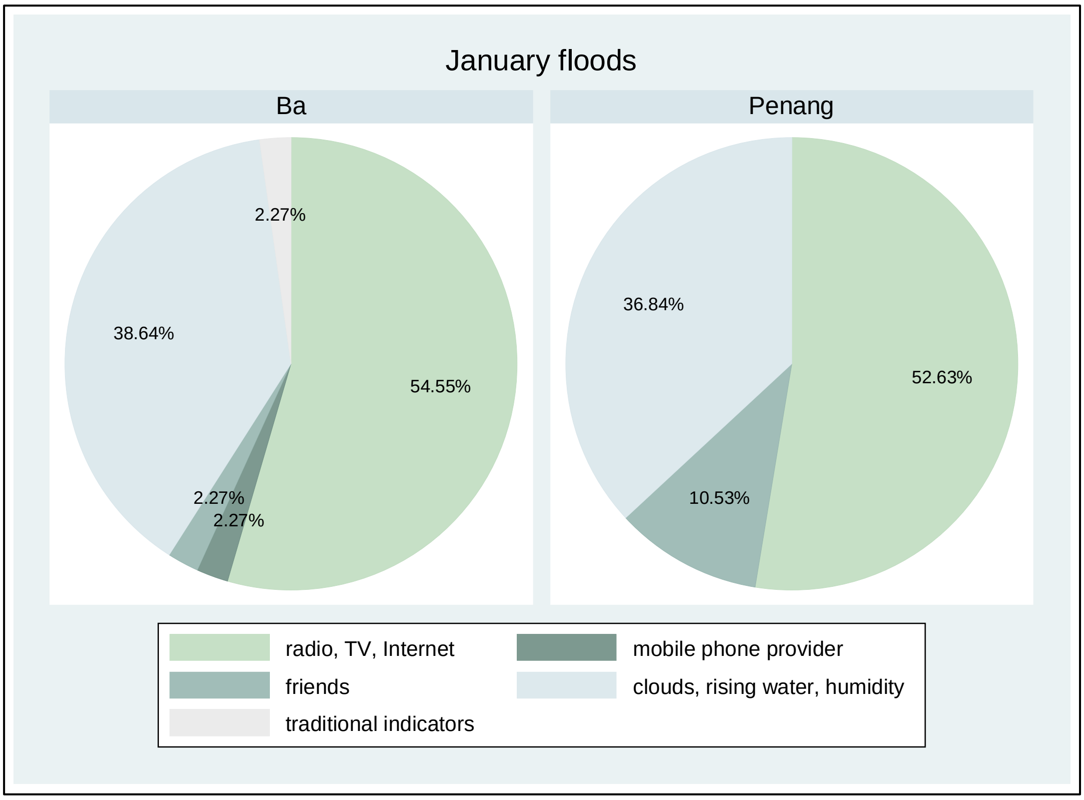


Figure 8. Form of notification, January flooding

[10] Warning about the March 2012 floods were communicated via similar methods, albeit with a significant uptick in text messages from mobile phone providers.

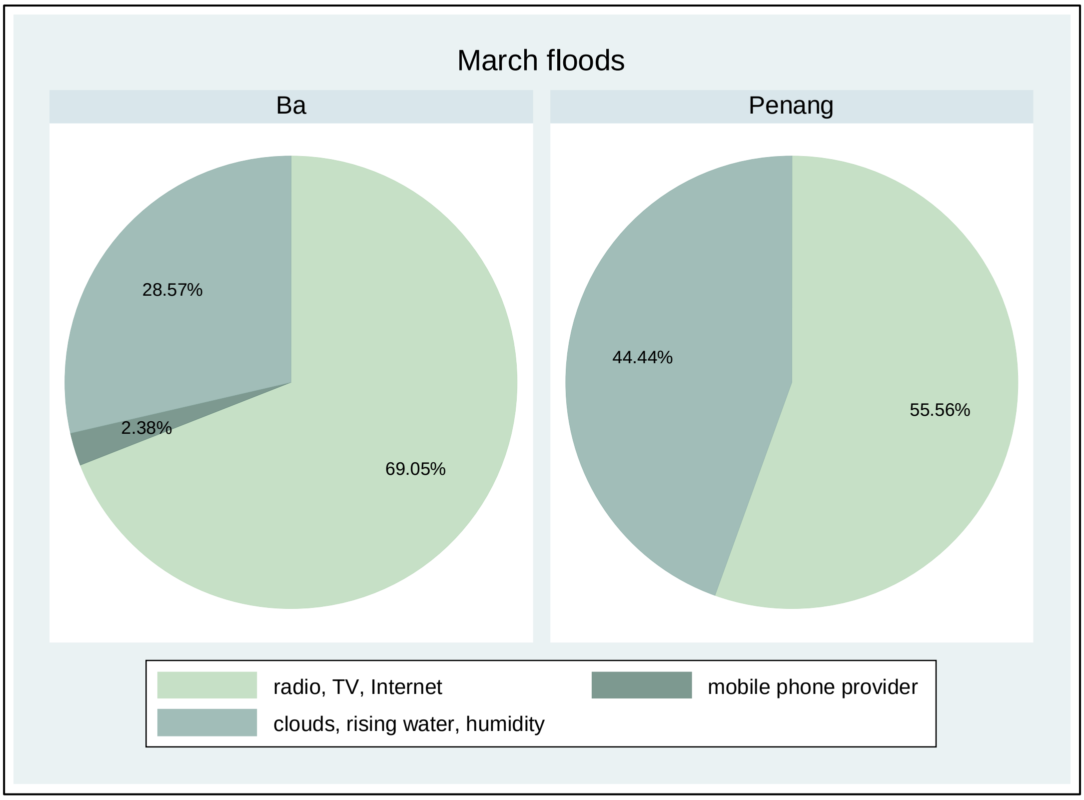


Figure 9. Form of notification, March flooding

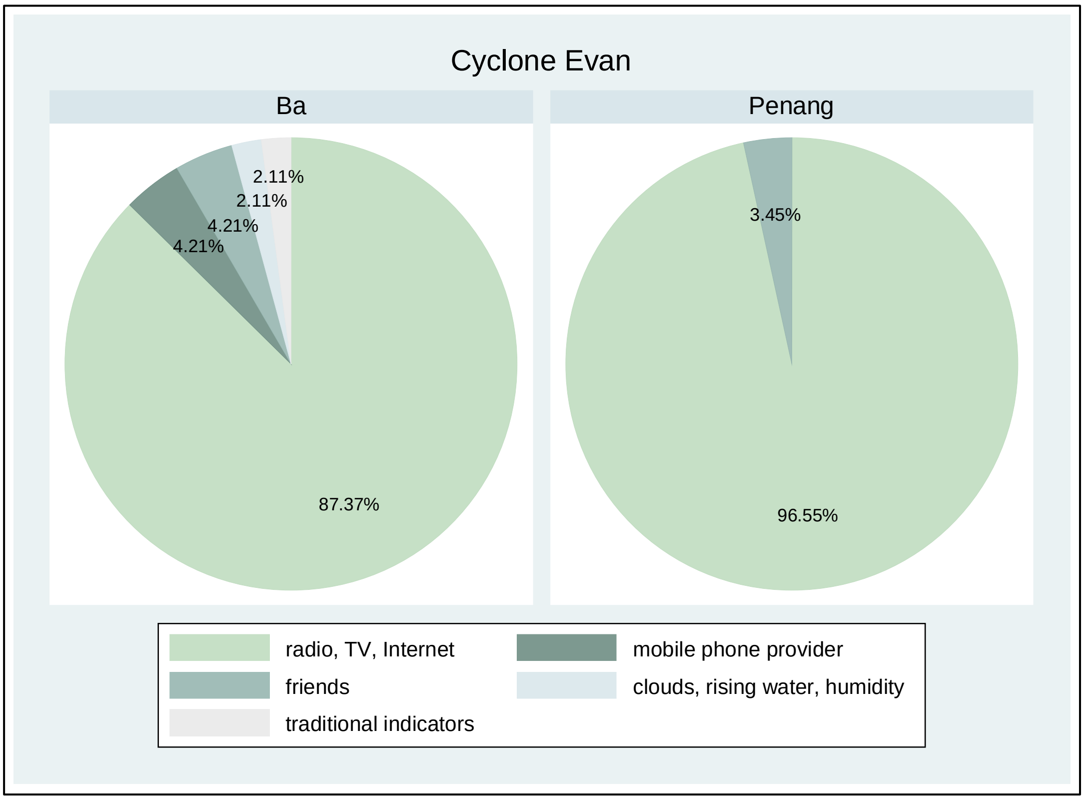


Figure 10. Form of notification, Cyclone Evan

Differences in lead time enabled different preparations to be made for flooding and cyclones in 2012. With such short notice, preparations for flooding were generally limited to moving household goods and/or livestock to higher ground and to evacuating. With warnings about Cyclone Evan coming two or more days in advance, households were able to move or secure household goods and/or livestock, cut branches and/or trees that may cause damage, reinforce roofing, shutter windows and doors, buy provisions, evacuate, and even to harvest some crops early. Nevertheless, the damages associated with Cyclone Evan exceeded those associated with flooding in many of the surveyed communities.

Hydrological models for the two catchments are used to illustrate the January and March 2012 peak flood height levels based on responses to the community survey. Reported peak flood heights for the Ba River catchment are shown in Figure 11 and Figure 12 while reported heights for Penang River catchment are shown in Figure 13 and Figure 14. Note that there are reported peak flood heights of 3 metres of more in survey sites outside the flood path of the main rivers, indicative of localised flooding from smaller streams, particularly in villages and settlements that are located near steep terrain.

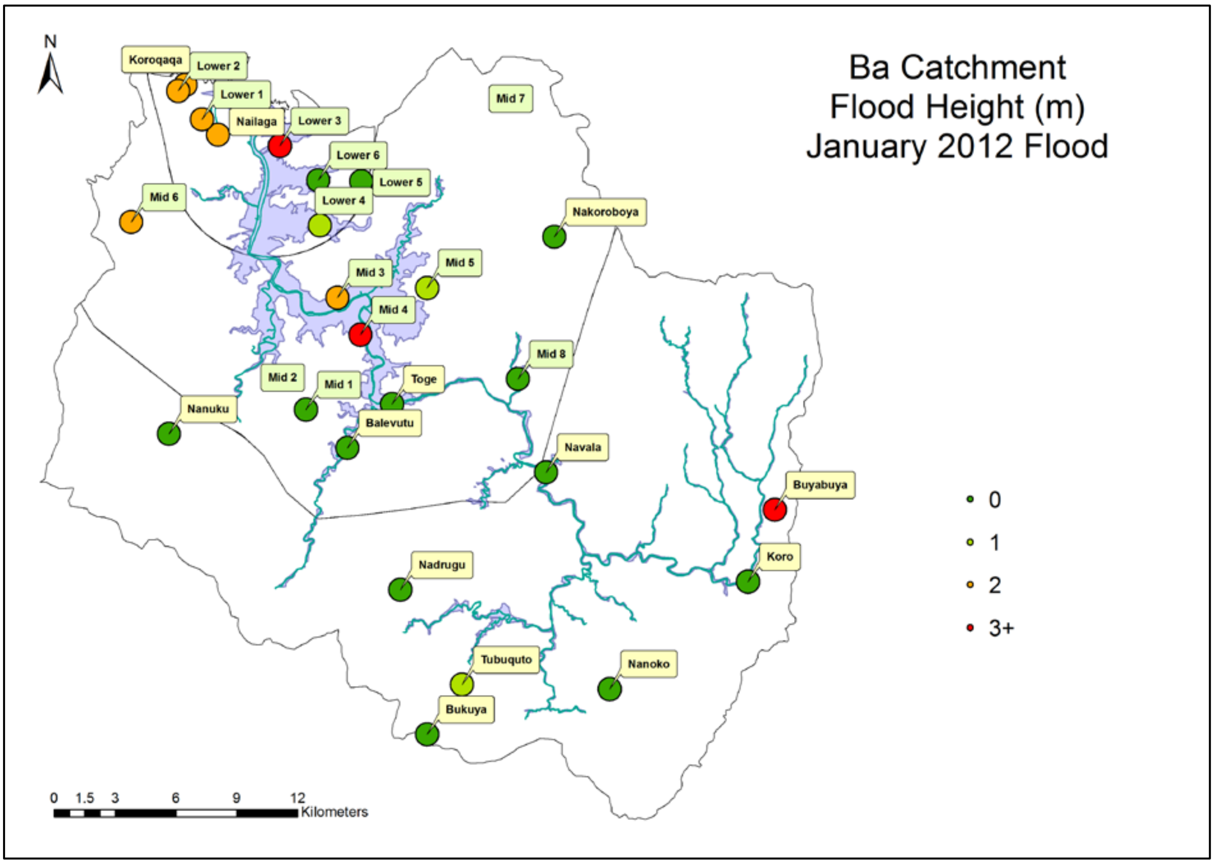


Figure 11. **Modelled January 2012 flood height, Ba River catchment**

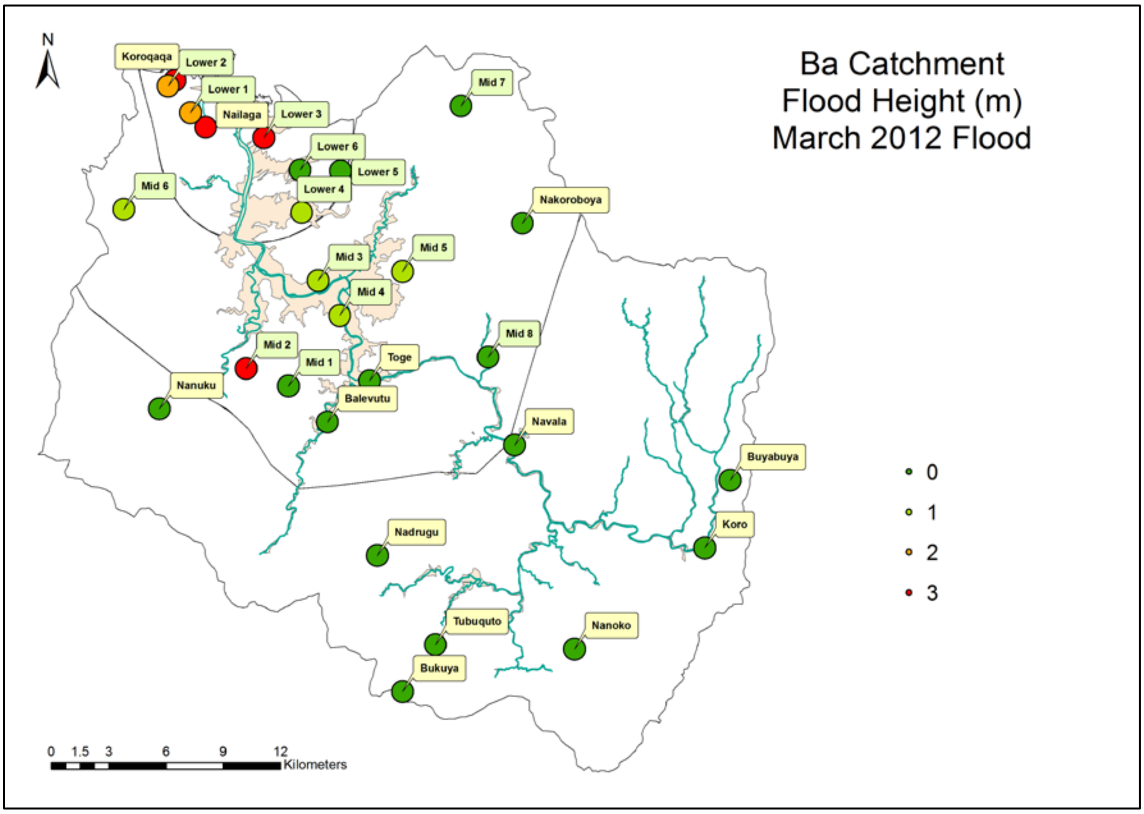


Figure 12. Modelled March 2012 flood height, Ba River catchment

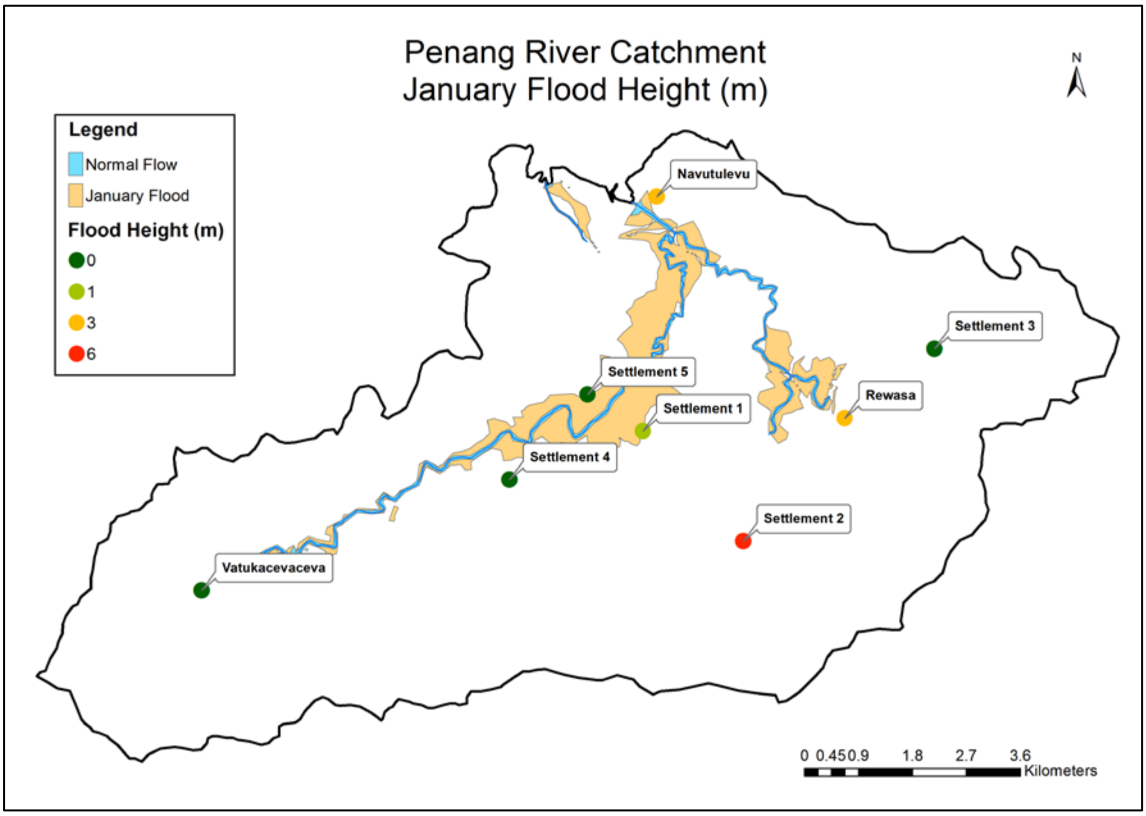


Figure 13. Modelled January 2012 flood height, Penang River catchment

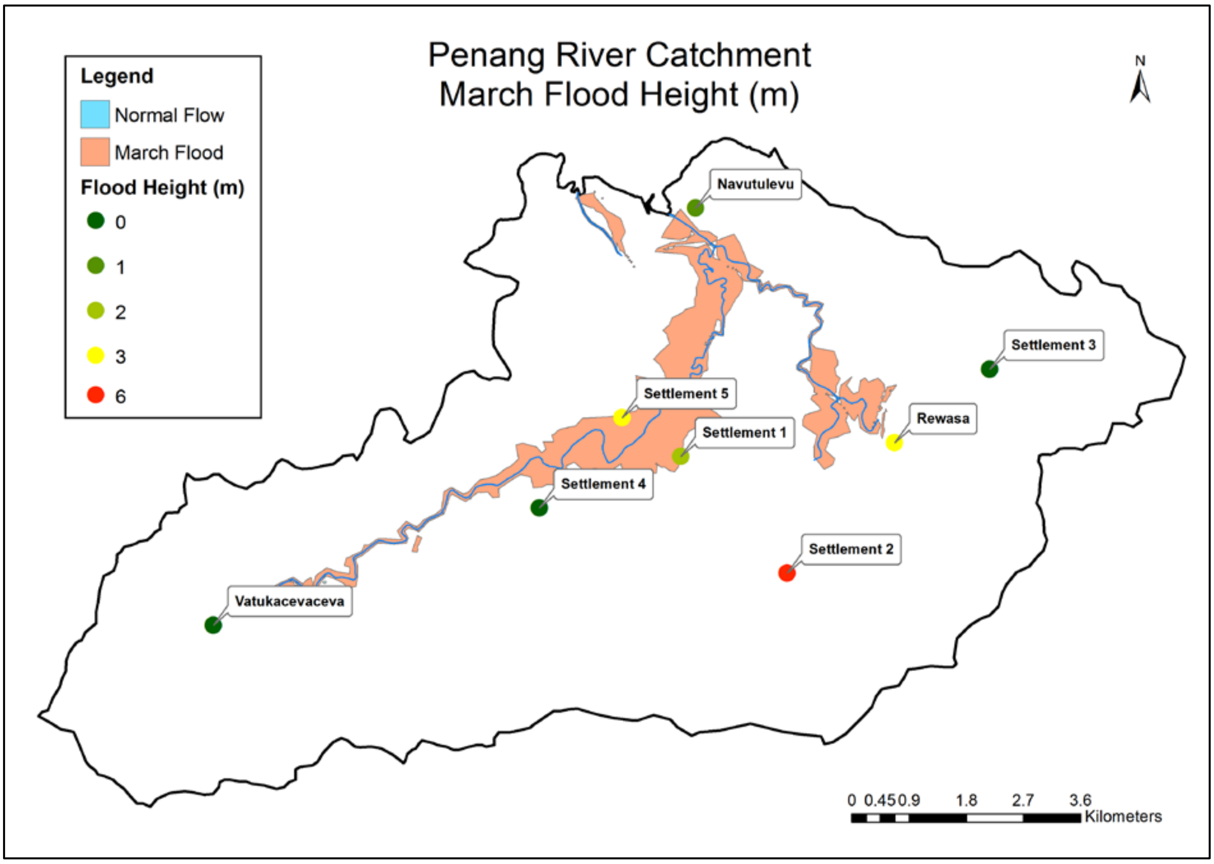


Figure 14. **Modelled March 2012 flood height, Penang River catchment**

Table 14 presents detailed data on damages to crops, livestock, housing, durables, and other categories incurred in the Ba River catchment during the January flooding. For example, six of the 12 households surveyed in Balevutu reported crop damage from the January floods. Among those that suffered losses, the average value of those crop losses was FJ$ 1683. One surveyed household in Balevutu lost livestock worth FJ$ 1700 and one surveyed household incurred property damage that cost FJ$400 to repair. These damages among affected households amount to 21.4% of the annual income from all 12 surveyed households, i.e., the January floods are estimated to have caused losses of over one-fifth the value of annual income village wide. The January flooding was especially severe in Navala, where several households lost kava crops worth several times the average annual household income.[11] Notably, damages to crops greatly exceeded damages to livestock, housing, durables, and other categories in the Ba River catchment during the January floods. Damages associated with the March flooding follows similar patterns (Table 15), although crop damages are generally lower because many households in flood-prone areas had already lost crops to the January floods. However, crop damages were substantially worse after the March floods than the January floods in one community ('Ba Lower 4'), possibly because some drainage ditches that were blocked during the January floods had not been cleared prior to March.

Cyclone Evan had a devastating effect on communities in the Ba River catchment (Table 16). All 12 households that were surveyed in Nanoko and Buyabuya lost crops, including significant shares of the kava crop that had been planted several years earlier. As a result, average damages exceeded average annual income in Nanoko and Buyabuya by 158% and 49%, respectively. Most communities also experienced damage to the housing stock, adding significantly to total damages. In addition, many households suffered indirect damages such as lost work opportunities or having to purchase pre-packaged food, although these losses are modest, on average.

Analogous figures for the January floods, March floods, and Cyclone Evan in the Penang River catchment are presented in Table 17, Table 18, and Table 19 respectively. The general pattern of damages closely follows that present in the Ba River catchment, although catastrophic losses to sugarcane (as opposed to kava) underlay the high value of crop losses in some communities. Flooding caused damages totalling up to one-third average annual household income in the Penang River catchment; Cyclone Evan caused damages of up to 97% of average annual household income.

[11] Similarly, one household in Koro suffered catastrophic losses of its kava crop.

Table 14. Damages to Ba River catchment communities, January floods

Community	# crop damage Jan	mean crop damage if > 0	# stock damage Jan	mean stock damage if > 0	# house damage Jan	mean house damage if > 0	# durable damage Jan	mean durable damage if > 0	# indirect damage Jan	mean indirect damage if > 0	damage as a share of income
Ba Lower 1	10	FJ$848	1	FJ$5,700					4	FJ$163	14.79%
Ba Lower 2	3	FJ$2,991	2	FJ$2,890	1	FJ$55			4	FJ$23	19.12%
Ba Lower 3	7	FJ$2,566			2	FJ$2,750	3	FJ$2,667	5	FJ$444	33.52%
Ba Lower 4	2	FJ$604							1	FJ$200	1.61%
Ba Lower 5	2	FJ$1,020			1	FJ$200			3	FJ$133	4.33%
Ba Lower 6	1	FJ$1,051							2	FJ$155	2.01%
Ba Mid 1	1	FJ$2,333									6.79%
Ba Mid 2	1	FJ$389							3	FJ$93	2.08%
Ba Mid 3	9	FJ$2,392			2	FJ$550	1	FJ$500	7	FJ$141	20.89%
Ba Mid 4	7	FJ$1,842	1	FJ$1,850					3	FJ$290	14.86%
Ba Mid 5	4	FJ$2,044	1	FJ$4,160	1	FJ$400			1	FJ$60	25.82%
Ba Mid 6	4	FJ$7,287									40.65%
Ba Mid 7	7	FJ$2,275									13.53%
Ba Mid 8	1	FJ$3,449									7.68%
Balevutu	6	FJ$1,683	1	FJ$1,700	1	FJ$400					21.43%
Bukuya	4	FJ$1,971									13.43%
Buyabuya	2	FJ$4,219									11.06%
Koro	1	FJ$12,693									6.45%
Koroqaqa	9	FJ$2,000							1	FJ$15	23.12%
Nadrugu	5	FJ$6,721									34.52%
Nailaga	8	FJ$892			1	FJ$700					15.40%
Nakoroboya	5	FJ$2,727									21.01%
Nanoko	2	FJ$951									3.40%
Nanuku	9	FJ$2,213									20.30%
Navala	6	FJ$15,903									48.49%
Toge	7	FJ$1,107			1	FJ$200			1	FJ$30	14.16%
Tubuquto	5	FJ$5,347							1	FJ$400	36.51%
Votua	12	FJ$585					1	FJ$500	1	FJ$30	8.57%

Table 15. Damages to Ba River catchment communities, March floods

Community	# crop damage March	Mean crop damage if > 0	# stock damage March	Mean stock damage if > 0	# house damage March	Mean house damage if > 0	# durable damage March	Mean durable damage if > 0	# indirect damage March	Mean indirect damage if > 0	Damage as a share of income
Ba Lower 1	9	FJ$738	2	FJ$3,675			1	FJ$1,000	4	FJ$224	15.85%
Ba Lower 2	3	FJ$2,863							3	FJ$17	11.08%
Ba Lower 3	6	FJ$3,394	1	FJ$710	3	FJ$433	3	FJ$2,033	4	FJ$479	30.25%
Ba Lower 4	3	FJ$3,933							2	FJ$200	13.94%
Ba Lower 5	2	FJ$1,017							3	FJ$142	4.04%
Ba Lower 6	1	FJ$1,051							1	FJ$500	2.29%
Ba Mid 1	2	FJ$1,834									10.68%
Ba Mid 2	1	FJ$389							3	FJ$105	2.19%
Ba Mid 3	8	FJ$1,925			2	FJ$100			7	FJ$166	14.53%
Ba Mid 4	7	FJ$1,827	1	FJ$860			1	FJ$150	4	FJ$255	14.10%
Ba Mid 5	4	FJ$1,622	1	FJ$990					1	FJ$60	15.20%
Ba Mid 6	4	FJ$1,858							1	FJ$100	10.50%
Ba Mid 7	7	FJ$1,566							1	FJ$120	9.42%
Ba Mid 8	2	FJ$2,028									9.03%
Balevutu	4	FJ$511									3.59%
Bukuya	2	FJ$700									2.38%
Buyabuya	4	FJ$1,515									7.95%
Koro	1	FJ$12,693									6.45%
Koroqaqa	5	FJ$1,213							1	FJ$15	7.80%
Nadrugu	5	FJ$2,660									13.66%
Nailaga	4	FJ$68									0.53%
Nakoroboya	5	FJ$145	1	FJ$6,540							11.20%
Nanoko	1	FJ$1,046									1.87%
Nanuku	2	FJ$39									0.08%
Navala	5	FJ$5,564									14.14%
Toge	6	FJ$239									2.55%
Tubuquto	4	FJ$1,415									7.61%
Votua	9	FJ$183							1	FJ$20	1.90%

Table 16. Damages to Ba River catchment communities, Cyclone Evan

Community	# crop damage Evan	Mean crop damage if > 0	# stock damage Evan	Mean stock damage if > 0	# house damage Evan	Mean house damage if > 0	# durable damage Evan	Mean durable damage if > 0	# indirect damage Evan	Mean indirect damage if > 0	damage as a share of income
Ba Lower 1	10	FJ$1,120			6	FJ$1,233	1	FJ$8,000	7	FJ$191	27.86%
Ba Lower 2	3	FJ$3,936			3	FJ$783			3	FJ$35	18.30%
Ba Lower 3	7	FJ$7,134			3	FJ$137			3	FJ$188	50.67%
Ba Lower 4	8	FJ$1,208			3	FJ$333	1	FJ$800	5	FJ$166	14.05%
Ba Lower 5	3	FJ$181			5	FJ$1,140	1	FJ$200	5	FJ$194	12.16%
Ba Lower 6	4	FJ$2,226			2	FJ$200	1	FJ$10	4	FJ$115	14.47%
Ba Mid 1	7	FJ$2,017			6	FJ$408	2	FJ$100	6	FJ$184	52.04%
Ba Mid 2	4	FJ$2,650			1	FJ$50			3	FJ$110	34.19%
Ba Mid 3	9	FJ$2,947			7	FJ$1,693	1	FJ$1,000	9	FJ$134	35.16%
Ba Mid 4	9	FJ$2,899			5	FJ$660	1	FJ$100	6	FJ$131	28.81%
Ba Mid 5	6	FJ$3,314			2	FJ$1,100			2	FJ$85	44.89%
Ba Mid 6	6	FJ$9,305			5	FJ$1,820	1	FJ$200	4	FJ$268	92.33%
Ba Mid 7	9	FJ$3,538			1	FJ$100			1	FJ$50	27.19%
Ba Mid 8	4	FJ$7,928	1	FJ$6,450	2	FJ$1,550			3	FJ$45	92.17%
Balevutu	10	FJ$1,009			2	FJ$500			3	FJ$40	19.70%
Bukuya	12	FJ$3,846			1	FJ$200					78.95%
Buyabuya	12	FJ$9,411			1	FJ$300			1	FJ$23	148.51%
Koro	10	FJ$17,588			1	FJ$200			1	FJ$25	89.45%
Koroqaqa	8	FJ$1,305	1	FJ$640	3	FJ$257	1	FJ$500	3	FJ$82	16.16%
Nadrugu	12	FJ$5,131			1	FJ$100					63.34%
Nailaga	4	FJ$197			1	FJ$5,000			1	FJ$35	11.45%
Nakoroboya	11	FJ$3,011							1	FJ$20	51.08%
Nanoko	12	FJ$11,842	1	FJ$1,850	1	FJ$200			1	FJ$150	258.33%
Nanuku	10	FJ$2,016	1	FJ$5,700	1	FJ$200	1	FJ$100	2	FJ$139	26.95%
Navala	12	FJ$11,606			2	FJ$125			2	FJ$30	70.94%
Toge	10	FJ$2,058	2	FJ$5,800	1	FJ$100			1	FJ$5	57.32%
Tubuquto	11	FJ$6,392									94.60%
Votua	10	FJ$393			2	FJ$1,550			1	FJ$51	8.03%

Table 17. Damages to Penang River catchment communities, January floods

Community	# crop damage January	Mean crop damage if > 0	# stock damage Jan	Mean stock damage if > 0	# house damage Jan	Mean house damage if > 0	# durable damage Jan	Mean durable damage if > 0	# indirect damage Jan	Mean indirect damage if > 0	Damage as a share of income
Navutulevu	9	FJ$1,058							1	FJ$20	7.71%
Ra 1	7	FJ$1,789			2	FJ$350	1	FJ$100	5	FJ$168	11.23%
Ra 2	3	FJ$9,307							1	FJ$200	32.74%
Ra 3	4	FJ$2,835							2	FJ$35	25.70%
Ra 4	4	FJ$3,280			1	FJ$500			1	FJ$200	14.75%
Ra 5	2	FJ$2,844							1	FJ$30	4.99%
Rewasa	8	FJ$1,335							2	FJ$260	15.43%
Vatukacevaceva	10	FJ$970									10.95%

Table 18. Damages to Penang River catchment communities, March floods

Community	# crop damage March	Mean crop damage if > 0	# stock damage March	Mean stock damage if > 0	# house damage March	Mean house damage if > 0	# durable damage March	Mean durable damage if > 0	# indirect damage March	Mean indirect damage if > 0	damage as a share of income
Navutulevu	7	FJ$892									5.04%
Ra 1	7	FJ$1,910			3	FJ$253	1	FJ$250	4	FJ$126	11.80%
Ra 2	3	FJ$2,238							1	FJ$200	8.05%
Ra 3	4	FJ$1,961	1	FJ$1,070					1	FJ$30	20.15%
Ra 4	3	FJ$1,513	1	FJ$5,640					1	FJ$100	10.97%
Ra 5	3	FJ$2,004							1	FJ$30	5.27%
Rewasa	8	FJ$1,032							1	FJ$200	11.65%
Vatukacevaceva	10	FJ$1,210	1	FJ$2,640							16.63%

Table 19. Damages to Penang River catchment communities, Cyclone Evan

Community	# crop damage Evan	Mean crop damage if > 0	# stock damage Evan	Mean stock damage if > 0	# house damage Evan	Mean house damage if > 0	# durable damage Evan	Mean durable damage if > 0	# indirect damage Evan	Mean indirect damage if > 0	Damage as a share of income
Navutulevu	12	FJ$2,692									26.09%
Ra 1	8	FJ$2,858			8	FJ$573	1	FJ$50	6	FJ$191	22.70%
Ra 2	4	FJ$10,662	1	FJ$2,000	3	FJ$533	1	FJ$200	3	FJ$62	54.29%
Ra 3	4	FJ$1,919			3	FJ$1,033			2	FJ$48	24.49%
Ra 4	5	FJ$5,491	1	FJ$6,900	5	FJ$410	1	FJ$50	5	FJ$280	40.40%
Ra 5	5	FJ$7,176			4	FJ$1,575	2	FJ$170	4	FJ$99	37.43%
Rewasa	11	FJ$5,741							1	FJ$28	87.03%
Vatukacevaceva	11	FJ$2,870									35.62%

Scaling the household-level estimates up to the catchment-wide population level shows that the January 2012 flood caused about FJ$12.8 million in household damages to the Ba River catchment and FJ$2.4 million to the Penang River catchment (Table 21 and Table 22). The March 2012 flood caused an estimated FJ$8.5 million and FJ$1.9 million in the Ba River catchment and Penang River catchment, respectively. By comparison, Ambroz (2009) estimated that the 2009 floods in Ba River catchment caused an estimated FJ$30.5 in damage to households.

Table 20. Catchment-wide damages to Ba River catchment

Event	Category	Indo-Fijian *(FJ$)*	iTaukei *(FJ$)*	Total *(FJ$)*
January 2012 Flood	Crops	7,477,044	3,072,301	10,549,345
	Livestock	558,236	19,809	578,045
	Housing	538,580	80,831	619,411
	Durables	693,044	11,949	704,993
	Indirect	383,370	4,034	387,404
	Business	n/a	n/a	23,504,593
	Total	**9,650,273**	**3,188,925**	**36,343,791**
March 2012 Flood	Crops	6,199,696	626,810	6,826,506
	Livestock	441,256	126,142	567,398
	Housing	117,973	–	117,973
	Durables	558,944	–	558,944
	Indirect	438,364	557	438,921
	Business	n/a	n/a	15,578,702
	Total	**7,756,233**	**753,510**	**24,088,444**
Cyclone Evan	Crops	17,922,239	6,210,126	24,132,365
	Livestock	198,551	389,452	588,002
	Housing	2,671,342	608,998	3,280,340
	Durables	516,938	3,870	520,808
	Indirect	554,781	12,581	567,362
	Business	n/a	n/a	53,252,721
	Total	**21,863,851**	**7,225,027**	**82,341,598**

Table 21. Catchment-wide damages to Penang River catchment

Event	Category	Indo-Fijian *(FJ$)*	iTaukei *(FJ$)*	Total *(FJ$)*
January 2012 Flood	Crops	1,620,904	701,651	2,322,554
	Livestock	–	0	0
	Housing	20,112	0	20,112
	Durables	1,832	0	1,832
	Indirect	25,729	15,690	41,418
	Business	n/a	n/a	9,764,956
	Total	**1,668,576**	**717,340**	**12,150,872**
March 2012 Flood	Crops	1,121,627	550,888	1,672,515
	Livestock	149,148	25,087	174,235
	Housing	13,920	0	13,920
	Durables	4,579	0	4,579
	Indirect	15,634	5,792	21,426
	Business	n/a	n/a	6,472,154
	Total	**1,304,908**	**581,767**	**8,358,829**
Cyclone Evan	Crops	3,231,311	3,146,510	6,377,821
	Livestock	118,079	–	118,079
	Housing	595,478	–	595,478
	Durables	18,173	–	18,173
	Indirect	66,164	811	66,975
	Business	n/a	n/a	29,371,720
	Total	**4,029,204**	**3,147,321**	**36,548,245**

Businesses in the two catchments were also impacted by the two flooding events. We did not explicitly survey local businesses in the Ba and Rakiraki towns about the damages they accrued by the events. Instead, we derive estimates using the valued losses to businesses found from the Ambroz (2009) study of the 2009 Ba flood of FJ$55.9 million for 479 formal businesses in the catchment, or about FJ$116,600/business. Given that our estimates for Ba household damage for the January 2012 flood was 42% of the estimated household damages from Ambroz (2009), we scale the business damages by the same factor to yield an estimated damage in the January 2012 flood of about FJ$49,000 per business in the Ba River catchment, or a total of FJ$23.5 million. Assuming that the 199 formal businesses in the Penang River catchment faced the same level of damage, the total damage to businesses in that catchment from the January flood were estimated at FJ$9.8 million. Applying the same logic to the March 2012 flood yields estimates of FJ$32,500/business. This amounts to about FJ$15.6 million and FJ$6.5 million in the respective Ba and Penang River catchments for the March 2012 floods.

Combining damages to households and businesses yields an estimated total damage from the January 2012 flood of FJ$36.3 million for the Ba River catchment and FJ$12.2 million for the Penang River catchment. For the March 2012 flood, total damages were estimated to be FJ$24.1 million in the Ba River catchment and FJ$8.4 million in the Penang River catchment.

Cyclone Evan also had a major impact on the two catchments, inflicting the most damage of the three events to hit the study area in 2012. The cyclone caused FJ$29.1 million in damages to households in the Ba River catchment and FJ$7.1 million in damages to households in the Penang River catchment. Using the same method as the two flood events to estimate business-related damages, we find that businesses in the Ba and Penang river catchments faced accrued economic impacts of FJ$53.3 and FJ$29.3 million, respectively. The total value of damages from Cyclone Evan was thus FJ$82.3 million in the Ba River catchment and FJ$36.5 million in the Penang River catchment.

4.2.2.1 Flood exceedence probability curves

The January 2012 flood was considered to be a 1-in-50 year event while the March 2012 flood was estimated to be a 1-in-20 event. We use the damage figures from these two events to construct flood exceedence probability curves for 1-in-100 (1%), 1-in-50 (2%), 1-in-20 (5%), 1-in-10 (10%), and 1-in-5 (20%) year events for each of the villages surveyed. The 1-in-100 event was assumed to create twice the damage as the 1-in-50 event, while the 1-in-10 and 1-in-5 events were assumed to respectively produce one-half and one-fourth of the damages accrued in the 1-in-20 event. The flood exceedence probability curves for all of the survey sites are shown in Figure 15. The area under each of these curves yields the expected value of annual damages from flooding to the average household in each catchment, estimated to be approximately FJ$165 per household per year under the current climate scenario in the Ba River catchment. In the Penang River catchment, the expected annual damages are FJ$225 per household per year for the current climate scenario.

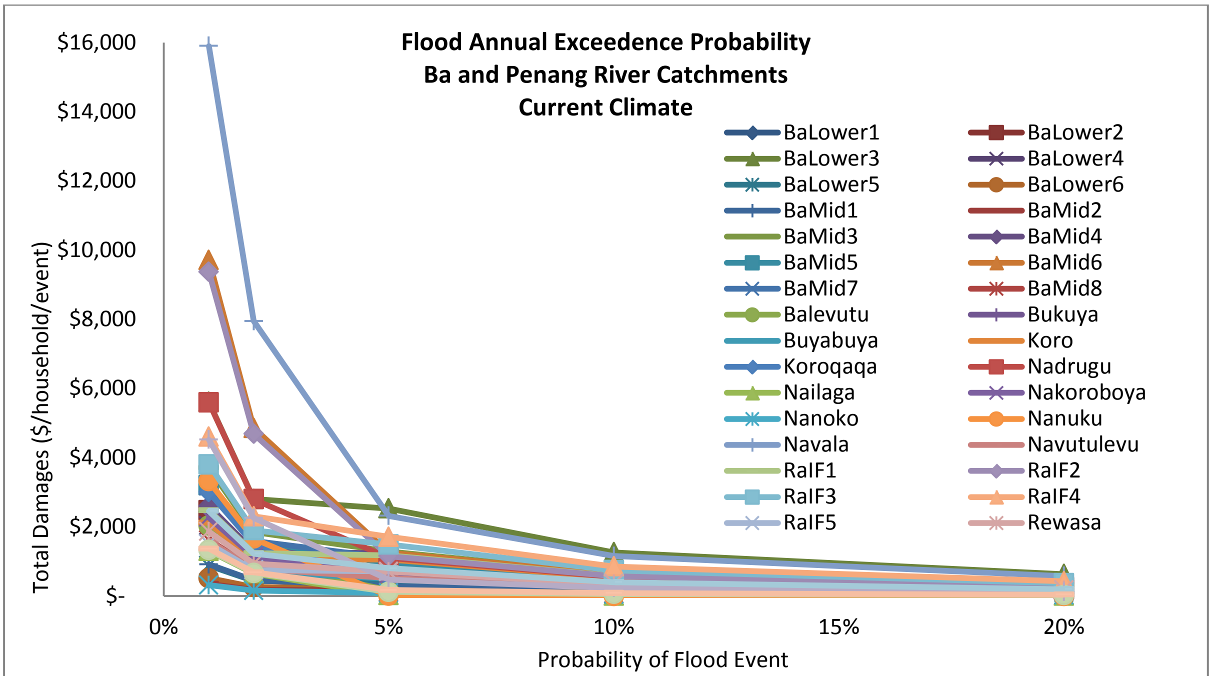


Figure 15. Flood exceedence probability curves by survey site

4.2.2.2 Flood damage under climate change

We use the range of projected shifts in extreme heavy rainfall return periods discussed in Section 4.1.7 and Appendix 1 to construct two climate change scenarios for estimating the likely range of future damages from flooding in the Ba and Penang River catchments relative to current climate. Recall that the 'moderate' scenario follows projections similar what may occur under the SRES B2 or relative concentration pathway (RCP) 6.0 scenarios while the 'severe' scenario follows projected changes under the SRES A2 or RCP 8.5 scenario.

The range of average household and business damages estimated for various flood exceedence probabilities for the two catchments under the three climate scenarios are shown in Table 22. Taking a weighted average of the estimated damages that would accrue under the different flood exceedence probabilities yields the expected value of average annual damages. In the Ba River catchment, this is estimated to range from FJ$165 per household per year under the current climate scenario to FJ$686 per household per year under the severe climate scenario. In the Penang River catchment, the expected annual damages range from FJ$225 per household per year for the current climate scenario to FJ$830 per household per year for the severe climate change scenario. Applying the same method to local businesses yields damages to the average business in each catchment of FJ$6,841 per year for the current climate, FJ$12,884 per year for the moderate climate, and FJ$24,170 per year for the severe climate change scenario.

Table 22. Expected damages (FJD) to average Ba and Penang River catchment households and businesses, three climate scenarios

Category	Climate Scenario	Flood Annual Exceedence Probability 20% *(FJ$)*	10% *(FJ$)*	5% *(FJ$)*	2% *(FJ$)*	1% *(FJ$)*	Expected Annual Damage *(FJ$)*
Average Ba Household	Current	173	346	693	1,519	3,039	165
	Moderate	346	693	1,519	3,039	6,077	336
	Severe	693	1,519	3,039	6,077	12,155	686
Average Penang Household	Current	259	518	1,036	1,731	3,461	225
	Moderate	518	1,036	1,731	3,461	6,923	432
	Severe	1,036	1,731	3,461	6,923	13,846	830
Average Ba and Penang Business	Current	8,131	16,262	32,523	49,070	98,140	6,841
	Moderate	16,262	32,523	49,070	98,140	196,281	12,884
	Severe	32,523	49,070	98,140	196,281	392,561	24,170

Scaling the average household and business estimates up to the catchment population level yields significantly higher damage estimates under the two climate change scenarios. In the Ba River catchment, the total expected annual damage accrued by households and businesses range from FJ$4.9 million to FJ$18.2 million (Table 23). Damages from a 1-in-50 year flood under the moderate and severe climate-change scenarios are projected to cause between FJ$F76.5 and FJ$153 million in damages, a 100-300% increase relative to the January 2012 flood that is considered to have same frequency under the current climate scenario. In the Penang River catchment, the total expected annual damage accrued by households and businesses ranges from FJ$1.8 million to FJ$6.4 million (Table 24), and damages from a 1-in-50 year flood under the moderate and severe climate change scenario are estimated to be between FJ$26.2 and FJ$52.4 million.

Table 23. Catchment-wide damages to Ba River catchment from flooding, three climate scenarios

	Climate Scenario	Flood Annual Exceedence Probability 20% *(FJ$)*	10% *(FJ$)*	5% *(FJ$)*	2% *(FJ$)*	1% *(FJ$)*	Expected Annual Damage *(FJ$)*
Household Damages	Current	1,681,344.61	3,362,343	6,725,032	14,747,992	29,495,985	1,598,674
	Moderate	3,362,343	6,725,032	14,747,992	29,495,985	58,991,969	3,262,211
	Severe	6,725,032	14,747,992	29,495,985	58,991,969	117,983,938	6,654,284
Business Damages	Current	3,894,675	7,789,351	15,578,702	23,504,593	47,009,186	3,276,989
	Moderate	7,789,351	15,578,702	23,504,593	47,009,186	94,018,372	6,171,337
	Severe	15,578,702	23,504,593	47,009,186	94,018,372	188,036,745	11,577,394
Total Damages	Current	5,576,020	11,151,693	22,303,733	38,252,585	76,505,171	4,875,663
	Moderate	11,151,693	22,303,733	38,252,585	76,505,171	153,010,341	9,433,548
	Severe	22,303,733	38,252,585	76,505,171	153,010,341	306,020,683	18,231,677

Table 24. Catchment-wide damages to Penang River catchment from flooding, three climate scenarios

	Climate Scenario	Flood Annual Exceedence Probability 20% (FJ$)	10% (FJ$)	5% (FJ$)	2% (FJ$)	1% (FJ$)	Expected Annual Damage (FJ$)
Household Damages	Current	497,618	994,996	1,990,712	3,326,664	6,653,567	431,628
	Moderate	994,996	1,990,712	3,326,664	6,653,567	13,307,135	830,546
	Severe	1,990,712	3,326,664	6,653,567	13,307,135	26,614,270	1,595,773
Business Damages	Current	1,618,038	3,236,077	6,472,154	9,764,956	19,529,912	1,361,421
	Moderate	3,236,077	6,472,154	9,764,956	19,529,912	39,059,825	2,563,875
	Severe	6,472,154	9,764,956	19,529,912	39,059,825	78,119,650	4,809,815
Total Damages	Current	2,115,656	4,231,072	8,462,866	13,091,620	26,183,480	1,793,049
	Moderate	4,231,072	8,462,866	13,091,620	26,183,480	52,366,960	3,394,421
	Severe	8,462,866	13,091,620	26,183,480	52,366,960	104,733,920	6,405,588

4.2.2.3 Exposure to risk and expectations of future damages

As described in Section 4.1.2, survey respondents were asked to imagine a scenario in which they experienced the maximum possible damage in a year with one or more catastrophic disasters and were then asked to assign probabilities to disasters of different magnitudes occurring over the next 20 years. Their responses enable us to create cumulative distribution functions of the expected damage over this period.

These cumulative distribution functions are depicted as box plots in Figure 16. From top to bottom, the three horizontal bars comprising the boxes represent the 75th percentile, median, and 25th percentile of the total expected damages. The whiskers extend to include all data points within 1.5 times the length of the inter-quartile range. The means for each catchment are marked with *x*'s and outlying values are indicated with circles.

The mean total expected damage from disasters over the next 20 years is FJ$155,292 (FJ$7765 per year) in the Ba River catchment and FJ$255,880 in the Penang River catchment (FJ$12,794 per year), a difference that is statistically significant at the 1% level using a two-sided *t* test. That is, respondents in the Penang River catchment anticipate a higher frequency of more costly disasters for the foreseeable future. The median total expected damage is also higher among respondents in the Penang River catchment, as is the variation in responses.

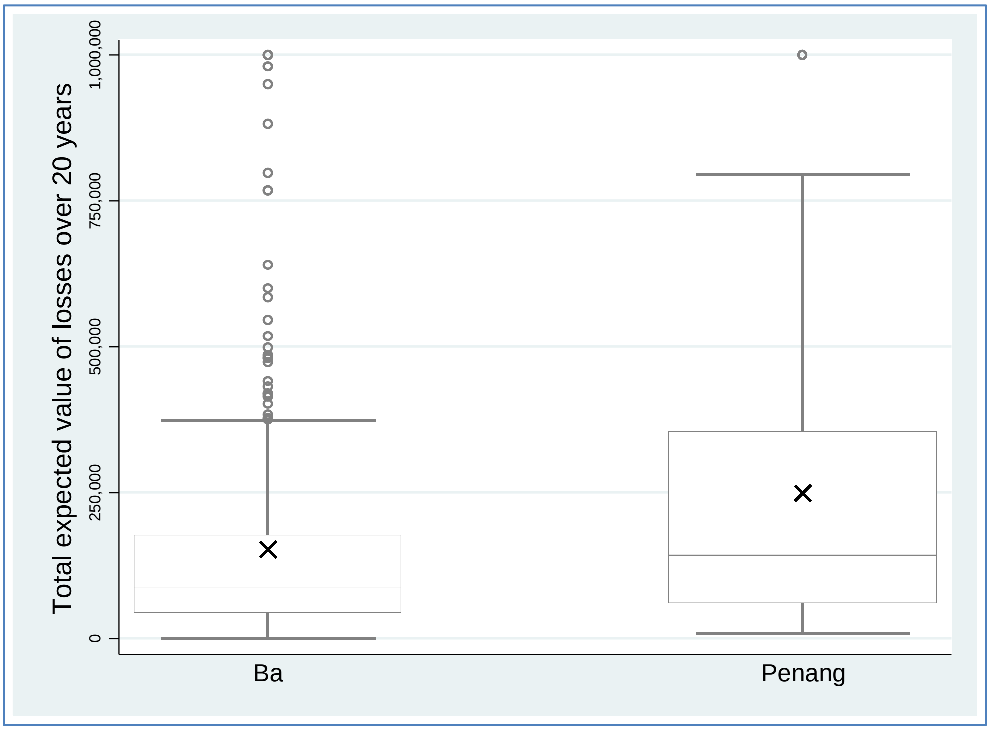


Figure 16. Total expected damage over the next 20 years by catchment

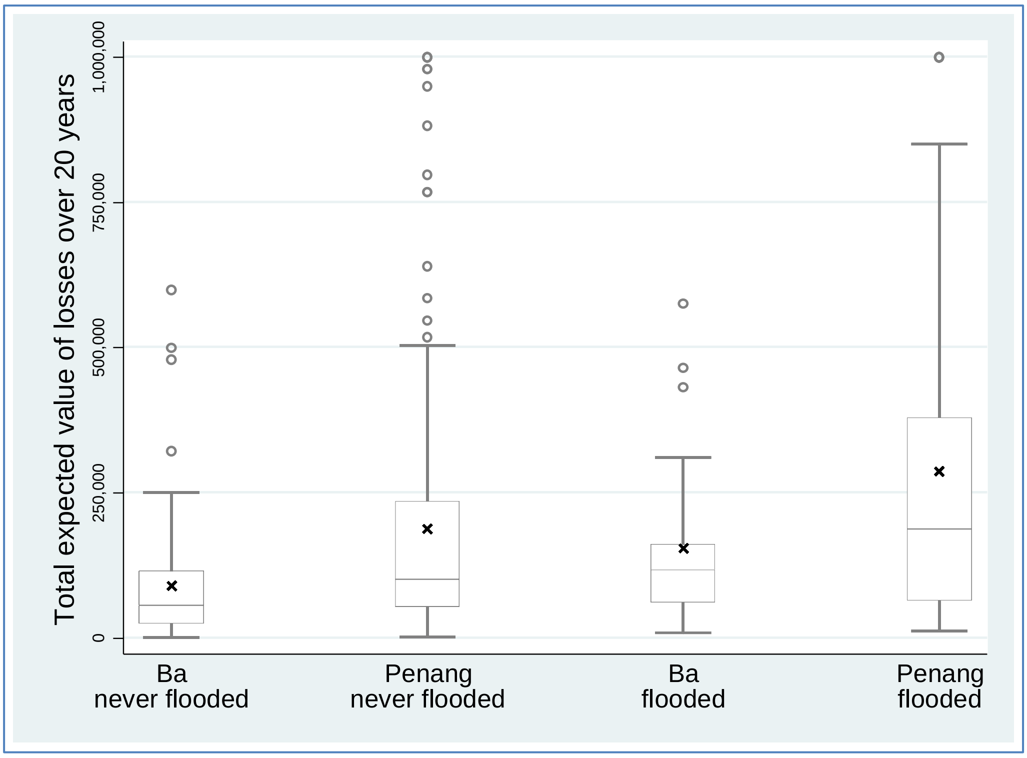


Figure 17. Expected damage over the next 20 years by catchment and previous experience with flooding

By further dividing the sample according to whether respondents experienced flood damage over the previous decade, we are able to test the Botzen et al. (2009) hypothesis that previous exposure to flooding influences expectations about future losses to natural disaster. Figure 17 is analogous to Figure 16 except that four groups are now depicted, i.e., Ba River catchment residents with no previous exposure to flooding, Penang River catchment residents with no previous exposure to flooding, Ba River catchment residents with previous exposure to flooding, and Penang River catchment residents with previous exposure to flooding. The mean expected damage from disasters over the next 20 years among households who experienced flooding in the last decade is FJ$191,165 in the Ba River catchment. The mean expected damage for those who have not experienced flooding in the last decade is FJ$90,378, a difference that is statistically significant at the 1% level. Similarly, the mean expected damage from disasters among households who experienced flooding in the last decade is FJ$295,947 in the Penang River catchment while the mean expected damage for those who have not experienced flooding is FJ$154,757, a difference that is statistically significant at the 10% level. That is, previous exposure to flood risk significantly raises perceptions of future flood risk.

The stated values for total damages over the next 20 years are compared to our estimates of total damages should a given event occur in each year for the next 20 years in Table 25. The estimates from the detailed household survey indicate that households in the Ba River catchment and Ra River catchments can expect average annual damage of FJ$165-FJ$685 per year and FJ$225-FJ$830, respectively. These figures are a small fraction of the expected annual damages explicitly stated by survey responders, indicating that recent exposure to an infrequent but high-damage event may cause people to overestimate exposure risk. For example, a 1-in-50 year flood under moderate climate change would have to occur more at least once a year over the next 20 years in the Ba River catchment for households to accrue their stated expected damages. In the Penang River catchment, a 1-in-100 year flood would have to occur annually to reach the stated maximum damages over the next 20 years.

Table 25. Estimated total damages to average household from recurring flooding over next 20 years

Catchment	Flood Return*	Survey Response *(FJ$)*	Current Climate *(FJ$)*	Moderate climate change *(FJ$)*	Severe Climate *(FJ$)*
Ba	Annual Expected	155,292	3,294	6,722	13,711
	1-in-20		13,856	30,387	60,774
	1-in-50		30,387	60,774	121,549
	1-in-100		60,774	121,549	243,097
Penang	Expected	255,880	4,491	8,641	16,603
	1-in-20		20,713	34,613	69,228
	1-in-50		34,613	69,228	138,455
	1-in-100		69,228	138,455	276,910

* Assumes estimated damages from an event with given return period occurs each year for 20 years

4.2.2.4 Community resilience

Survey respondents were also asked to evaluate the resilience of the communities in which they live. Specifically, using a 201-gradient Likert scale, respondents were asked the extent to which they agreed with statements such as 'The community has the skills and knowledge to limit the damage from natural disasters'. Scores above (below) zero indicate agreement (disagreement), with higher scores indicating higher levels of agreement and lower scores indicating higher levels of disagreement. Resilience is discussed at length in Section 1.5, although Figure 18 provides an example of how one dimension of resilience differs across catchments using histograms.

Specifically, Figure 18 shows the distribution of agreement with the following statement: 'The community is able to identify new ways to solve problems.' The blue bars depict the share of respondents in each catchment that assigned scores within each 25-point band and the green curve represents a normal density plot of the empirical distribution. The strength of agreement increases as the masses of the boxes and density curve shift to the right. In total, 30% of respondents in the Ba River catchment and 34% of respondents in the Penang River catchment assigned scores between 75 and 100, indicating very high levels of agreement. Similarly 20% of the respondents in the Ba River catchment and 25% of respondents in the Penang River catchment assigned scores between 50 and 75, indicating agreement, albeit less strong agreement than those that assigned higher scores. On the opposite end of the spectrum, 20% of survey respondents in the Ba River catchment assigned scores between -100 and -50, indicating strong disagreement. In contrast, only 6% of survey respondents in the Penang River catchment held similar views. Overall, these figures suggest that respondents in the Penang River catchment have higher confidence that the community is able to identify new ways to solve problems, a hypothesis that is confirmed using a two-sided *t* test for the equality of means (statistically significant at the 5% level).

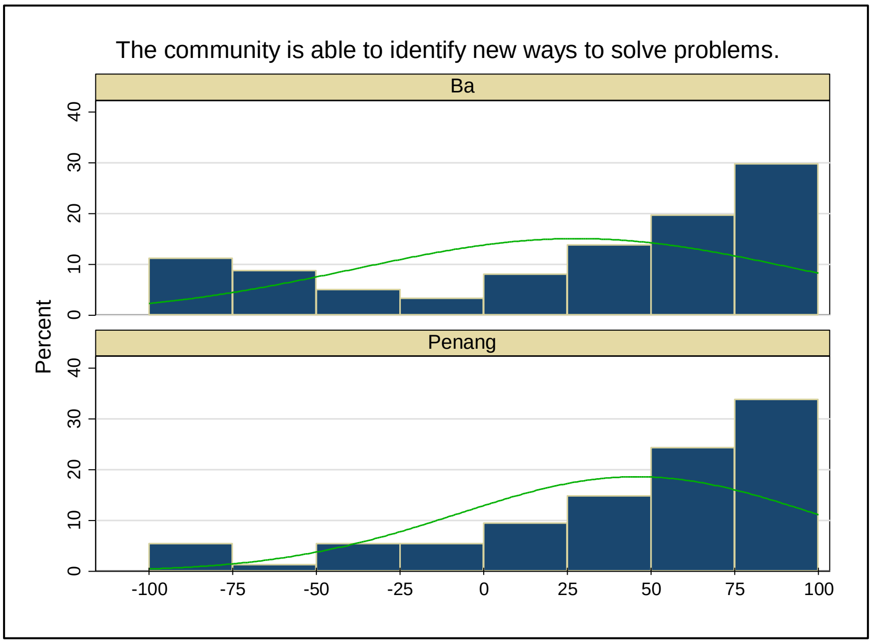


Figure 18. Distribution of responses to a question on community resilience, by catchment

4.3 Cost-benefit analysis

In this report, we consider several means of adaptation that could be implemented in the Ba and Penang River catchments. Each option considered will produce a benefit relative to doing nothing, which would produce the level of damages estimated under the three climate change scenarios (i.e., current, moderate, severe). However adaptation also incurs costs. This section explicitly outlines each of these costs and benefits, places values on those categories that can be monetised, quantifies the net present value (NPV) of costs and benefits over the lifetime of the intervention, and then ranks the options based on the highest NPV. We also perform sensitivity analysis around the range of effectiveness (i.e., base, low, high) for each option as well as discount rates (i.e., 4%, 8%, 12%). A summary of the key assumptions for each of these adaptation options is listed in Table 26, with more details on the mixed intervention approach listed in Table 27.

Table 26. Summary of adaptation options evaluated in cost-benefit analysis

Option	Ba River catchment	Penang River catchment
Do nothing	Assumes status quo of limited interventions undertaken prior to 2012 floods	Assumes status quo of limited interventions undertaken prior to 2012 floods
Plant riparian buffers	Plant 30m buffer of native vegetation along all stream-banks (1,291 ha)	Plant 30m buffer of native vegetation along all stream-banks (138 ha)
Afforest upper catchment	Plant native trees on all talasiga (open grassland) in upper catchment (35,626 ha)	Plant native trees on all of talasiga (open grassland) in catchment (4,645 ha)
Plant floodplain vegetation	Plant native vegetation on 10% of cropland in catchment flood plain (total 1,631 ha)	Plant native vegetation on 10% of cropland in catchment flood plain (437 ha)
Reinforce riverbanks	Construct levies and other 'hard' infrastructure along stream-bank of lower and mid-reaches of river (115.3 km)	Construct levies and other 'hard' infrastructure along stream-bank of lower reaches of river (28.8 km)
River dredging	Dredge lower portion of the Ba River (3,845,000 m3)	Dredge lower portion of the Penang River (500,000 m3)
Raising houses	Elevate living area of 3,000 vulnerable houses in catchment	Elevate living area of 1,000 vulnerable houses in catchment
Mixed interventions	Mix of options undertaken in various parts of the catchment (see Table 27)	Mix of options undertaken in various parts of the catchment (see Table 27)

Table 27. Summary of mixed approach options evaluated in cost-benefit analysis

Option	Ba River catchment	Penang River catchment
Plant riparian buffers	Plant 30m buffer of native vegetation along 323 ha of stream-banks	Plant 30m buffer of native vegetation along 35 ha of stream-banks
Afforest upper catchment	Plant native trees on 8,907 ha of talasiga in upper catchment	Plant native trees on 1,161 ha of talasiga in upper catchment
Plant floodplain vegetation	Plant native vegetation on 408 ha of cropland in catchment flood plain	Plant native vegetation on 109 ha of cropland in catchment flood plain
Reinforce riverbanks	Construct levies and other 'hard' infrastructure along 28.8 km of stream-banks in lower reaches of Penang	Construct levies and other 'hard' infrastructure along 7.2 km of stream-banks in lower reaches of Penang
River dredging	Dredge 961,250 m3 from lower portion of the Ba River	Dredge 125,000 m3 from lower portion of the Penang River

4.3.1 Identifying costs and benefits

Each of the adaptation options considered in this study faces a distinct set of costs and benefits. A summary of the costs and benefits used in the cost-benefit analysis are listed in Table 28. The primary benefits of each option are typically the avoided damages, although some of the EbA approaches also provide benefits such as NFTP and carbon sequestration. Key costs include labour, initial capital, and annual operations and maintenance. Some of the EbA approaches also incur opportunity costs as cropland may be planted with native vegetation as part of floodplain, riparian, or upland afforestation.

Table 28. Costs and benefits of flood mitigation

Category	Riparian buffers	Upland afforest	Floodplain vegetation	Reinforce riverbanks	Raise houses	Dredge river	Mixed intervention
Monetised Costs							
Labour	×	×	×	×	×	×	×
Capital	×	×	×	×	×	×	×
Materials	×	×	×	×	×	×	×
Operating & maintenance	×	×	×	×		×	×
Monitoring	×	×	×				×
Opportunity costs - agriculture	×		×				×
Monetised Benefits							
Avoided damages - agriculture	×	×	×	×	×	×	×
Avoided damages - livestock	×	×	×	×	×	×	×
Avoided damages – housing	×	×	×	×	×	×	×
Avoided damages – durable assets	×	×	×	×	×	×	×
Avoided damages – indirect costs	×	×	×	×	×	×	×
Avoided damages – businesses	×	×	×	×	×	×	×
Provision of NTFP	×	×	×				×
Carbon sequestration	×	×	×				×
Non-monetised Benefits							
Soil erosion control	×	×	×	×			×
Maintenance of soil fertility	×	×	×				×
Biodiversity & habitat	×	×	×				×
Potential recreation values	×	×	×				×
Spiritual values	×	×	×				×

4.3.2 Effectiveness of adaptation

The literature discussed in Section 2.2 and the hydrological model described in Section 4.2.1.3 each have some uncertainty with regard to the effectiveness of adaptation measures. For each adaptation measure, we thus consider three levels of effectiveness – 'low', 'high', and 'base', where the latter is the mean of the low and high effectiveness – to allow for considerable sensitivity testing in our recommendations (Table 29).

Table 29. Effectiveness of adaptation measures (assumptions)

Adaptation Option	Range of Effectiveness	'Base' Effectiveness	'Low' Effectiveness	'High' Effectiveness
Riparian buffers	10-40%	25%	10%	40%
Upland afforestation	20-70%	50%	20%	70%
Floodplain vegetation	10-25%	20%	10%	25%
Reinforce riverbanks	30-80%	50%	30%	80%
River dredging	30-80%	50%	30%	80%
Raise houses	50-90%^	75%*	50%*	90%*
Mixed intervention	50-100%	75%	50%	100%

* Applies to damages to housing and durable assets only.

The impact of the baseline effectiveness on the estimated damages for the average household in the Ba River catchment under the current climate scenario is shown in Figure 19, while the estimates for the Penang river catchment are shown in

Figure 20. The difference in the area under the 'do nothing' curve and each adaptation option is the value of avoided damages to each household.

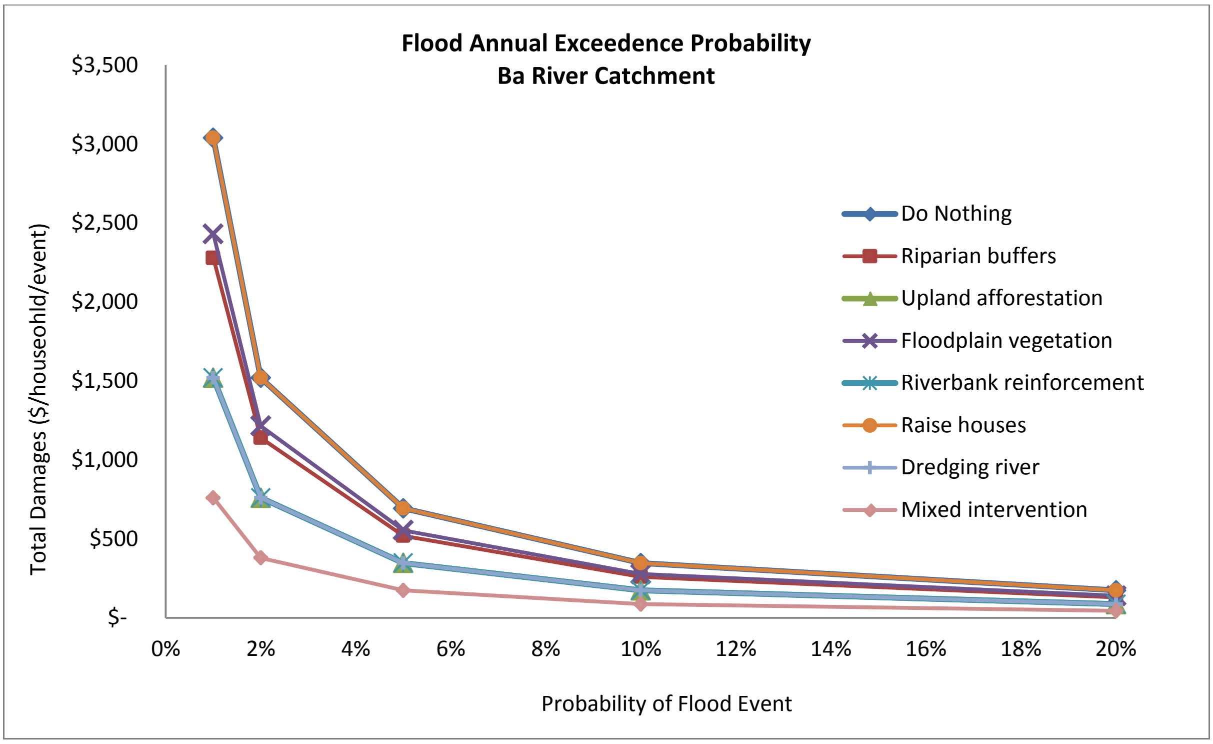


Figure 19. **Flood exceedence probability curve for adaptation options, current climate scenario, Ba River catchment**

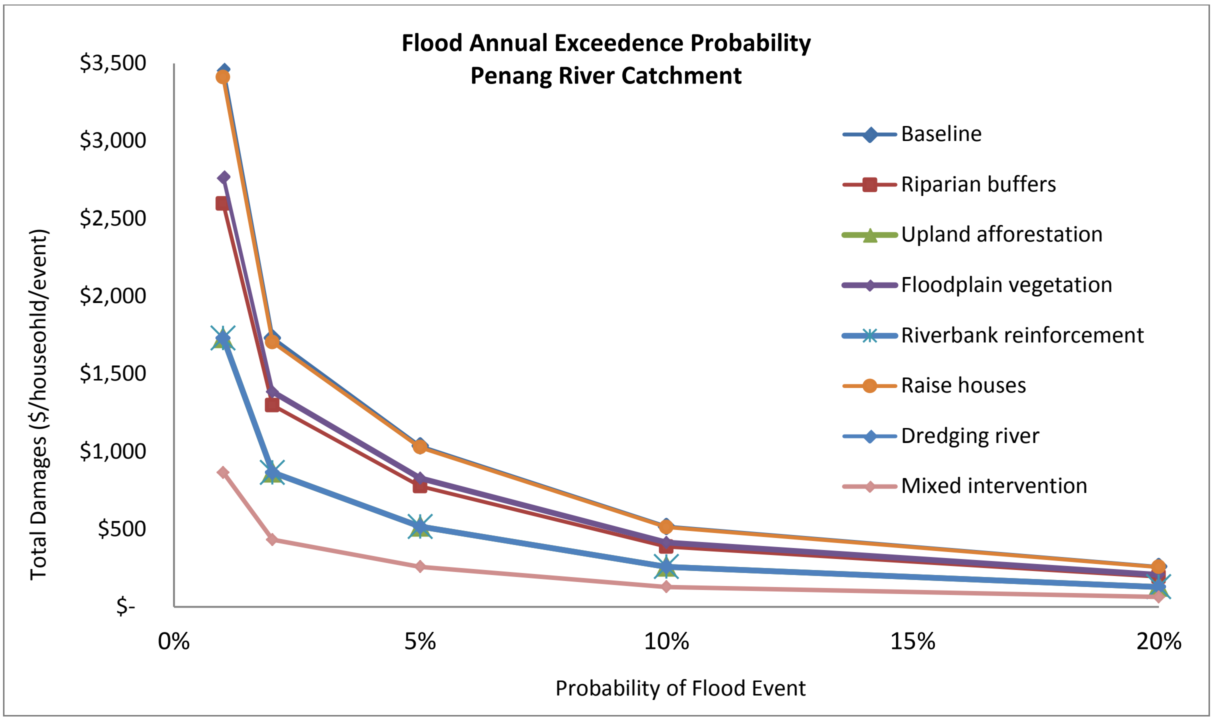


Figure 20. **Flood exceedence probability curve for adaptation options, current climate scenario, Penang River catchment**

4.3.3 Monetising costs and benefits of adaptation

The monetised values for the benefits (i.e., avoided damages) vary by adaptation method. An overview of the key monetised benefits are outlined in Table 30.

Table 30. Monetised values of benefits from implementing flood adaptation in the Ba River and Penang River catchments

Benefit Category	Unit Value	Assumptions/Notes
Avoided damages – households	FJ$/HH	Difference between estimated damages accrued under adaptation option relative to the 'do nothing' option. Includes avoided damages for crops, livestock, housing, durable assets, and indirect costs.
Avoided damages - businesses	FJ$/Business	Difference between estimated damages accrued under adaptation option relative to the 'do nothing' option for the average business in each catchment.
NFTP	FJ$/ha	Average household income obtained from the value of collecting, using and/or selling NTFP in one hectare of new forests, riparian buffers, and floodplain vegetation. Estimated from household survey to be FJ$18/ha/yr in the Ba River catchment and FJ$77/ha/yr in Penang River catchment, based on current area planted.
Carbon sequestration	FJ$/tCO2e	Value of carbon sequestered in native vegetation planted under EbA. Valued at FJ$20 per tonne carbon dioxide equivalent (FJ$ /tCO2e) based on average global market carbon price. Native forests estimated to sequester 500 tCO2e/ha after reaching maturity (Payton and Weaver, 2011)

The costs (i.e., costs of inputs) also vary by option, as shown in Table 31. Capital, labour and monitoring costs are assumed to be the same for activities in both catchments, however opportunity costs for lost income from agriculture differ between Ba and Penang because of varying crop values. Note also that units also vary by option. In addition, dredging is assumed to only occur once every 10 years. The costs of the mixed intervention option are not shown because they are accounted for in the other options included in the table.

Table 31. Monetised values of benefits from implementing flood adaptation options in the Ba River and Penang River catchments

Period	Cost	Riparian Planting (FJ$/ha)	Afforestation (FJ$/ha)	Floodplain Planting (FJ$/ha)	Reinforce riverbanks (FJ$/m)	Raise House (FJ$/house)	Dredge River (FJ$/m3)*
			Ba River Catchment				
Year 1	Capital	1,050	1,050	500	0	5,000	6
	Labour	0	0	0	1,067	0	2
	Monitoring	0	0	0	0	0	0
	Opportunity	145	0	853	0	0	0
	Total	**1,195**	**1,050**	**1,353**	**1,067**	**5,000**	**8**
Years 2-100	Capital	0	0	0	0	0	6
	Labour	0	0	0	0	0	2
	Monitor	225	225	225	0	0	0
	Opportunity	145	0	853	0	0	0
	Total	**370**	**225**	**1,078**	**0**	**0**	**8**
			Penang River Catchment				
Year 1	Capital	1,050	1,050	500	0	5,000	6
	Labour	0	0	0	1,067	0	2
	Monitor	0	0	0	0	0	0
	Opportunity	212	0	497	0	0	0
	Total	**1,262**	**1,050**	**997**	**1,067**	**5,000**	**8**
Years 2-100	Capital	0	0	0	0	0	6
	Labour	0	0	0	0	0	2
	Monitor	225	225	225	0	0	0
	Opportunity	212	0	497	0	0	0
	Total	**437**	**225**	**723**	**0**	**0**	**8**

*Assumed to be repeated every 10 years

4.3.4 Ba River catchment CBA

4.3.4.1 Initial assumptions

Results for the Ba River catchment under the initial assumptions of base effectiveness, a discount rate of 8%, and a 100-year time horizon for the three climate scenarios are listed in Table 32. Estimates indicate that under the current climate regime, upland afforestation and riparian buffers yield positive NPV of FJ$19.5 million and FJ$12.6 million, respectively. Under moderate climate change, the increase in avoided damages from the various adaptation options renders floodplain vegetation, river dredging, and a mix of interventions economically feasible. Under the severe climate change scenarios, all options except for reinforce riverbanks and raising houses yield positive NPV. Upland afforestation yields the highest total NPV for all three climate scenarios, ranging from FJ$19.5 to FJ$101.8 million; however, afforesting talasiga also entails costs of FJ$2,612/ha (NPV) after accounting for labour and materials during planting as well as annual monitoring and maintenance, making afforestation a relatively expensive mitigation strategy.

The NPV costs of the options are constant across the three climate scenarios as the labour, capital, materials, and opportunity costs are insensitive to climate change. Hence, the BCR for all options increases as the severity of climate change increases. In each case, the BCR is found to be highest for riparian buffers due to its low cost of implementation.

Table 32. Cost-benefit analysis of adaptation to flood risk in Ba River catchment, base effectiveness (t=100 years, r=8%)

Option	NPV Benefits *(FJ$ million)*	NPV Costs *(FJ$ million)*	Total NPV *(FJ$ million)*	BC Ratio
Current Climate				
Riparian buffers	19.6	7.0	12.6	2.8
Upland afforestation	146.8	127.4	19.5	1.2
Floodplain vegetation	17.6	22.4	(4.8)	0.8
Reinforce riverbanks	30.8	113.9	(83.2)	0.3
Raise houses	0.4	13.9	(13.5)	0.0
River dredging	30.8	53.0	(22.3)	0.6
Mixed Intervention	77.6	80.9	(3.3)	1.0
Moderate Climate Change				
Riparian buffers	33.7	7.0	26.8	4.9
Upland afforestation	175.1	127.4	47.8	1.4
Floodplain vegetation	28.9	22.4	6.6	1.3
Reinforce riverbanks	59.1	113.9	(54.9)	0.5
Raise houses	0.8	13.9	(13.1)	0.1
River dredging	59.1	53.0	6.0	1.1
Mixed Intervention	120.0	80.9	39.1	1.5
Severe Climate Change				
Riparian buffers	60.8	7.0	53.8	8.7
Upland afforestation	229.2	127.4	101.8	1.8
Floodplain vegetation	50.6	22.4	28.2	2.3
Reinforce riverbanks	113.2	113.9	(0.8)	1.0
Raise houses	1.6	13.9	(12.3)	0.1
River dredging	113.2	53.0	60.1	2.1
Mixed Intervention	169.7	80.9	88.8	2.1

4.3.4.2 Varying effectiveness

Results are sensitive to the effectiveness of adaptation. Assuming that each option has low effectiveness (Table 33), the total NPV of each option falls relative to the initial estimates. Nevertheless, the results are nearly identical as those presented above except that riparian buffers yield the highest total NPV for the current climate scenario and that floodplain vegetation has a negative total NPV under moderate climate change scenario (and is thus not economically viable).

Table 33. Cost-benefit analysis of adaptation to flood risk in Ba River catchment, low effectiveness (t=100 years, r=8%)

Option	NPV Benefits *(FJ$ million)*	NPV Costs *(FJ$ million)*	Total NPV *(FJ$ million)*	BC Ratio
Current Climate				
Riparian buffers	10.4	7.0	3.4	1.5
Upland afforestation	128.4	127.4	1.0	1.0
Floodplain vegetation	11.5	22.4	(10.9)	0.5
Reinforce riverbanks	18.5	113.9	(95.5)	0.2
Raise houses	0.4	13.9	(13.5)	0.0
River dredging	18.5	53.0	(34.6)	0.3
Mixed Intervention	62.2	80.9	(18.7)	0.8
Moderate Climate Change				
Riparian buffers	16.0	7.0	9.1	2.3
Upland afforestation	139.7	127.4	12.3	1.1
Floodplain vegetation	17.1	22.4	(5.3)	0.8
Reinforce riverbanks	35.4	113.9	(78.5)	0.3
Raise houses	0.8	13.9	(13.1)	0.1
River dredging	35.4	53.0	(17.6)	0.7
Mixed Intervention	90.5	80.9	9.5	1.1
Severe Climate Change				
Riparian buffers	26.8	7.0	19.9	3.9
Upland afforestation	161.3	127.4	33.9	1.3
Floodplain vegetation	27.9	22.4	5.6	1.2
Reinforce riverbanks	67.9	113.9	(46.0)	0.6
Raise houses	1.6	13.9	(12.3)	0.1
River dredging	67.9	53.0	14.9	1.3
Mixed Intervention	113.2	80.9	32.2	1.4

Assuming that each option has high effectiveness (Table 34), the total NPV of each option rises relative to the initial estimates. The rank ordering of options is preserved, i.e., upland afforestation consistently yields the highest total NPV with estimates between FJ$31.8 million and FJ$147.1 million, while the riparian buffers option consistently offers the highest BCR (4.1 to 13.6). With high effectiveness, reinforcing riverbanks again becomes economically feasible under the severe climate change scenario, yielding a total NPV of FJ$67.1 million.

Table 34. Cost-benefit analysis of adaptation to flood risk in Ba River catchment, high effectiveness (t=100 years, r=8%)

Option	NPV Benefits *(FJ$ million)*	NPV Costs *(FJ$ million)*	Total NPV *(FJ$ million)*	BC Ratio
Current Climate				
Riparian buffers	28.8	7.0	21.9	4.1
Upland afforestation	159.1	127.4	31.8	1.2
Floodplain vegetation	20.7	22.4	(1.7)	0.9
Reinforce riverbanks	49.3	113.9	(64.7)	0.4
Raise houses	0.4	13.9	(13.5)	0.0
River dredging	49.3	53.0	(3.8)	0.9
Mixed Intervention	93.0	80.9	12.0	1.1

Option	NPV Benefits *(FJ$ million)*	NPV Costs *(FJ$ million)*	Total NPV *(FJ$ million)*	BC Ratio
Moderate Climate Change				
Riparian buffers	51.5	7.0	44.5	7.4
Upland afforestation	198.8	127.4	71.4	1.6
Floodplain vegetation	34.9	22.4	12.5	1.6
Reinforce riverbanks	94.5	113.9	(19.4)	0.8
Raise houses	0.8	13.9	(13.1)	0.1
River dredging	94.5	53.0	41.5	1.8
Mixed Intervention	149.6	80.9	68.6	1.8
Severe Climate Change				
Riparian buffers	94.7	7.0	87.8	13.6
Upland afforestation	274.5	127.4	147.1	2.2
Floodplain vegetation	61.9	22.4	39.5	2.8
Reinforce riverbanks	181.1	113.9	67.1	1.6
Raise houses	1.6	13.9	(12.3)	0.1
River dredging	181.1	53.0	128.0	3.4
Mixed Intervention	226.3	80.9	145.4	2.8

More details on the NPV of costs and benefits for both the low and high effectiveness estimates are listed in Appendix 5.

4.3.4.3 Varying discount rates

As noted in Section 2.2.9, the median discount rate used for long-term environmental management projects in the Pacific is 8% (Lal and Holland, 2010). However, to assess the sensitivity of results, the CBA is re-implemented with discount rates of 4% and 12%. We find that estimates are sensitive to discount rates (Table 35). For example, riparian buffers are estimated to have the highest NPV and BCR for the current climate for both the 4% and 12% discount rates, although upland afforestation remains economically feasible. For moderate climate change, the mixed intervention approach has the highest NPV (FJ$984 million) with a 4% discount rate while upland afforestation has the highest NPV with a discount rate of 12%. Under sever climate change, upland afforestation yields the highest NPV regardless of the discount rate.

Some options become economically (in)feasible under the different discount rate assumptions as well. For example, the mixed intervention option yields a total NPV of FJ$15.1 with a 4% discount rate under current climate but a negative NPV under the 8% and 12% discount rates. As with the case of the 8% discount rate, all options with exception of the raising houses and reinforcing riverbanks are economically feasible with severe climate change and high discount rates. However, with low discount rates, even reinforcing riverbanks yields a positive NPV. Details on the NPV of costs and benefits are listed in Appendix 5.

Table 35. **Discount rate sensitivity analysis for CBA of Flood Mitigation in Ba River catchment, base effectiveness (t=100 years, r=4% or 12%)**

Option	Total NPV *(FJ$ million)*		BC Ratio	
	r = 4%	r = 12%	r = 4%	r = 12%
Current Climate				
Riparian buffers	23.7	8.0	2.9	2.6
Upland afforestation	8.5	0.4	1.0	1.0
Floodplain vegetation	(11.5)	(3.5)	0.7	0.8
Reinforce riverbanks	(57.9)	(89.3)	0.5	0.2
Raise houses	(13.7)	(13.1)	0.1	-
River dredging	(29.5)	(20.0)	0.7	0.5
Mixed Intervention	15.1	(15.3)	1.1	0.8

Option	Total NPV *(FJ$ million)*		BC Ratio	
	r = 4%	r = 12%	r = 4%	r = 12%
Moderate Climate Change				
Riparian buffers	51.5	17.4	5.0	4.5
Upland afforestation	64.1	19.3	1.3	1.2
Floodplain vegetation	10.8	4.0	1.2	1.3
Reinforce riverbanks	(2.4)	(70.5)	1.0	0.4
Raise houses	(12.9)	(12.9)	0.1	-
River dredging	26.0	(1.1	1.3	1.0
Mixed Intervention	98.4	13.0	1.8	1.2
Severe Climate Change				
Riparian buffers	104.6	35.4	9.2	8.2
Upland afforestation	170.2	55.4	1.8	1.6
Floodplain vegetation	53.2	18.5	2.2	2.2
Reinforce riverbanks	103.8	(34.4)	1.9	0.7
Raise houses	(11.3)	(12.3)	0.2	0.1
River dredging	132.2	35.0	2.5	1.9
Mixed Intervention	210.8	47.4	2.7	1.7

4.3.4.4 Recommendations for the Ba River catchment

Riparian buffers are found to yield positive NPV and BCR above 1 for every scenario. Although planting along streams and riverbanks does not provide the highest level of protection from flooding given relatively low effectiveness rates, the low cost of implementation coupled with the ecosystem services such as carbon sequestration, non-timber forest products, and habitat provision that the native vegetation provides suggests that it is a viable option for the catchment.

Upland afforestation of the more than 35,000 ha of *talasiga* in the catchment is found to have positive NPV and BCR above 1 under most scenarios. The lone exceptions occur for low levels of effectiveness (20%) with discount rates of either 4% or 12% (See Appendix 5). Afforestation also has the highest total NPV in most cases because planting such a large amount of forest can not only reduce the damages from flooding but also produce large quantities of monetised ecosystem services such as NTFP and carbon sequestration. Afforestation can also provide benefits that were not monetised in this study such habitat provision and erosion control. However, the relatively high costs of planting and monitoring such a large area resulted in comparatively low BCR of between 1.0 and 2.0. Hence, this approach may be considered cost-prohibitive without strong organisational support and community acceptance.

Planting native vegetation in the floodplains is estimated to have positive NPV and BCR greater than 1 in several of the moderate and severe climate change scenarios. The opportunity costs to planting in areas previously used for agriculture and the planting and monitoring costs themselves are modest given the small share of the floodplain that would be planted with native vegetation. Nevertheless, planting floodplains in native vegetation is only expected to reduce flooding damages in the entire catchment by between 10-25%; hence, this approach is better suited as part of a mixed intervention.

Reinforcing riverbanks does not produce net economic benefits for most of the scenarios evaluated for this report because the high cost of materials and labour cannot be offset by the avoided damages. However, this option is found to yield positive NPV under some scenarios, including under severe climate change and high effectiveness, in which average annual damages from flooding could be reduced by as much as 80% relative to the 'do nothing' case. In addition, there are likely specific communities that could benefit from reinforced riverbanks even under a less severe climate change scenario, as we evaluated in the mixed intervention approach.

Raising houses is not estimated to be economically feasible under any scenario or assumption evaluated in the report because the majority of value of damages (e.g, damage to crops and businesses) still accrue. Hence, this option may be better suited as a part of the mixed intervention.

River dredging produces total net benefits in cases in which there is high effectiveness and/or low discount rates. River dredging is also found to be economically feasible under the moderate and current climate change scenarios. However, the cost of dredging is high relative to the benefits it produces in the lower portion of the catchment. Moreover, because dredging the river has no effect on the villages and settlements in the upper catchment, it is best considered in conjunction with other options such as riparian planting or afforestation to ensure that all communities benefit from the catchment-wide flood mitigation plan.

The mixed approach often produced high net benefits, but not necessarily the largest total NPV. The relatively high cost of implementation also resulted in negative NPV for many of the current climate scenarios. This option was found to be economically feasible for almost every moderate and severe climate scenario, typically resulting in a BCR of 1.5 to 2.5. Note that our estimates are based on relatively general assumptions about the areas of the catchment in which the mixed approach would be implemented, suggesting that we may underestimate the benefits of this approach; hence, with careful planning, the mixed intervention could be preferred over other options, particularly when considering the biophysical characteristics and flood risks faced by specific communities in the Ba river catchment.

4.3.5 Penang River catchment CBA Results

4.3.5.1 Initial assumptions

Results for the Penang River catchment under the initial assumptions of base effectiveness, a discount rate of 8%, and a 100-year time horizon for the three climate scenarios are listed in Table 36. Estimates indicate that under the current climate regime, several of the options yield positive NPV, with upland afforestation and mixed approach having the highest values of FJ$8.6 million and FJ$6.1 million, respectively. Under moderate climate change, the increase in avoided damages from the various adaptation options renders all but riverbank reinforcement and raising houses economically feasible, and the mixed interventions are found to have the largest NPV. Under the severe climate change scenarios, reinforce riverbanks also yields a positive NPV, and thus all but raising houses are deemed feasible. As with moderate climate change, the mixed intervention option is estimated to yield the highest total NPV ($FJ42.6 million), followed by upland afforestation ($FJ35.7 million) and river dredging ($FJ31.0 million)

The NPV costs of the options are constant across the three climate scenarios as the labour, capital, materials, and opportunity costs are insensitive to climate change. Hence, the BCR for all options increases as the severity of climate change increases. In each case, the BCR is found to be highest for riparian buffers due to its low cost of implementation.

iTaukei house in the Penang River catchment.

Table 36. Cost-benefit analysis of adaptation to flood risk in Penang River catchment, base effectiveness (t=100 years, r=8%)

Option	NPV Benefits *(FJ$ million)*	NPV Costs *(FJ$ million)*	Total NPV *(FJ$ million)*	BC Ratio
Current Climate				
Riparian buffers	5.8	0.9	5.0	6.8
Upland afforestation	25.2	16.6	8.6	1.5
Floodplain vegetation	5.7	4.0	1.6	1.4
Reinforce riverbanks	10.8	28.3	(17.5)	0.4
Raise houses	0.0	4.6	(4.6)	0.0
River dredging	10.8	6.9	3.9	1.6
Mixed Intervention	20.3	14.2	6.1	1.4
Moderate Climate Change				
Riparian buffers	10.6	0.9	9.7	12.3
Upland afforestation	34.7	16.6	18.1	2.1
Floodplain vegetation	9.5	4.0	5.4	2.3
Reinforce riverbanks	20.3	28.3	(8.0)	0.7
Raise houses	0.0	4.6	(4.6)	0.0
River dredging	20.3	6.9	13.4	2.9
Mixed Intervention	34.5	14.2	20.3	2.4
Severe Climate Change				
Riparian buffers	19.4	0.9	18.5	22.5
Upland afforestation	52.3	16.6	35.7	3.1
Floodplain vegetation	16.5	4.0	12.4	4.1
Reinforce riverbanks	37.8	28.3	9.5	1.3
Raise houses	0.0	4.6	(4.6)	0.0
River dredging	37.8	6.9	31.0	5.5
Mixed Intervention	56.8	14.2	42.6	4.0

4.3.5.2 Varying effectiveness

Results are sensitive to the effectiveness of adaptation. Assuming that each option has low effectiveness (Table 37), the total NPV of each option falls relative to the initial estimates. In this case, the results vary from the 'base' effectiveness scenarios. In the current climate scenario, only riparian buffers, upland afforestation, and the mixed intervention approach are found to be economically feasible, with afforestation again yielding the highest total NPV. For the moderate and severe climate change scenario, all but the riverbank reinforcement and raising houses options have a positive NPV, with the mixed intervention having the highest NPV, estimated at $FJ10.2 million and FJ23.7 million, respectively.

As with the initial assumptions, riparian planting was found to have the highest benefit-cost ratio. This is because the low cost of planting about 138 ha of native vegetation along stream-banks was more than offset by the benefits from avoided damages and ecosystem services, even if it only was only assumed to reduce the impact of flooding by 10%.

Table 37. Cost-benefit analysis of adaptation to flood risk in Penang River catchment, low effectiveness (t=100 years, r=8%)

Option	NPV Benefits *(FJ$ million)*	NPV Costs *(FJ$ million)*	Total NPV *(FJ$ million)*	BC Ratio
Current Climate				
Riparian buffers	2.6	0.9	1.7	3.0
Upland afforestation	18.7	16.6	2.1	1.1
Floodplain vegetation	3.5	4.0	(0.5)	0.9
Reinforce riverbanks	6.5	28.3	(21.8)	0.2
Raise houses	0.0	4.6	(4.6)	0.0
River dredging	6.5	6.9	(0.4)	0.9
Mixed Intervention	14.9	14.2	0.7	1.0
Moderate Climate Change				
Riparian buffers	4.5	0.9	3.6	5.2
Upland afforestation	22.5	16.6	5.9	1.4
Floodplain vegetation	5.4	4.0	1.4	1.3
Reinforce riverbanks	12.2	28.3	(16.1)	0.4
Raise houses	0.0	4.6	(4.6)	0.0
River dredging	12.2	6.9	5.3	1.8
Mixed Intervention	24.3	14.2	10.2	1.7
Severe Climate Change				
Riparian buffers	8.0	0.9	7.1	9.3
Upland afforestation	29.6	16.6	12.9	1.8
Floodplain vegetation	8.9	4.0	4.9	2.2
Reinforce riverbanks	22.7	28.3	(5.6)	0.8
Raise houses	0.0	4.6	(4.6)	0.0
River dredging	22.7	6.9	15.8	3.3
Mixed Intervention	37.8	14.2	23.7	2.7

Indo-Fijian house in a sugarcane-producing area.

Assuming that each option has high effectiveness (**Error! Not a valid bookmark self-reference.**), the total NPV of each option rises relative to the initial estimates. In this case, the feasibility of each option is the same as found with the 'base' effectiveness assumption. The rank ordering of options is also relatively preserved, i.e., mixed intervention, upland afforestation and river dredging consistently yield the highest total NPV, while the riparian buffers option consistently offers the highest BCR (10.5 to 35.6). Under the severe climate change scenario, the mixed approach is estimated to produce $FJ 61.5 in net benefits, or about $5.30 in benefits per $1 spent on the intervention.

Table 38. Cost-benefit analysis of adaptation to flood risk in Penang River catchment, high effectiveness (t=100 years, r=8%)

Option	NPV Benefits *(FJ$ million)*	NPV Costs *(FJ$ million)*	Total NPV *(FJ$ million)*	BC Ratio
Current Climate				
Riparian buffers	9.1	0.9	8.2	10.5
Upland afforestation	29.6	16.6	13.0	1.8
Floodplain vegetation	6.8	4.0	2.7	1.7
Reinforce riverbanks	17.3	28.3	(11.0)	0.6
Raise houses	0.0	4.6	(4.6)	0.0
River dredging	17.3	6.9	10.4	2.5
Mixed Intervention	25.7	14.2	11.5	1.8
Moderate Climate Change				
Riparian buffers	16.7	0.9	15.8	19.3
Upland afforestation	42.8	16.6	26.2	2.6
Floodplain vegetation	11.5	4.0	7.4	2.8
Reinforce riverbanks	32.4	28.3	4.1	1.1
Raise houses	0.0	4.6	(4.6)	0.0
River dredging	32.4	6.9	25.6	4.7
Mixed Intervention	44.6	14.2	30.4	3.1
Severe Climate Change				
Riparian buffers	30.7	0.9	29.8	35.6
Upland afforestation	67.4	16.6	50.8	4.1
Floodplain vegetation	20.3	4.0	16.2	5.0
Reinforce riverbanks	60.6	28.3	32.3	2.1
Raise houses	0.0	4.6	(4.6)	0.0
River dredging	60.6	6.9	53.7	8.8
Mixed Intervention	75.7	14.2	61.5	5.3

More details on the NPV of costs and benefits for both the low and high effectiveness estimates are listed in Appendix 5.

4.3.5.3 Varying discount rates

We find that estimates are sensitive to discount rates from 8% to 4% or 12% (Table 39), but not as sensitive as the results for the Ba River catchment. For example, upland afforestation is estimated to have the highest NPV for the current climate for both the 8% and 12% discount rates, but the mixed approach has the highest total NPV for the 4% case. This is because the future benefits of avoided damages from the more effective mixed approach are discounted less for the 4% scenario and hence have a greater impact on the net benefits over the lifetime of the project. For moderate and severe climate change, the mixed intervention approach continues to have the highest NPV with a 4% (FJ$45.6 to $FJ 91.5 million) and a 12% (FJ$10.9 to $FJ 25.9 million) discount rate. In both climate change and discount rate scenarios, upland afforestation was found to be the second best option, followed by river dredging.

As with the prior scenarios that assumed an 8% discount rate, riparian buffers are found to have the highest benefit-cost ratio, which ranges from 6.4 to 23.7. Additionally, the large riverbank reinforcement and raising houses options are still deemed to be economically infeasible under the different discount rate assumptions, although riverbank reinforcement is feasible with climate change and a discount rate of 4%. Details on the NPV of costs and benefits for all of these scenarios are listed in Appendix 5.

Table 39. Discount rate sensitivity analysis for CBA of Flood Mitigation in Penang River catchment, base effectiveness (t=100 years, r=4% or 12%)

Option	Total NPV *(FJ$ million)*		BC Ratio	
	r = 4%	r = 12%	r = 4%	r = 12%
Current Climate				
Riparian buffers	9.6	3.3	7.0	6.4
Upland afforestation	12.7	4.2	1.4	1.3
Floodplain vegetation	2.6	1.0	1.3	1.4
Reinforce riverbanks	(8.2)	(20.1)	0.7	0.3
Raise houses	(4.8)	(4.5)	0.0	0.0
River dredging	9.6	2.0	1.8	1.4
Mixed Intervention	17.7	1.4	1.9	1.1
Moderate Climate Change				
Riparian buffers	18.9	6.4	12.9	11.6
Upland afforestation	31.3	10.5	2.1	1.9
Floodplain vegetation	10.0	3.5	2.3	2.3
Reinforce riverbanks	10.4	(13.8)	1.4	0.5
Raise houses	(4.8)	(4.5)	0.0	0.0
River dredging	28.1	8.3	3.4	2.6
Mixed Intervention	45.6	10.9	3.3	1.9
Severe Climate Change				
Riparian buffers	36.2	12.3	23.7	21.3
Upland afforestation	65.8	22.3	3.2	2.8
Floodplain vegetation	23.8	8.2	4.0	4.0
Reinforce riverbanks	44.9	(2.1)	2.5	0.9
Raise houses	(4.7)	(4.4)	0.0	0.0
River dredging	62.6	20.0	6.4	4.8
Mixed Intervention	91.5	25.9	5.6	3.2

4.3.5.4 Recommendations for the Penang River catchment

Riparian buffers are found to yield positive NPV and BCR above 1 for every scenario. Although planting along streams and riverbanks does not provide the highest level of protection from flooding given relatively low effectiveness rates (i.e., 10-40%), the low cost of implementation coupled with the ecosystem services such as carbon sequestration, non-timber forest products, and habitat provision that the native vegetation provides suggests that it is a viable option for the catchment.

Upland afforestation of the more than 1,160 ha of *talasiga* in the catchment is found to have positive NPV and BCR above 1 under all scenarios, and routinely ranked in the top 3 interventions in terms of total net benefits. Afforestation has a large total NPV in most cases because planting such a large amount of forest can not only reduce the damages from flooding but also produce large quantities of monetised ecosystem services such as NTFP and carbon sequestration. Afforestation can also provide benefits that were not monetised in this study such habitat provision and erosion control. However, the relatively high costs of planting and monitoring such a large area resulted in comparatively low BCR that was typically between 1.0 and 1.5 for the current climate scenario and between 2.0 and 4.0 for the severe climate change scenario. Hence, this approach may be considered cost-prohibitive without strong organisational support and community acceptance.

Planting native vegetation in the floodplains is estimated to have positive NPV and BCR greater than 1 in several of the scenarios, particularly if there is medium to high effectiveness. The opportunity costs to planting in areas previously used for agriculture and the planting and monitoring costs themselves are modest given the small share of the floodplain that would be planted with native vegetation (i.e., 437 ha). Nevertheless, planting floodplains in native vegetation is only expected to reduce flooding damages in the entire catchment by between 10-25%; hence, this approach is better suited as part of a mixed intervention.

Reinforcing riverbanks does not produce net economic benefits for most of the scenarios evaluated for this report because the high cost of materials and labour cannot be offset by the avoided damages. However, this option is found to yield positive NPV under some scenarios, including under climate change and high effectiveness, in which average annual damages from flooding could be reduced by as much as 80% relative to the 'do nothing' case. In addition, there are likely specific communities that could definitely benefit from reinforced riverbanks even under a less severe climate change scenario, as we evaluated in the mixed intervention approach.

Raising houses is not estimated to be economically feasible under any scenario or assumption evaluated in the report because the majority of value of damages (e.g, damage to crops and businesses) still accrue. Hence, this option may be better suited as a part of a mixed intervention in the catchment or on select houses that have repeatedly been damaged from flooding.

River dredging produces total net benefits in all cases, with exception of low effectiveness under current climatic conditions. In most cases, it was found to be the second or third best option in the Penang River catchment, often yielding total net benefits of $FJ 10 million or more from avoided damages over the lifetime of the intervention. However, because dredging the river has no effect on the villages and settlements in the upper catchment, it is recommended that this option be considered in conjunction with other options such as riparian planting or afforestation to ensure that all communities benefit from the catchment-wide flood mitigation plan.

The mixed approach produced positive total net benefits and a BCR greater than 1 for nearly every modelled scenario. The one exception was when there was low effectiveness and a discount rate of 12% (see Appendix 5). Although it has a relatively high cost of implementation, total NPV was typically found to be $FJ 20 million or more, particularly when accounting for increased flooding from climate change. As a result, this option was found to yield the highest NPV of all options in about 75% of the modelled scenarios. Note that our estimates are based on relatively general assumptions about the areas of the catchment in which the mixed approach would be implemented, suggesting that we may underestimate the benefits of this approach; hence, with careful planning, the mixed intervention could be preferred over other options, particularly when considering the biophysical characteristics and flood risks faced by specific communities in the Ba river catchment.

APPENDICES

1 DISASTER RISK PROJECTIONS FOR FIJI

1.1 Observed Changes in Climate

Climate monitoring stations are sparse in the Pacific due to long distances between islands. Despite this challenge, observed increases in temperature are consistent. For example, many of the region's warmest recorded years have occurred in the past 20 years, and rates of temperature increase have generally been between 0.08°C and 0.2°C per decade in the last 50 years (Australian Bureau of Meteorology and CSIRO, 2011). Temperature has risen by 0.6°C in the South Pacific region in the last hundred years, which is slightly less than the global average due to moderating effect of the ocean. Sea-surface temperatures also increased since 1950, albeit at slightly slower rates than land surface temperatures (Australian Bureau of Meteorology and CSIRO, 2011).

Unlike temperature, observed precipitation changes in the Pacific are sparse. Global datasets suggest that rainfall has increased slightly to the north-east of the South Pacific Convergence Zone, and decreased to the south-west (in the vicinity of Fiji) (Australian Bureau of Meteorology and CSIRO, 2011). However these precipitation records show large annual and decadal variability. Moreover, Pacific Islanders have reported shifting rainfall patterns and the Pacific Climate Change Science Program has found that extreme rainfall has caused more frequent and severe flooding and landslides throughout the region (Australian Bureau of Meteorology and CSIRO, 2011).

1.2 Climate Change Projections for the Ba River catchment

At present, projections indicate that the observed increases in temperature, changes in precipitation, and increases in the variability of these parameters are likely to continue over the coming decades. In order to form projections for regional climate in this investigation, output data from eight GCMs for a 5° grid square centred on Ba Township at 17.35° south and 177.40° east were downloaded from the KNMI Climate Explorer website (http://climexp.knmi.nl/). These eight GCMs are well respected and up-to-date IPCC AR4 models, known to perform well in the South Pacific region and chosen to represent a broad spectrum of possible climate futures (Australian Bureau of meteorology and CSIRO, 2011). A 5° grid square was chosen to allow for varying GCM resolution. The data produced were analysed graphically to compare century-averaged model data centred on 1950 and 2050.

1.2.1 Temperature

Figure A1.1 shows increases in temperature throughout the annual cycle. These temperature increases are in the range of approximately 1-2°C and are slightly higher during the austral summer months of December, January, and February and lower during the austral winter months of June, July, and August. While there is considerable uncertainty between GCMs as to the degree of warming throughout the annual cycle, this uncertainty is smaller than the projected warming. The expectation of a warmer climate by 2050 can therefore be seen as robust to the uncertainty between GCMs.

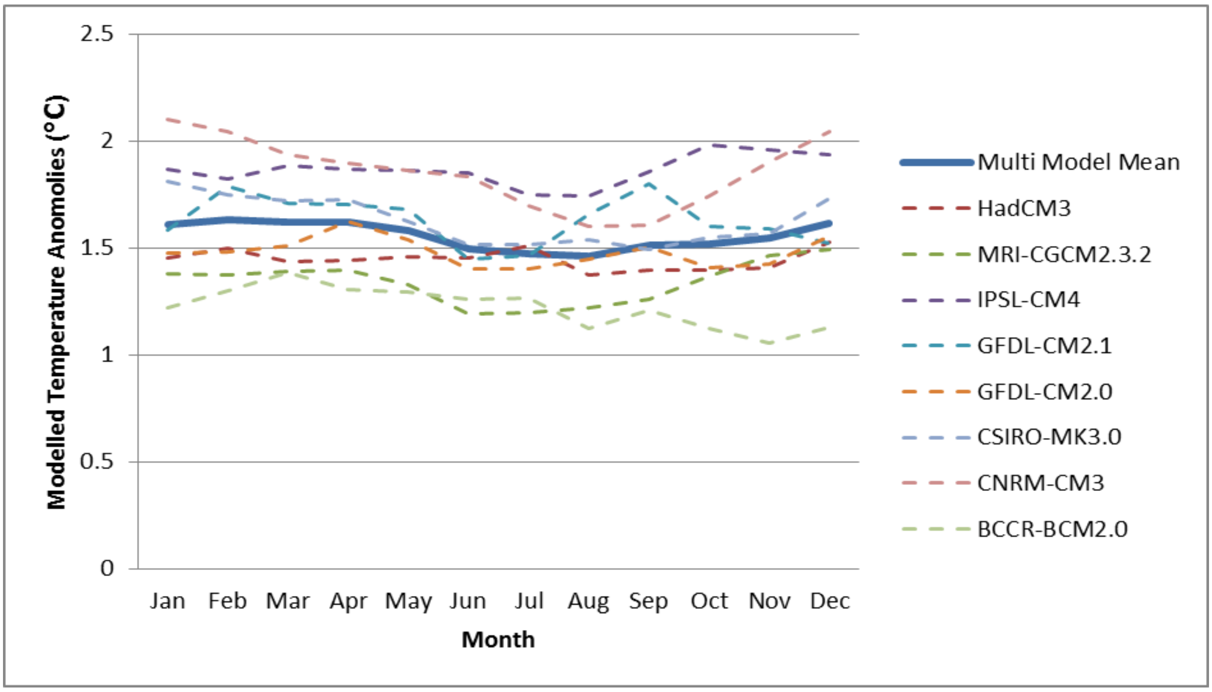


Figure A1.1: **Increase in modelled surface temperature between the century centred on 1950 and the century centred on 2050. Data were generated using the A1B emissions scenario for a 5° grid cell centred on Ba Township.**

Projections for temperature in Figure A1.1 are generally reflected in other model studies of the region. For example, the Pacific Climate Change Science Program indicates that warming in the region may be between 1°C and 1.5°C by 2055 and between 1.5°C and 3°C by 2090 (Australian Bureau of Meteorology and CSIRO, 2011). These increases are only about 70% as large as the projected globally averaged warming over the same period because ocean temperatures are expected to rise more slowly than terrestrial temperatures.

The regional profile of warming is shown in Figure A1.2 (Australian Bureau of Meteorology and CSIRO, 2011). Modelled warming in the South Pacific is generally consistent with other oceanic parts of the globe while a band of increased warming exists in the central equatorial Pacific (Solomon *et al.*, 2007).

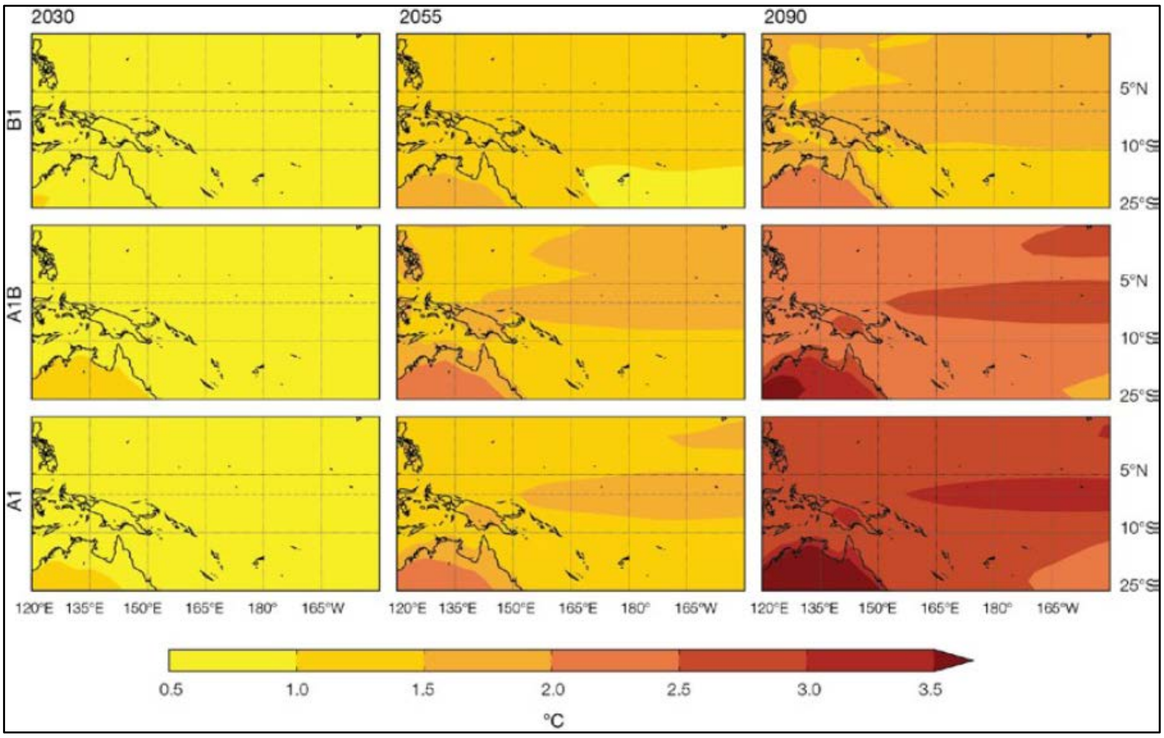


Figure A1.2: **Spatial distribution of multi-model projected surface air temperature change for 2030, 2055, and 2090, relative to 1990 for the A2, A1B, and B1emissions scenarios.**

Source: Australian Bureau of Meteorology and CSIRO (2011).

Figure A1.3 shows dynamically downscaled projections for warming over the Fiji Islands (Australian Bureau of Meteorology and CSIRO, 2011). Warming is greatest over the cyclone season between November and April and is generally consistent over the area. Warming is less pronounced during the Austral winter from May to October; however, greater warming rates are observed in the vicinity of the main land masses of Viti Levu and Vanua Levu, a result that may occur because the incidence of sunny days in Fiji is greater during the Austral winter, allowing for greater disparity between land and ocean temperatures.

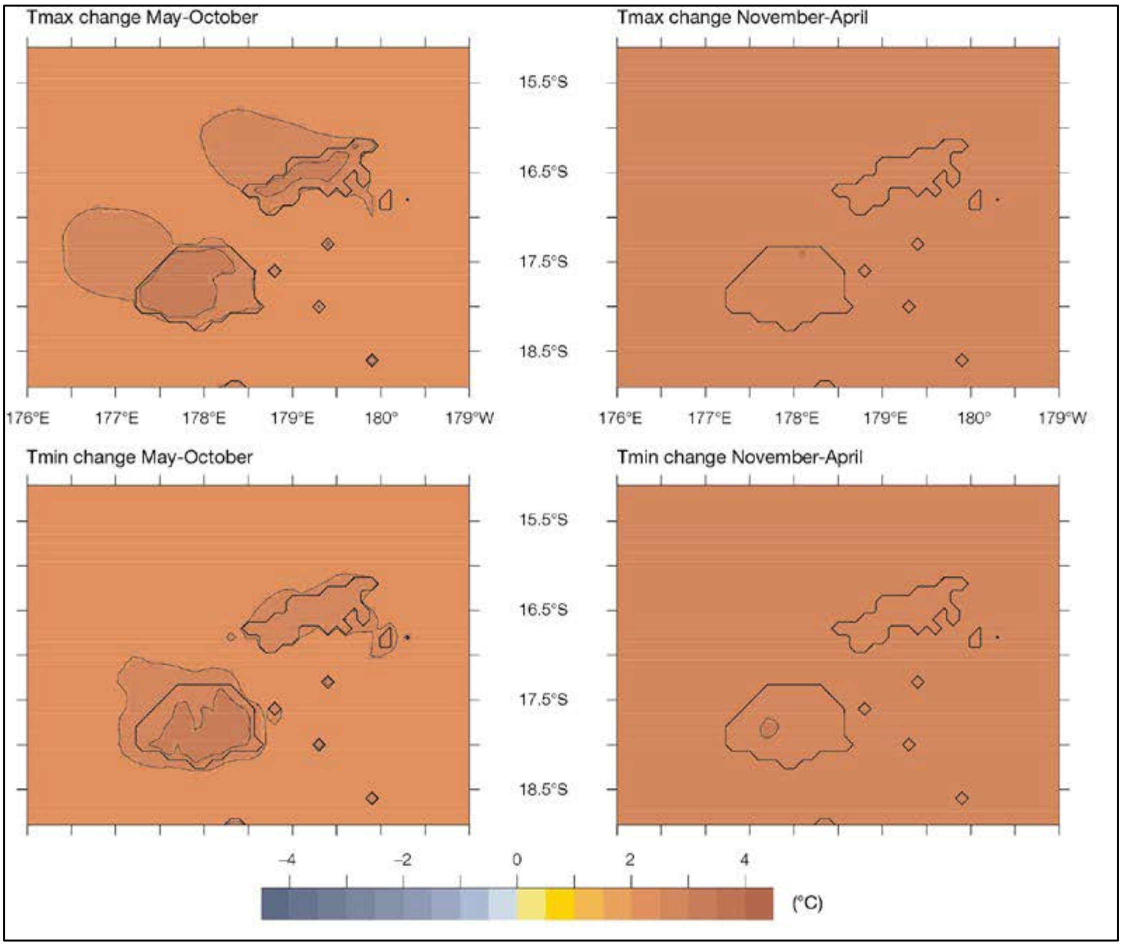


Figure A1.3: **Spatial distribution of projected changes in maximum and minimum surface air temperatures over Fiji using the Conformal Cubic Atmospheric Model (CCAM) 8km multi-model mean simulations for 2090 relative to 1990.**

Source: Australian Bureau of Meteorology and CSIRO (2011)

In many parts of the world, increases in mean temperature are expected to coincide with a broadening of the range of extremely high maximum and minimum temperatures (Solomon *et al*., 2007a). According to Australian Bureau of Meteorology and CSIRO (2011), however, variability of temperature in the Pacific may remain constant around a gradually increasing mean.

1.2.2 Precipitation

Precipitation projections are far less certain than projections for temperature. Figure A1.4 shows modelled precipitation anomalies between 1950 and 2050 for the same 5° grid square centred on Ba Township. Again, this figure was produced by an analysis of data from the KNMI Climate Explorer website. Overall changes in modelled precipitation are difficult to discern from this output and the multi-model mean shows only weak and seasonally dependent changes in precipitation.

This multi-model mean suggests slight to moderate increases in precipitation during the cyclone season (December, January, February, and March) followed by slight decreases for much of the rest of the year. At no time during the year is there consistency between GCMs as to the direction of change. The changes in the multi-model mean are, therefore, smaller than the uncertainty between GCMs. These outputs show that very little is known about how precipitation may change in the Fijian region, other than indicating that substantial changes of some nature are possible.

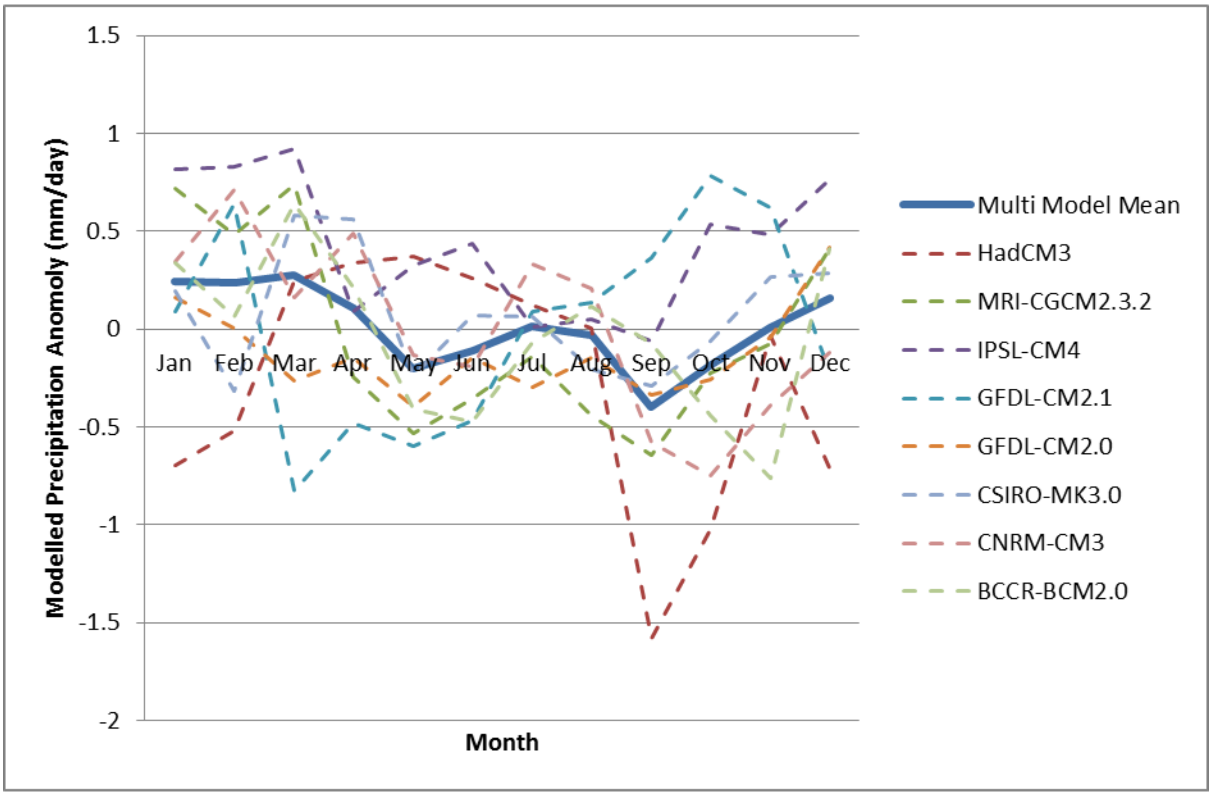


Figure A1.4: **Increase in modelled surface precipitation between the century centred on 1950 and the century centred on 2050. Data were generated using the A1B emissions scenario for a 5° grid cell centred on Ba Township.**

Uncertainty surrounding changes in precipitation is reflected in complex modelling; however some general projections can be made. Figure A1.5 shows the spatial distribution of changes in precipitation in the region (Australian Bureau of Meteorology and CSIRO, 2011). The climate models generally suggest that precipitation will increase in the equatorial Pacific while changes in precipitation in the South Pacific are smaller in magnitude and much less certain (Australian Bureau of Meteorology and CSIRO, 2011). Projected increases in precipitation around the equator and to the north-east of Fiji are associated with increased moisture convergence in the vicinity of the Inter-tropical Convergence Zone and the South Pacific Convergence Zone.

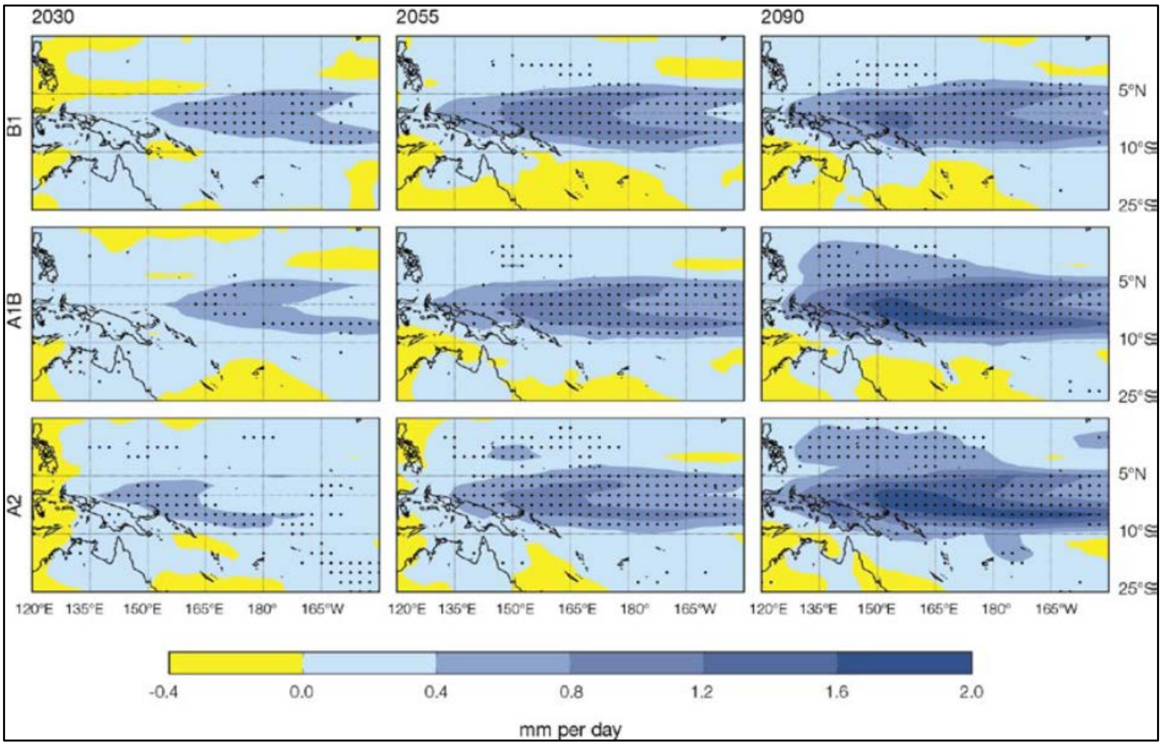


Figure A1.5: **Spatial distribution of multi-model projected rainfall change for 2030, 2055, and 2090, relative to 1990 for the A2, A1B, and B1emissions scenarios. The stippled areas indicate where more than 80% of GCMs agree on the direction of change.**

Source: Australian Bureau of Meteorology and CSIRO (2011).

The spatial pattern of precipitation change varies markedly over the seasonal cycle. As shown in Figure A1.6, precipitation may decrease slightly over Fiji during the Austral winter, although fewer than 80% of models agree on this. Projections are more consistent during the cyclonic Austral summer and suggest increases in rainfall of between 0.4 and 1.2 millimetres per day by 2090 relative to 1990. Increases in precipitation during the Austral summer appear to be closely related to intensification of the South Pacific Convergence Zone, which branches in a south-easterly direction from the equator toward the Solomon Islands. Rainfall in the South Pacific Convergence Zone is expected to increase, while its position is expected to remain similar during the cyclone season and shift to the north east during the Austral winter (Australian Bureau of Meteorology and CSIRO, 2011). This projection is consistent with the observations of Griffiths *et al.* (2003), which show areas to the south west of the South Pacific Convergence Zone become drier while those to the north east experienced more rainfall over the period from 1961 to 2000.

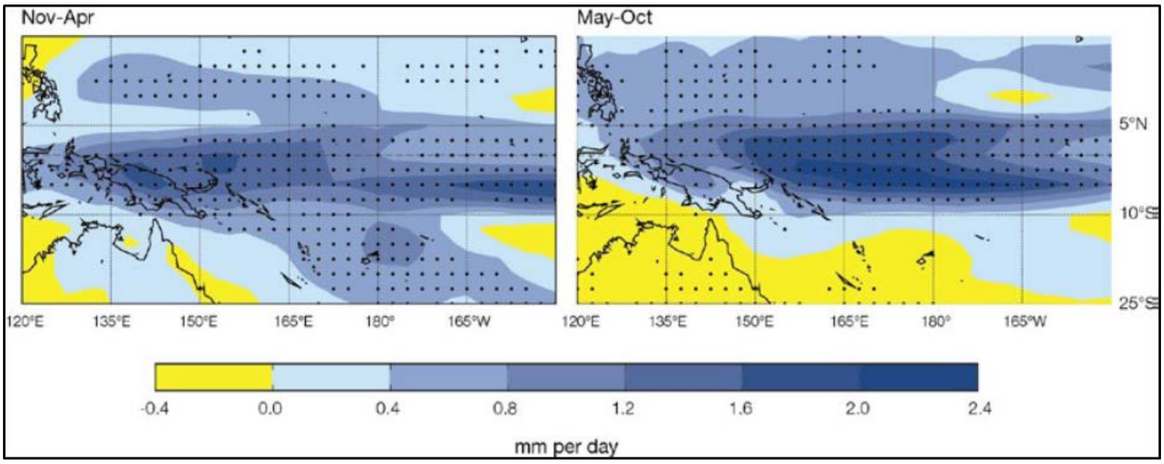


Figure A1.6: **Spatial and seasonal distribution of multi-model projected rainfall change for 2090 relative to 1990 for the A2 emissions scenario. The stippled areas indicate where more than 80% of GCMs agree on the direction of change.**

Source: Australian Bureau of Meteorology and CSIRO (2011).

Figure A1.7 shows dynamically downscaled projections for changes in precipitation over Fiji. These suggest that changes in rainfall are greater over the main landmasses of Viti Levu and Vanua Levu than in the surrounding oceanic area. This outcome may result from meso-scale hydrological events caused by the thermal and topographical discontinuity between these landmasses and the surrounding sea surface (Australian Bureau of Meteorology and CSIRO, 2011). These projections suggest that considerable increases in rainfall may occur on the north-western side of Viti Levu during the cyclone season, which may reflect a change in the dominant airflow pattern interacting with the island's topography. These projections, however, remain highly speculative as they are based on only a small number of GCMs and downscaled using only a single regional climate model (Australian Bureau of Meteorology and CSIRO, 2011).

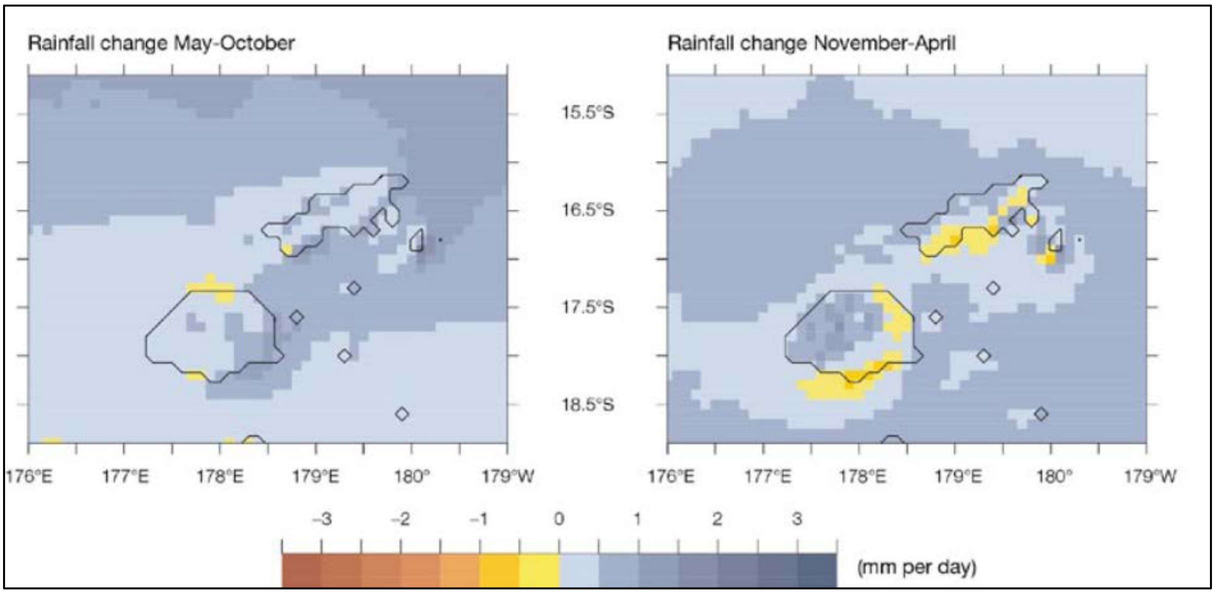


Figure A1.7: **Spatial and seasonal distribution of multi-model projected rainfall change for 2090 relative to 1990 for the A2 emissions scenario. Results are downscaled to 8km resolution using the CCAM regional climate model.**

Source: Australian Bureau of Meteorology and CSIRO (2011).

Changes in seasonal or annual precipitation often differ from changes in precipitation extremes. Climate change shifts not only average precipitation totals, but also alters statistical distributions such that extremes of high, low, heavy, and light precipitation become more common in both absolute and relative terms (Boé *et al.*, 2009). According to Solomon *et al*. (2007) and IPCC (2012), it is likely that the ratio of heavy rainfall to total rainfall will increase over the 21st century in many parts of the world, particularly in regions affected by tropical cyclones. The IPCC (2012) suggest that in many parts of the world, annual maximum daily precipitation amounts that have a probability of 1-in-20 years today are likely to have a probability of between 1-in-5 and 1-in-15 years by 2100. Precipitation intensity may increase even where average precipitation is expected to decrease concurrent with longer periods between rainfall events.

Projections for changes in extreme rainfall in the Pacific region generally reflect global projections. According to Rao *et al.* (2012), while annual rainfall in the region may remain reasonably constant, it is likely to be more concentrated in the cyclone season, and extreme rainfall events are likely to increase in magnitude. The maximum five-day rainfall total is expected to increase in the Pacific as a greater proportion of rainfall is projected to occur as intense heavy rainfall (Australian Bureau of Meteorology and CSIRO, 2011). 1-in-20 year rainfall events are expected to have a 1-in-5 year probability by 2055 and a 1-in-3 year probability by 2090 under the A2 emissions scenario (Australian Bureau of Meteorology and CSIRO, 2011).

Downscaled projections for Fiji suggest that the number of rainy days is unlikely to change dramatically, although increases in extreme heavy rainfall can be expected (Australian Bureau of Meteorology and CSIRO, 2011). Increases are expected to be most prominent in the northern regions of the country while slight decreases are possible to the south (Australian Bureau of Meteorology and CSIRO, 2011). These projections are likely to be conservative, as GCMs have been found to underestimate both the number of days with extreme heavy rainfall and the intensity of heavy rainfall events in the Pacific Region (Australian Bureau of Meteorology and CSIRO, 2011).

1.2.3 Tropical cyclones

It is difficult to discern changes in tropical cyclone frequency or intensity in the Pacific over the observational record. No significant trends are observable in the South Pacific over the satellite record spanning 1981 to 2007 (Australian Bureau of Meteorology and CSIRO, 2011). Longer proxy records suggest that cyclones declined in frequency over north-eastern Australia since 1872 (Callaghan and Power, 2010). However, the observed decline is complicated by considerable inter-decadal variability (Callaghan and Power, 2010).

Global models generally suggest that the overall number of tropical cyclones may decrease while the proportion of the most intense tropical cyclones may increase (Solomon *et al*., 2007). Regional projections for the Pacific generally reflect global projections, with fewer, more severe cyclones expected (Solomon *et al*., 2007; Australian Bureau of Meteorology and CSIRO, 2011; Rao *et al.*, 2012). For example, Australian Bureau of Meteorology and CSIRO (2011) suggest that decreases in cyclone frequency could be between 45 and 80% by the late 21st century in the eastern South Pacific. These decreases may be linked to changes in the thermodynamic makeup of the atmosphere and increased vertical wind shear in the region caused by atmospheric and sea surface warming. Most model simulations also project a southward displacement of the region of maximum cyclone intensity (Australian Bureau of Meteorology and CSIRO, 2011).

Projected changes in the frequency and intensities of tropical cyclones must, however, be interpreted with caution. Conditions like sea surface temperature that contribute to tropical cyclone generation are poorly simulated by current climate models and the spatial scale of individual cyclones is too small for general circulation models or regional climate models to resolve (Solomon *et al*., 2007; Australian Bureau of Meteorology and CSIRO, 2011). Specialised models resolved to a grid spacing of less than 5km are required to capture the dynamics of tropical cyclones (Australian Bureau of Meteorology and CSIRO, 2011). Furthermore, general circulation models are often unable to represent patterns or variability in large scale climate circulations like ENSO accurately (Solomon *et al*., 2007; Australian Bureau of Meteorology and CSIRO, 2011).

1.2.4 Floods

Forming projections for changes in flood frequency and severity is problematic because observational records of floods are often short, sparse, and confounded by influences such as channel constriction and land use change (IPCC, 2012). Catchments are highly idiosyncratic geographic features, therefore the relationship between climate and flood risk often needs to be assessed on a case by case basis (IPCC, 2012). Based on physical reasoning, there is medium confidence that in areas like Fiji, where heavy rainfall is expected to increase, that flooding may increase in some catchments (Rao *et al.*, 2012; IPCC, 2012). In the absence of detailed data and hydrological modelling in the region, however, the specifics and magnitude of these changes remain uncertain.

1.3 Climate model performance and uncertainty

The modelling of climate dynamics in the Pacific region is complicated by the lack of historical data and monitoring sites as well as the small-scale climatic discontinuities caused by small islands (Solomon et al., 2007; Australian Bureau of meteorology and CSIRO, 2011). Despite these difficulties, CMIP3 models show reasonable ability when simulating mean climate over the south Pacific, returning Probability Density Function (PDF) overlap skill scores of 0.8 and 0.6-0.8 for temperature and precipitation respectively. These models are, however, less able to simulate extremes of temperature and precipitation and uncertainty increases when shorter time periods are analysed (Solomon et al., 2007). The uncertainty surrounding the simulation of extreme events makes forming projections for disaster risk problematic. While the specifics of how disaster risk may change remain uncertain, increases in mean precipitation during the cyclone season coupled with expected increases in variability give reason to expect that flooding will increase in the future.

2 COMMUNITY SURVEY

Village name: ______________________________

Name of survey leader: ______________________________

Mobile phone number of survey leader: ______________________________

Other researchers in attendance: ______________________________

Date: ______________________________

Time started: __________ AM / PM Time ended: __________ AM / PM

Name of village headman or most senior person in attendance: ______________________________

Name of contact person in village: ______________________________

Mobile phone number of contact person in village: ______________________________

Number of people in attendance by gender and approximate age

	Men	Women
Age 0-14		
Age 15-25		
Age 25-40		
Age 40-60		
Age 60+		

GENERAL INFORMATION

How many households are in this community?:	________________________	*(households)*

How many households are in this community?:	________________________	*(persons)*

How many households are in this community?:	________________________	*(persons)*

Think back to 1 January 2012, a little more than a year ago. We would like to ask you about things that were in your village at that time.

FILL OUT **ALL** COLUMNS UNDER QUESTION 3 IN ATTACHED ASSET TABLE

Does your village have any trust funds or savings?	◯ Yes	◯ No

If yes, what is the approximate value of this fund/savings?	________________________

	Purpose of fund	% of total	Purpose of fund	% of total
What is this fund/savings typically used for?	☐ Education		☐ Infrastructure (e.g. pipes, wells)	
	☐ Weddings		☐ Land management	
	☐ Funeral		☐ Other 1 (__________________)	
	☐ Purchase new assets		☐ Other 2 (__________________)	
	☐ Maintenance of assets			

Notes:

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JANUARY 2012 FLOOD

Was this village affected by the January 2012 flood?	◯ Yes	◯ No

IF **YES**, THEN FILL OUT **ALL** COLUMNS UNDER QUESTION 4 IN ATTACHED TABLE

How many households were flooded?: ______________________________

How high did the water rise?: ______________________________ *(metres)*

How many days did it take the water level to subside?: ____________________ *(days)*

How were the people in this community first alerted about the flood in January 2012?	☐ Radio	______________________________
	☐ Television	______________________________
	☐ Newspaper	______________________________
	☐ Internet	______________________________
	☐ Warning from DISMAC	______________________________
	☐ Warning from other government	______________________________
	☐ Visited by friends/neighbours	______________________________
	☐ Phoned by friends/neighbours	______________________________
	☐ Text from friends/neighbours	______________________________
	☐ Text from network provider	______________________________
	☐ Saw heavy rain coming	______________________________
	☐ Saw water rising	______________________________
	☐ Increased heat and humidity	______________________________
	☐ Water entered buildings	______________________________
	☐ Traditional indicators from nature	______________________________
	☐ Other (specify)	______________________________

How much notice did the community have before the flood arrived?: ____________ *(hours)*

How did the community respond to the flood in January 2012? *(check all that apply)*	☐ Move village assets	______________________________
	☐ Move household goods	______________________________
	☐ Move livestock	______________________________
	☐ Cut branches/trees at risk	______________________________
	☐ Harvest crops early	______________________________
	☐ Temporarily relocate within village	# households relocated __________
	☐ Evacuate to areas outside village	# households evacuated __________
	☐ Build temporary structures to protect house and village assets	______________________________
	☐ Buy provisions	______________________________
	☐ Other (specify)	______________________________

Notes:

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MARCH 2012 FLOOD

Was this village affected by the March 2012 flood? ◯ Yes ◯ No

IF **YES**, THEN FILL OUT **ALL** COLUMNS UNDER MARCH 2012 IN ATTACHED TABLE

How many households were flooded?: ______________________

How high did the water rise?: ______________________ *(metres)*

How many days did it take the water level to subside?: ______________ *(days)*

How were the people in this community first alerted about the flood in March 2012?	☐ Radio	______________________
	☐ Television	______________________
	☐ Newspaper	______________________
	☐ Internet	______________________
	☐ Warning from DISMAC	______________________
	☐ Warning from other government	______________________
	☐ Visited by friends/neighbours	______________________
	☐ Phoned by friends/neighbours	______________________
	☐ Text from friends/neighbours	______________________
	☐ Text from network provider	______________________
	☐ Saw heavy rain coming	______________________
	☐ Saw water rising	______________________
	☐ Increased heat and humidity	______________________
	☐ Water entered buildings	______________________
	☐ Traditional indicators from nature	______________________
	☐ Other (specify)	______________________

How much notice did the community have before the flood arrived?: __________ *(hours)*

How did the community respond to the flood in March 2012? *(check all that apply)*	☐ Move village assets	______________________
	☐ Move household goods	______________________
	☐ Move livestock	______________________
	☐ Cut branches/trees at risk	______________________
	☐ Harvest crops early	______________________
	☐ Temporarily relocate within village	# households relocated __________
	☐ Evacuate to areas outside village	# households evacuated __________
	☐ Build temporary structures to protect house and village assets	______________________
	☐ Buy provisions	______________________
	☐ Other (specify)	______________________

Notes:

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CYCLONE EVAN

Was this village affected by the Cyclone Evan in December 2012?	◯ Yes ◯ No

IF **YES**, THEN FILL OUT **ALL** COLUMNS UNDER CYCLONE EVAN IN ATTACHED TABLE

How many households were impacted by the cyclone?:	______________________	*(households)*
If there was flooding from the cyclone, how high did the water rise?:	______________________	*(metres)*
How many days did it take the water level to subside?:	______________________	*(days)*

How were people in the community first alerted about Cyclone Evan? *(check all that apply)*	☐ Radio	____________________________
	☐ Television	____________________________
	☐ Newspaper	____________________________
	☐ Internet	____________________________
	☐ Warning from DISMAC	____________________________
	☐ Warning from other government	____________________________
	☐ Visited by friends/neighbours	____________________________
	☐ Phoned by friends/neighbours	____________________________
	☐ Text from friends/neighbours	____________________________
	☐ Text from network provider	____________________________
	☐ Saw heavy rain coming	____________________________
	☐ Saw water rising	____________________________
	☐ Increased heat and humidity	____________________________
	☐ Water entered buildings	____________________________
	☐ Traditional indicators from nature	____________________________
	☐ Other (specify)	____________________________

How much notice did the community have before the cyclone arrived?:	__________	*(hours)*

How did the community respond to the Cyclone Evan in December 2012? *(check all that apply)*	☐ Move village assets	____________________________
	☐ Move household goods	____________________________
	☐ Move livestock	____________________________
	☐ Cut branches/trees at risk	____________________________
	☐ Harvest crops early	____________________________
	☐ Temporarily relocate within village	# households relocated __________
	☐ Evacuate to areas outside village	# households evacuated __________
	☐ Build temporary structures to protect house and village assets	____________________________
	☐ Buy provisions	____________________________
	☐ Other (specify)	____________________________

Notes:

____

____

OTHER NATURAL DISASTERS (DROUGHT, FIRE, ETC.)

Was this village affected by other disasters in 2012 such as drought or fire? ◯ Yes ◯ No

IF **YES**, THEN FILL OUT **ALL** COLUMNS UNDER OTHER DISASTERS IN ATTACHED TABLE

Type of disaster(s): ____

Date of disaster(s): ____

List key qualities and impacts of disaster(s):

____

____

____

DISASTER MANAGEMENT

What has this community done to reduce their risk of impacts from natural disasters? *(check all that apply)*	☐ Relocate buildings	________________
	☐ Reinforce buildings	________________
	☐ Raise buildings	________________
	☐ Change cropping practices/varieties	________________
	☐ Store crops/food supply	________________
	☐ Plant riparian buffers along waterways	________________
	☐ Plant mangroves	________________
	☐ Protect reef	________________
	☐ Plant trees	________________
	☐ Create fire break, fire bans	________________
	☐ Change forestry practice/harvest ages	________________
	☐ Improve village drainage system	________________
	☐ Construct diversion channel	________________
	☐ Construct sea wall	________________
	☐ Dredge river	________________
	☐ Save money for disaster response	________________
	☐ Develop evacuation plan/committee	________________
	☐ Designate evacuation centre	________________
	☐ Request government assistance	________________
	☐ Other (specify)	________________
	☐ Other (specify)	________________

What do you think is the main cause of flooding?

____

____

____

____

____

What do you think is the main cause of cyclones?	______
What do you think is the main cause of other natural disasters?	______
What can be done to help solve the problems created by natural disasters?	______

Notes:

Community Assets	1 January 2012				January Flood		March Flood		Cyclone Evan		Other 2012 Disasters	
	Exist on 1 January 2012 (y/n)	Physical Quantity	Year Built or Purchased	Estimated Value ($)	Damaged in January Flood (y/n)	Cost to Repair or Replace ($)	Damaged in March Flood (y/n)	Cost to Repair or Replace ($)	Damaged in Other 2012 Disaster (y/n)	Cost to Repair or Replace ($)	Damaged in Other 2012 Disaster (y/n)	Cost to Repair or Replace ($)
Buildings (#)												
School												
Church												
Village hall												
Village dispensary												
Village owned canteen/co-op												
Pastor’s house												
Lodge/Resort												
Other Building 1 (specify)												
Other Building 2 (specify)												
Roads and Pathways (meters)												
PWD roads												
Village roads												
FSC roads												
Farm roads (non-FSC)												
Concrete pathways												
Pedestrian bridge												
Other Road or Path 1 (specify)												

Community Assets	1 January 2012				January Flood		March Flood		Cyclone Evan		Other 2012 Disasters	
	Exist in December 2011 (y/n)	Physical Quantity	Year Built or Purchased	Estimated Value ($)	Damaged in January Flood (y/n)	Cost to Repair or Replace ($)	Damaged in March Flood (y/n)	Cost to Repair or Replace ($)	Damaged in Other 2012 Disaster (y/n)	Cost to Repair or Replace ($)	Damaged in Other 2012 Disaster (y/n)	Cost to Repair or Replace ($)
Vehicles (#)												
Village carrier												
Village cane truck												
Village tractor												
Other Vehicle 1 (specify)												
Other Vehicle 2 (specify)												
Water and Power Supply (#)												
Water supply – dam												
Water supply – tanks												
Water supply - pipes (houses)												
FEA power lines distance (metres)												
Community generator												
Other Utility 1 (specify)												
Other Utility 2 (specify)												
Communal Land												
Community forest plantation												
Community cropland												
Church planation												
Church cropland												
Village grounds or park												
Other Communal Land 1 (specify)												
Other Communal Land 2 (specify)												

Community Assets	1 January 2012				January Flood		March Flood		Cyclone Evan		Other 2012 Disasters	
	Exist in December 2011 (y/n)	Physical Quantity	Year Built or Purchased	Estimated Value ($)	Damaged in January Flood (y/n)	Cost to Repair or Replace ($)	Damaged in March Flood (y/n)	Cost to Repair or Replace ($)	Damaged in Other 2012 Disaster (y/n)	Cost to Repair or Replace ($)	Damaged in Other 2012 Disaster (y/n)	Cost to Repair or Replace ($)
Fishing and Coastal Protection												
Wharf/dock (#)												
Sea wall (metres and material)												
Community boats (#)												
Other Coast 1 (specify)												
Other Coast 2 (specify)												
Monuments and Cemeteries												
Monument/shrine (#)												
Cemetery/gravesite (# graves)												
Other Major Assets Valued Over $500												
Agricultural Tools (plough, chainsaw, etc.)												
Kitchenware (pots, pans, cutlery, etc.)												
Other 1 (specify)												
Other 2 (specify)												
Other 3 (specify)												
Other 4 (specify)												

3 MATAQALI SURVEY

Mataqali Form *To be asked of the head of selected mataqali.*

Village: ______________________________________

Mataqali: ______________________________________

Does your mataqali grow crops and/or timber to provide income and/or food for the mataqali (this is distinct from crops grown by individuals within the mataqali for their own consumption or for sale) ? ◯ Yes ◯ No

If **yes**, what crops and/or timber are grown by your mataqali? *Check all that apply, state the area planted, and specify the percentage of the 2012 annual yield that was lost to pests and natural disasters aside from Cylcone Evan in 2012.*

Crop	Acres	Disease %	Drought %	Jan floods %	March floods %	Pests %	Specify pest	Other losses %	Specify loss
☐ Yaqona									
☐ Tavioka									
☐ Dalo									
☐ Dalo ni tana									
☐ Vudi									
☐ Jaina									
☐ Sila									
☐ Weleti									
☐ Painapiu									
☐ Uvi									
☐ Kumala									
☐ Bele									
☐ Papukeni									
☐ Baigani									
☐ Rourou									
☐ Tabua/Moca									
☐ Kaveti Olo									
☐ Kaveti ni Jaini									
☐ Kerela									
☐ Okra									
☐ Tomata									
☐ Kiukaba									
☐ Duruka									
☐ Patete									
☐ Dovu									
☐ Zucchini									
☐ French bean									
☐ Long bean									
☐ Ginger									
☐ Meleni									
☐ Chili									
☐ Coriander									
☐ Curry leaves									
☐ Pine									
☐ Mahogany									
☐ Teak									
Other (_________)									
Other (_________)									
Other (_________)									
Other (_________)									

Check all crops that were growing at the time of Cyclone Evan. State the area *planted for harvest in 2013* when Cyclone Evan arrived in December 2012, and specify the percentage of the expected yield that was lost to Cylcone Evan as well as how many acres you *replanted* for harvest in 2013 after Cyclone Evan.

Crop	Acres planted for 2013 before Cyclone Evan	% lost to Cyclone Evan	Acres replanted for 2013
☐ Yaqona			
☐ Tavioka			
☐ Dalo			
☐ Dalo ni tana			
☐ Vudi			
☐ Jaina			
☐ Sila			
☐ Weleti			
☐ Painapiu			
☐ Uvi			
☐ Kumala			
☐ Bele			
☐ Papukeni			
☐ Baigani			
☐ Rourou			
☐ Tabua/Moca			
☐ Kaveti Olo			
☐ Kaveti ni Jaini			
☐ Kerela			
☐ Okra			
☐ Tomata			
☐ Kiukaba			
☐ Duruka			
☐ Patete			
☐ Dovu			
☐ Zucchini			
☐ French bean			
☐ Long bean			
☐ Ginger			
☐ Meleni			
☐ Chili			
☐ Coriander			
☐ Curry leaves			
☐ Pine			
☐ Mahogany			
☐ Teak			
Other (__________)			
Other (__________)			
Other (__________)			
Other (__________)			

Does your mataqali grow livestock to provide income and/or food for the mataqali (this is distinct from livestock grown by individuals within the mataqali for their own consumption or for sale)? ◯ Yes ◯ No

If **yes**, what livestock are grown by your mataqali? *Check all that apply, state the number of each that you owned in December 2011, and specify the percentage of these that was lost to pests and natural disasters in 2012.*

Livestock	No. owned	Disease %	Drought %	Jan floods %	March floods %	Cyclone Evan %	Pests %	Specify pest	Other losses %	Specify other loss
☐ Beef cattle										
☐ Dairy cattle										
☐ Horses										
☐ Pigs										
☐ Goats										
☐ Chickens										
☐ Ducks										
☐ Bees (hives)										
Other ( )										
Other ( )										
Other ( )										
Other ( )										

Does your mataqali have any assets worth more than $1,000 (this is distinct from assets owned by individuals within the mataqali for their own use and/or assets owned by the entire village)? ◯ Yes ◯ No

If **yes**, what assets are owned by your mataqali? *Check all that apply, state the number of each that you owned in December 2011, and specify the percentage of these that was lost to to natural disasters in 2012.*

Asset	No. owned	Value	January floods %	March floods %	Cyclone Evan %	Other losses %	Specify other loss
☐ Carrier							
☐ Truck							
☐ Tractor							
☐ Boat							
☐ Chainsaw							
☐ Plough							
☐ Roofing iron							
Other ( )							
Other ( )							
Other ( )							
Other ( )							
Other ( )							

Does your Mataqali lease out any of its land? ◯ Yes ◯ No

If **yes**, what is the purpose of the lease, the area planted, and the annual income generated by that lease?

Purpose of lease	Acres	Annual lease income received by the mataqal for this land in $
☐ Sugarcane		
☐ Other cropping		
☐ Livestock		
☐ Pine plantation		
☐ Hardwood plantation		
☐ Residential		
☐ Tourism		
☐ Commercial		
Other ( )		
Other ( )		

Does your mataqali have any trust funds or savings? ◯ Yes ◯ No

If **yes**, what is the approximate value of this fund/savings? ______________

What is this fund/savings typically used for?

Purpose of fund	% of total
☐ Education	
☐ Weddings	
☐ Funeral	
☐ Purchase new assets	
☐ Maintenance of assets	
☐ Infrastructure (e.g. pipes, wells)	
☐ Land management	
Other ( )	
Other ( )	

Notes:

____

____

____

____

____

4 HOUSEHOLD SURVEY

Hello. I am a student/staff member at the University of the South Pacific. Together with Landcare Research in New Zealand, we are conducting a study of village economics.

In total, we will interview 360 households from 30 different villages in Ba and Ra provinces.

Because this is an economics survey, we will ask some personal information about your income in addition to many questions about your crops, your livestock, your fishing activities, your children, how you spend your time, and several other topics. We will use these answers to conduct research, but our study will not show the names or other identifying characteristics of the people who answer our survey. We also promise not to share any personal data with *anyone*, including other people in the village.

The survey will take 1 to 1.5 hours to complete, and we will make a donation to the village fund for each survey that is finished.

Do you agree to participate in the survey?

I do not agree to participate in the survey.

I understand what I have been told and I agree to participate in the survey.

Enumerator: ______________________________

Village: ______________________________

HHxID: ______________________________

VERSION: ______________________________

PHONE: ______________ ETHNICITY: ______________

1. iTaukei 2. Indo-Fijian 3. Other (specify)

Form 1. Household Roster

NAMEx01	SEXx01	AGEx01	VILxYRSx01	RESIDENTx01	REASONxAWAYx01	MONTHSxAWAYx01	AWAYxLOCx01
Name of the man of this house (if no man, name of the woman)	MALE.......... 1 FEMALE....... 2	How many years old is [NAMEx01] now?	How many years has [NAMEx01] lived in this village?	Did [NAMEx01] spend 1 month or more away from the home during the past 12 months? YES ....1 NO...2 **>>NAMEx02**	Why was [NAMEx01] away during the past 12 months? STUDYING ....1 WORKING ....2 HOSPITAL OR PRISON ....3 OTHER (specify) 4	Of the last 12 months, how many months did [NAMEx01] sleep away from the house?	Where did [NAMEx01] spend most of his or her away from the household? THIS VILLAGE.............................. THIS DISTRICT, OTHER VILLAGE ... THIS PROVINCE, OTHER DISTRICT..................................... OTHER PROVINCE ON VITI LEVU.. ELSEWHERE IN FIJI...................... OTHER COUNTRY (specify) ....

	NAME	SEX	AGE	VILxYRS	RELATIONSHIP	RESIDENT	REASONxAWAY	MONTHSxAWAY	AWAYxLOC
	Name	MALE.........1 FEMALE......2	How many years old is [NAME] now?	How many years has [NAME] lived in this village?	What is [NAME]'s relationship to the household head? Spouse of household head ....1 Son/daughter of household head ....2 Son-in-law/daughter-in-law of household head ....3 Head's parent ....4 Spouse's parent ....5 Head's sibling ....6 Spouse's sibling ....7 Grandchild ....8 Head's grandparent ....9 Spouse's grandparent ....10 Other relative of the head .....11 Other relative of the spouse ..12 Non-relative 13	Did [NAME] spend 1 month or more away from the home during the past 12 months? YES .... 1 NO............................... 2 **>>NEXT PERSON**	Why was [NAME] away during the past 12 months? STUDYING ....1 WORKING ....2 HOSPITAL OR PRISON ...3 OTHER (specify) 4	Of the last 12 months, how many months did [NAME] sleep away from the house?	Where did [NAME] spend most of his or her away from the household? THIS VILLAGE..................... THIS DISTRICT, OTHER VILLAGE............................ THIS PROVINCE, OTHER DISTRICT .... OTHER PROVINCE ON VITI LEVU .... ELSEWHERE IN FIJI .... OTHER COUNTRY (specify) ....
02									
03									
04									
05									
06									
07									
08									
09									
10									

Notes01

Form 2. Education and Health

Ask if AGE>=5

EVERxSCHOOL	SCHOOLxYEARS	CURRENTxSCHOOL	ADL	ADL1	ADL2	ADL3
Did [NAME] ever attend school? YES .... 1 NO .... 2 **>>ADL**	How many classes of schooling did [NAME] complete??	Does [NAME] currently attend school? YES ....1 NO 2	Does [NAME]'s health limit him or her from performing daily activities in any way? YES .... 1 NO... 2 **>>NEXT PERSON**	How many days in the last month did [NAME]'s health limit him or her from performing vigorous activities such as running, lifting heavy objects, and doing difficult labour?	How many days in the last month did [NAME]'s health limit him or her from walking 100 metres?	How many days in the last month did [NAME]'s health limit him or her from performing light activities such as eating, dressing, and bathing?

Notes02

Form 3. Agriculture

CROPPING

Has any member of this household raised any crops in the past 12 months? __________

YES 1

NO.. 2 **>>NEXT FORM**

LANDxPERSONAL

How much land that is owned by your household is used to produce crops for your household's consumption or sales? __________

NONE 1

ENTER EXACT ACREAGE .... 2 specify (__________)

GARDEN PLOT 3

LESS THAN ¼ AC 4

¼-½ AC 5

½-1 AC... 6

1-3 AC.. 7

3-5 AC.. 8

5-8 AC.. 9

8-10 AC... 10

10-15 AC... 11

MORE THAN 15 AC............................. 12

LANDxLEASED

How much land that is leased by your household to produce crops for your household's consumption or sales? _________

NONE 1

ENTER EXACT ACREAGE .... 2 specify (__________)

GARDEN PLOT 3

LESS THAN ¼ AC 4

¼-½ AC 5

½-1 AC... 6

1-3 AC.. 7

3-5 AC.. 8

5-8 AC.. 9

8-10 AC... 10

10-15 AC... 11

MORE THAN 15 AC............................. 12

	CROP Which of the following crops were grown by your household in 2012? Select all that apply.	CROPxMAX5 Select the five crops that are most important for your household's consumption and sales.
01 Yaqona, Piper methysticum		
02 Tavioka, Manihot esculenta		
03 Dalo, Colocasia esculenta		
04 Dalo ni tana, Xanthosoma sagittifolium		
05 Vudi, Musa x paradisiaca L. subsp. Paradisiaca		
06 Jaina, Musa nana		
07 Sila, Zea mays		
08 Weleti, Carica papaya		
09 Painapiu, Ananas comosus		
10 Uvi, Dioscorea alata		
11 Kumala, Ipomea batatas		
12 Bele, Abelmoschus esculentus		
13 Papukeni (pumkin), Cucurbita maxima		
14 Baigani (eggplant), Solanum melongena		
15 Rourou, leaves of Colocasia esculenta		
16 Tubua/Moca, Amaranthus viridis		
17 Kaveti Olo (round cabbage), Brassica oleracea		
18 Kaveti balavu (chinese cabbage), Brassica oleracea variety		
19 Kerela (bitter gourd), *Momordica charantia*		
20 Okra, Abelmoschus esculentus		
21 Tomata (tomatoes), Solanum lycopersicum		
22 Cucumber, Cucumis sativa		
23 Duruka, Saccharum Edule		
24 Pateta (potato), Solanum tuberosum		
25 Sugarcane, Saccharum *barberi*		
26 Zuchinni		
27 French Bean, Phaseolus vulgaris		
28 Long bean, *Vigna unguiculata*		
29 Ginger, *Zingiber officinale*		
30 *Meleni (watermelon),* Citrullus lanatus		
31 Chilies		
32 Coriander		
33 Curry leaves		
34 Other (specify __________)		

	CROPxAREA What is the total size of the plot or plots used to grow [CROP] during the past 12 months? NONE .... 1 ENTER EXACT ACREAGE..... 2 GARDEN PLOT....................... 3 LESS THAN ¼ AC.................. 4 ¼-½ AC....... .... 5 ½-1 AC....... .... 6 1-3 AC......... .... 7 3-5 AC......... .... 8 5-8 AC...................................... 9 8-10 AC................................. 10 10-15 AC............................... 11 MORE THAN 15 AC............. 12	INDxUNITS UNIT OF MEASUREMENT	CROPxMAX If there were no disease, droughts, flood, pests, or other losses, how many [INDxUNITS] of [CROP] could you harvest during the 2012 harvest season?	CROPxDISEASE Of the total amount that you could have harvested during the 2012 harvest, what percentage was lost to disease? ENTER A NUMBER BETWEEN 0 and 100	CROPxDROUGHT Of the total amount that you could have harvested during the 2012 harvest, what percentage was lost to drought? ENTER A NUMBER BETWEEN 0 and 100.	CROPxFLOODxJAN Of the total amount that you could have harvested during the 2012 harvest, what percentage was lost to floods in January? ENTER A NUMBER BETWEEN 0 and 100	CROPxFLOODxMAR Of the total amount that you could have harvested during the 2012 harvest, what percentage was lost tofloods in March? ENTER A NUMBER BETWEEN 0 and 100	CROPxPESTS Of the total amount that you could have harvested during the 2012 harvest, what percentage was lost to pests? ENTER A NUMBER BETWEEN 0 and 100	CROPxPESTxMAIN What was the main pest that affected [CROP]? BOAR/PIGS......... 1 RATS/MICE......... 2 SNAILS............... 3 TARO BEETLE.... 4 ANTS/TERMITES 5 BIRDS..............6 OTHER (specify) . 7	CROPxLOSSxO Of the total amount that you could have harvested during the 2012 harvest, what percentage was lost to other causes? ENTER A NUMBER BETWEEN 0 and 100	CROPxLOSSxOxDESC Describe the cause of other losses.

	CROPxSOLD Of the [CROP] that your household harvested during the 2012 season, how many [INDxUNITS] were sold or given away?	CROPxPROCESSED Of the [CROP] that your household harvested during the 2012 season, how many [INDxUNITS] did your household process into chutney?	CROPxEVAN What percentage of the potential harvest of [CROP] for 2013 was lost to Cyclone Evan in December 2012? ENTER A NUMBER BETWEEN 0 and 100 **>>NEXT CROP**

ASK IF CROP=CHILIES

CHUT1xPRODUCED
How many jars of chili chutney did your household produce in 2012? __________ 0>>CROPxINPUT1

CHUT1xSOLD
How many jars of chili chutney did your household sell or give away in 2012? __________

ASK FOR ALL CROPS

	CROPxINPUT1	CROPxINPUT1xQTY
	Which of the following agricultural inputs were used by your household for crops in 2012? Select all that apply. Note, if you used these products for things other than crops, we'll ask about that later.	How many units of [CROPxINPUT1] did your household use in 2012? If you used [CROPxINPUT1] for things other than crops, estimate the amount used for crops only.
01 NPK 02 Urea 03 Orthene 04 Gramaxzone 05 Paraquat 06 Rambo 07 Round-Up 08 E40 09 Glysophate 10 Sunsis 11 Amin 12 Weed Killer 13 Other (specify) 14 None		

	CROPxINPUT2	CROPxINPUT2xAMT
	There are several other things related to farming that your household may have spent money on in the past 12 months. Which of the following apply? If you used these products for things other than crops, we'll ask about that later.	How much in total did your household spend on [CROPxINPUT2] for planting in 2012? If you used [CROPxINPUT2] for planting for things other than crops, estimate the amount used for crops only.
01 Lease land for planting 02 Purchase seeds or seed stock 03 Leased livestock for clearing land or planting 04 Leased labour for clearing land, planting, or harvesting 05 Leased equipment for clearing land, planting, or harvesting 06 Equipment maintenance 07 Transportation to market 08 Agricultural taxes or fees 09 Materials (e.g., shade cloth) 10 Other (specify) 11 None		

Notes03

Form 4. Livestock

I would now like to ask you about any livestock that your household raised in 2012. I will first ask about what kinds of livestock your household raised, and then I will ask about how many you bought and sold, how many were born, and how many you lost during the year. I will also ask about livestock products such as milk and eggs.

LIVESTOCK

Did any member of this household raised livestock, including cattle, horses, pigs, goats, chickens, ducks, and bees in 2012? __________

YES	1	
NO	2	➢NEXT FORM

STOCK

Which of the following livestock were raised by your household in the last 12 months? Select all that apply.

01 Cattle
02 Horses
03 Pigs
04 Goats
05 Chickens
06 Ducks
07 Bees

Note: Income will be calculated as

$$value\ of \begin{Bmatrix} milk \\ eggs \\ young \\ plowing \end{Bmatrix} \begin{Bmatrix} sold \\ consumed \end{Bmatrix} + value\ of \begin{Bmatrix} livestock\ sold \\ livestock\ consumed \end{Bmatrix} - replacement\ cost\ of \begin{Bmatrix} livestock\ sold \\ livestock\ consumed \end{Bmatrix} - cost\ of \begin{Bmatrix} feed \\ veterinary\ services \\ hired\ labour \\ transport\ to\ market \end{Bmatrix}$$

Replacement cost will be defined as cost of cattle and horses 1 year of age younger than the animal being sold to reflect annual change in the value of capital. There is no replacement cost for pigs, goats, chickens, ducks, and bees.

ASK IF STOCK = CATTLE OR GOATS

MILKxPRODUCED
How many litres of milk did your household produce in the last month?

MILKxSOLD
Of that, how many litres of milk were sold or given away last month?

ASK IF STOCK = CHICKENS OR DUCKS

EGGSxPRODUCED
How many dozens of eggs did your household produce last month?

EGGSxSOLD

Of that, how many dozens of eggs were sold or given away last month

ASK FOR ALL STOCK

	YOUNGxPRODUCED How many young did your [STOCK] produce in 2012? **0>>PLOUGHEDxOWN**	YOUNGxSOLD Of that, how many young [STOCK] were sold or given away in the last 12 months?	YOUNGxDIED How many young [STOCK] died from disease, drought, flooding, cyclones, other natural disasters, or pests in 2012?	YOUNGxLOST How many young [STOCK] were stolen or lost?	11 YOUNGxAVAILABLE And how many young [STOCK] that were born in the last 12 months you're does this household still have?
01 Cattle					
02 Horses					
03 Pigs					
04 Goats					
05 Chickens					
06 Ducks					
07 Bees					

ASK IF STOCK = CATTLE

PLOUGHxOWNx01

Were your cattle used to plough fields or clear land for yourself in 2012? __________

YES 1

NO 2 **>> PLOUGHxOTHERx01**

PLOUGHxDAYSx01

How many days were your own cattle used to plough fields or clear land for yourself in 2012? _________

PLOUGHxOTHERx01

Were your cattle used to plough fields or clear land for other people in 2012? __________

YES 1

NO 2 **>> PLOUGHxOWNx02**

PLOUGHxOTHERxDAYSx01

How many days were your cattle used to plough fields or clear land for other people in 2012? __________

PLOUGHxRENTx01

How much did you receive per day for renting your cattle out for ploughing, in dollars? __________

ASK IF STOCK = HORSES

PLOUGHxOWNx02
Were your horses used to plough fields or clear land for yourself in 2012? __________

YES 1
NO 2 **>> PLOUGHxOTHERx02**

PLOUGHxDAYSx02
How many days were your own horses used to plough fields or clear land for yourself in 2012? _________

PLOUGHxOTHERx02
Were your horses used to plough fields or clear land for other people in 2012? __________

YES 1
NO 2 **>> TRANSxOWNx02**

PLOUGHxOTHERxDAYSx02
How many days were your horses used to plough fields or clear land for other people in 2012? __________

PLOUGHxRENTx02
How much did you receive per day for renting your horses out for ploughing, in dollars? __________

TRANSxOWNx02
Were your horses used for transportating goods for your household or transporting members of your household in 2012? __________

YES 1
NO 2 **>> TRANSxOTHERx02**

TRANSxOWNxDAYSx02
How many days were your horses used for transportating goods for your household or transporting members of your household in 2012? _________

TRANSxOTHERx02
Were your horses used for transportating goods for other households or transporting other people in 2012? __________

YES 1
NO 2 **>> CATTLExOWN**

TRANSxOTHERxDAYSx02
For how many days were your horses used for transportating goods for other households or transporting people in 2012? __________

TRANSxRENTx02

How much did you receive per day that you rented your horses out for transport, in dollars? ___________

ASK IF STOCK = CATTLE

CATTLExOWN

Did your household own any cattle (other than calves) at the beginning of 2012?

YES	1	
NO	2	**>> CHICKENxCONS**

CATTLExOWNxFx5

Of those cattle that you owned at the beginning of 2012, how many were female aged 5 years and above? ___________

CATTLExOWNxFx4

Of those cattle that you owned at the beginning of 2012, how many were female aged 4 years? ___________

CATTLExOWNxFx3

Of those cattle that you owned at the beginning of 2012, how many were female aged 3 years? ___________

CATTLExOWNxFx2

Of those cattle that you owned at the beginning of 2012, how many were female aged 2 years? ___________

CATTLExOWNxFx1

Of those cattle that you owned at the beginning of 2012, how many were female aged 1 years? ___________

CATTLExOWNxMx5

Of those cattle that you owned at the beginning of 2012, how many were male aged 5 years and above? ___________

CATTLExOWNxMx4

Of those cattle that you owned at the beginning of 2012, how many were male aged 4 years? ___________

CATTLExOWNxMx3

Of those cattle that you owned at the beginning of 2012, how many were male aged 3 years? ___________

CATTLExOWNxMx2

Of those cattle that you owned at the beginning of 2012, how many were male aged 2 years? ___________

CATTLExOWNxMx1

Of those cattle that you owned at the beginning of 2012, how many were male aged 1 years? ___________

CATTLExCONS
Did your household sell or consume any cattle in 2012?

YES 1
NO 2 **>> CATTLExDIS**

CATTLExCONSxFx5
Of those cattle that you sold or consumed in 2012, how many were female aged 5 years and above? ___________

CATTLExCONSxFx4
Of those cattle that you sold or consumed in 2012, how many were female aged 4 years? ___________

CATTLExCONSxFx3
Of those cattle that you sold or consumed in 2012, how many were female aged 3 years? ___________

CATTLExCONSxFx2
Of those cattle that you sold or consumed in 2012, how many were female aged 2 years? ___________

CATTLExCONSxFx1
Of those cattle that you sold or consumed in 2012, how many were female aged 1 years? ___________

CATTLExCONSxMx5
Of those cattle that you sold or consumed in 2012, how many were male aged 5 years and above? ___________

CATTLExCONSxMx4
Of those cattle that you sold or consumed in 2012, how many were male aged 4 years? ___________

CATTLExCONSxMx3
Of those cattle that you sold or consumed in 2012, how many were male aged 3 years? ___________

CATTLExCONSxMx2
Of those cattle that you sold or consumed in 2012, how many were male aged 2 years? ___________

CATTLExCONSxMx1
Of those cattle that you sold or consumed in 2012, how many were male aged 1 years? ___________

CATTLExDIS

In 2012, did your household lose any cattle to theft, disease, drought, flooding, cyclones, or other natural disasters?

YES	1	
NO	2	**>> CHICKENxCONS**

		CATTLExDIS	CATTLExDISxFx5	CATTLExDISxFx4	CATTLExDISxFx3	CATTLExDISxFx2	CATTLExDISxFx1	CATTLExDISxFx5	CATTLExDISxMx4	CATTLExDISxMx3	CATTLExDISxMx2	CATTLExDISxMx1
		Which of the following disasters resulted in lost cattle over 2012? Select all that apply.	Of those cattle lost to [DISASTER] in 2012, how many were female aged 5 years and above?	Of those cattle lost to [DISASTER] in 2012, how many were female aged 4 years?	Of those cattle lost to [DISASTER] in 2012, how many were female aged 3 years?	Of those cattle lost to [DISASTER] in 2012, how many were female aged 2 years?	Of those cattle lost to [DISASTER] in 2012, how many were male aged 1 years?	Of those cattle lost to [DISASTER] in 2012, how many were male aged 5 years and above?	Of those cattle lost to [DISASTER] in 2012, how many were male aged 4 years?	Of those cattle lost to [DISASTER] in 2012, how many were male aged 3 years?	Of those cattle lost to [DISASTER] in 2012, how many were male aged 2 years?	Of those cattle lost to [DISASTER] in 2012, how many were male aged 1 years?
SICK	Disease											
DR	Drought											
JFL	January 2012 flooding											
MFL	March 2012 flooding											
EVAN	Cyclone Evan											
THEFT	Theft											
OTH	Other (specify)											

ASK IF STOCK = CHICKENS

CHICKENxSOLD

Did your household sell or give away any hens or roosters last month?

YES	1	
NO	2	**>> CHICKENxCONS**

CHICKENxSOLDxQTY

How many hens or roosters did you sell or give away last month?

CHICKENxCONS

Did your household consume any hens or roosters last month?

YES	1	
NO	2	**>> DUCKxSOLD**

CHICKENxCONSxQTY
How many hens or roosters did your household consume last month?

ASK IF STOCK = DUCKS

DUCKxSOLD
Did your household sell or give away any adult ducks last month?

YES 1
NO 2 **>> DUCKxCONS**

DUCKxSOLDxQTY
How many adult ducks did you sell or give away last month?

DUCKxCONS
Did your household consume any adult ducks last month?

YES 1
NO 2 **>> PIGSxOWN**

DUCKxCONSxQTY
How many adult ducks did your household consume last month?

ASK IF STOCK = PIGS

PIGSxOWN
Did your household own any adult pigs at the beginning of 2012?

YES 1
NO 2 **>> HORSESxOWN**

PIGSxOWNx1
Specify the number of males aged 1 year and above ___________

PIGSxOWNx2
Specify the number of females aged 1 year and above ___________

PIGSxCONS
Did your household sell or consume any adult pigs in 2012?

YES 1

NO 2 **>> PIGSxDIS**

PIGSxCONSx1
Specify the number of males aged 1 year and above __________

PIGSxCONSx2
Specify the number of females aged 1 year and above __________

PIGSxDIS
In 2012, did your household lose any pigs to disease, drought, flooding, cyclones, or other natural disasters?
YES 1
NO 2 **>> HORSESxOWN**

		PIGSxDIS Which of the following disasters resulted in lost cattle over 2012? Select all that apply.	PIGSxDISx1 Of those pigs lost to [DISASTER] in 2012, how many were male aged 1 year and above?	PIGSxDISx2 Of those pigs lost to [DISASTER] in 2012, how many were female aged 1 year and above?
SICK	Disease			
DR	Drought			
JFL	January 2012 flooding			
MFL	March 2012 flooding			
EVAN	Cyclone Evan			
OTH	Other (specify)			

ASK IF STOCK = HORSES

HORSESxOWN
Did your household own any adult horses at the beginning of 2012?
YES 1
NO 2 **>> GOATSxOWN**

HORSESxOWNx1
Of those horses that you owned at the beginning of 2012, how many were yearlings [1 year olds]? __________

HORSESxOWNx2
Of those horses that you owned at the beginning of 2012, how many were colts or fillies [1 to 3 years old]? __________

HORSESxOWNx3

Of those horses that you owned at the beginning of 2012, how many were mares [females aged 4 years and older]? __________

HORSESxOWNx4
Of those horses that you owned at the beginning of 2012, how many were stallions [males aged 4 years and older]? __________

HORSESxOWNx5
Of those horses that you owned at the beginning of 2012, how many were geldings [castrated males aged 4 years and older]? __________

HORSESxSOLD
Did your household sell or give away any adult horses at the beginning of 2012?

YES	1	
NO	2	**>> HORSESxDIS**

HORSESxSOLDx1
Of those horses that you sold or gave away in 2012, how many were yearlings [1 year olds]? __________

HORSESxSOLDx2
Of those horses that you sold or gave away in 2012, how many were colts or fillies [1 to 3 years old]? __________

HORSESxSOLDx3
Of those horses that you sold or gave away in 2012, how many were mares [females aged 4 years and older]? __________

HORSESxSOLDx4
Of those horses that you sold or gave away in 2012, how many were stallions [males aged 4 years and older]? __________

HORSESxSOLDx5
Of those horses that you sold or gave away in 2012, how many were geldings [castrated males aged 4 years and older]? __________

HORSESxDIS
In 2012, did your household lose any horses to theft, disease, drought, flooding, cyclones, or other natural disasters?

YES	1	
NO	2	**>> GOATSxOWN**

		HORSESxDIS	HORSESxDISx1	HORSESxDISx2	HORSESxDISx3	HORSESxDISx4	HORSESxDISx5
		Which of the following disasters resulted in lost horses over 2012? Select all that apply.	Of those horses lost to [DISASTER] in 2012, how many were yearlings?	Of those horses lost to [DISASTER] in 2012, how many were colts or fillies?	Of those horses lost to [DISASTER] in 2012, how many were mares?	Of those horses lost to [DISASTER] in 2012, how many were stallions?	Of those horses lost to [DISASTER] in 2012, how many were geldings?
SICK	Disease						
DR	Drought						
JFL	January 2012 flooding						
MFL	March 2012 flooding						
EVAN	Cyclone Evan						
THEFT	Theft						
OTH	Other (specify)						

ASK IF STOCK = GOATS

GOATSxOWN
Did your household own any adult goats at the beginning of 2012?

YES 1
NO 2 **>> HIVES**

GOATSxOWNx1
Of those goats that you owned at the beginning of 2012, how many were female juveniles? __________

GOATSxOWNx2
Of those goats that you owned at the beginning of 2012, how many were female adults? __________

GOATSxOWNx3
Of those goats that you owned at the beginning of 2012, how many were male juveniles? __________

GOATSxOWNx4
Of those goats that you owned at the beginning of 2012, how many were male adults? __________

GOATSxSOLD
Did your household sell or give away any adult goats at the beginning of 2012?

YES 1
NO 2 >> GOATSxDIS

GOATSxSOLDx1
Of those goats that you sold or gave away in 2012, how many were female juveniles? __________

GOATSxSOLDx2
Of those goats that you sold or gave away in 2012, how many were female adults? __________

GOATSxSOLDx3
Of those goats that you sold or gave away in 2012, how many were male juveniles? __________

GOATSxSOLDx4
Of those goats that you sold or gave away in 2012, how many were male adults? __________

GOATSxDIS
In 2012, did your household lose any goats to disease, drought, flooding, cyclones, or other natural disasters?

YES	1	
NO	2	>> HIVES

		GOATSxDIS	GOATSxDISx1	GOATSxDISx2	GOATSxDISx3	GOATSxDISx4	GOATSxDISx5
		Which of the following disasters resulted in lost goats over 2012? Select all that apply.	Of those goats lost to [DISASTER] in 2012, how many were yearlings?	Of those goats lost to [DISASTER] in 2012, how many were colts or fillies?	Of those goats lost to [DISASTER] in 2012, how many were mares?	Of those goats lost to [DISASTER] in 2012, how many were stallions?	Of those goats lost to [DISASTER] in 2012, how many were geldings?
SICK	Disease						
DR	Drought						
JFL	January 2012 flooding						
MFL	March 2012 flooding						
EVAN	Cyclone Evan						
OTH	Other (specify)						

ASK IF STOCK = BEES

HIVES
How many hives did you own at the beginning of 2012? __________

HONEYxPRODUCED
How many bottles of honey did your household produce in 2012? __________
0>>BEES_DIS

HONEYxSOLD
Of that, how many bottles of honey were sold or given away in 2012? __________

BEESxDIS

In 2012, did your household lose any bee hives to disease, drought, flooding, cyclones, or other natural disasters? __________

YES	1	
NO	2	**>>LIVESTOCKxINPUT**

		BEESxDIS	BEESxDISxHIVES
		Which of the following disasters resulted in lost goats over 2012? Select all that apply.	How many hives were lost to [DISASTER] in 2012?
SICK	Disease		
DR	Drought		
JFL	January 2012 flooding		
MFL	March 2012 flooding		
EVAN	Cyclone Evan		
OTH	Other (specify)		

ASK FOR ALL STOCK

	LIVESTOCKxINPUT	LIVESTOCKxINPUTxAMT
	On which of the following inputs did you spend money to raise livestock in 2012? Select all that apply. If you used these products for things other than livestock, we'll ask about that later.	How much in total did your household spend on [LIVESTOCKxINPUT] in 2012?
01 Feed		
02 Veterinary services		
03 Transportation		
04 Paid labour for herding		
05 Materials, e.g., fencing		
06 Other (specify)		

Notes04

Form 5. Firewood

I am now going to ask you a few questions about firewood, foods that you harvest from the forest, and visits from extension officers.

FIREWOOD
Has any member of this household harvested timber for firewood in the past month? __________

YES 1
NO 2 **>> FORREST**

FIREWOODxQTY
In total, how many bundles of firewood did your household harvest in the last month? __________

FIREWOODxSOLD
Of this, how many bundles of firewood did your household sell in the last month? __________

FOREST
In the last month, did any member of this household collect wild foods such as ota, ivi [naibi], wild yam, wild pigs, tarawau, kavika [jamun], maqo [aam], moli [nimbo], niu [nariyal], ota, jackfruit [kathar], quwawa [amrood], or tamarind [emlly] or other products from the forest? __________

YES 1
NO 2 **>> NOTES05**

	FORESTxPROD	FORESTxPRODxMAX5
	Which of the following forest products did your household harvest for personal consumption or commercial sale in the last month? Select all that apply.	Of all the forest products that your household collected in 2012, which 5 are the most important for commercial and consumption purposes?
01 Ota		
02 Ivi [naibi]		
03 Wild yam		
04 Wild pigs		
05 Tarawau		
06 Kavika [jamun]		
07 Maqo [aam]		
08 Moli [nimbo]		
09 Niu [nariyal]		
10 Uto		
11 Jackfruit [kathar]		
12 Quwawa [amrood]		
13 Tamarind [emlly]		
14 Other (specify)		

	FORESTxPRODxUNIT UNIT OF MEASUREMENT	FORESTxPRODxQTY How many [UNITS] of [FORESTxPROD] did your household collect in total, whether for sale or for personal consumption, in the past month?

ASK IF FORESTxPROD = NIU

COCONUTxPRODUCTS

Did your household produce virgin oil or coconut oil in 2012? __________

YES 1

NO .... 2 **>> Notes05**

VIRGINxOILxPRODUCED

How many bottles of virgin oil did your household produce in 2012? __________

0 >> COCONUTxOILxPRODUCED

VIRGINxOILxSOLD

How many bottles of virgin oil did your household sell or give away in 2012? __________

COCONUTxOILxPRODUCED

How many bottles of coconut oil did your household produce in 2012? __________

0 >> CHUT2

COCONUTxOILxSOLD

How many bottles of coconut oil did your household sell or give away in 2012? __________

ASK IF FORESTxPROD = TAMARIND

CHUT2

Did your produce chutney from tamarind that you gathered in 2012? __________

YES 1

NO .... 2 **>> Notes05**

CHUT2xPRODUCED

How many jars of tamarind chutney did your household produce in 2012? __________

CHUT2xSOLD

How many jars of tamarind chutney did your household sell or give away in 2012? __________

Notes 05

Form 6. Extension Services

EXTxCROPS

Did any member of this household meet with an extension officer to discuss raising crops (part from sugarcane) in 2012? __________

YES 1

NO .... 2 **>> EXTxLIVESTOCK**

EXTxCROPS

What kind of information or assistance was provided about raising crops in 2012? Select all that apply.

01 use of fertilizer or soil problems

02 use of pesticides or weed problems

03 irrigation

04 new seed varieties

05 crop disease

06 drought

07 flooding

08 storm surge

09 planting advice

10 marketing advice

11 credit advice

12 sustainable land management

13 Control of African tulip tree

14 Control of merremia vine

15 Control of boar/pig

16 Control of taro beetle

17 control of birds

18 Other

EXTxLIVESTOCK

Did any member of this household met ewith an extension officer to discuss raising livestock in 2012? __________

YES 1

NO .... 2 **>> EXTxFORESTRY**

EXTxLIVESTOCK

What kind of information or assistance was provided about raising livestock in 2012? Select all that apply.

01 vaccinations

02 animal nutrition

03 animal disease

04 animal husbandry and insemination services

05 other aspect of animal welfare

06 marketing advice

07 flooding

08 storm surge

09 planting advice

10 credit advice

11 sustainable land management

12 Control of mongoose

13 Control of boar/pig

14 Other

EXTxFORESTRY

Did any member of this household meet with an extension officer to discuss forestry in 2012? __________

YES 1

NO .... 2 **>> EXTxFSC**

EXTxFORESTRY

What kind of information or assistance was provided about forestry in 2012? Select all that apply.

01 use of fertilizer or soil problems
02 use of pesticides or weed problems
03 irrigation
04 erosion control
05 new tree varieties
06 tree disease
07 drought
08 flooding
09 storm surge
10 planting advice
11 marketing advice
12 sustainable land management
13 credit adice
14 Control of African tulip tree
15 Control of merremia vine
16 Control of boar/pig
17 Insects that attack trees
18 Other

EXTxFSC

Did any member of your household meet with representatives from the Fiji Sugar Corporation in 2012?

YES 1

NO .... 2 **>> NOTES06**

EXTxFSC

What kind of information or assistance was provided about forestry in 2012? Select all that apply.

01 use of fertilizer or soil problems
02 use of pesticides or weed problems
03 irrigation
04 new cane varieties
05 cane disease
06 drought
07 flooding
08 storm surge
09 planting advice
10 marketing advice
11 credit adice
12 control of pests
13 sustainable land management
14 Other

Notes 06

Form 7. Fishing

I would now like to ask you about any fishing that your household did in 2012, including reef fishing, freshwater fishing, and gleaning.

REEFxFISHING

In 2012, did any member of this household go reef fishing for the purpose of consumption or sales? _________

FISHING FOR WAGES SHOULD BE INCLUDED UNDER WAGE WORK, NOT FISHING.

YES 1

NO .... 2 **>> GLEANING**

REEFxFISHINGxTRIPS

How many reef fishing trips did members of your household make in a typical month? __________

	REEFxFISH Which of the following reef fish did your household catch for the purpose of consumption or sales in 2012? Select all that apply.	REEFxFISHxMAX5 Of all the reef fish that your household caught in 2012, which 5 are the most important for commercial and consumption purposes?
01 Nuqa (rabbitfish)		
02 Salala (mackerel)		
03 Kanace (mullett)		
04 Surgeonfish		
05 Ose (goatfish)		
06 Kawakawa (groupers)		
07 Kabatia/Kake (emperors)		
08 Tunas		
09 Saqa (trevallies/jacks)		
10 Damu (snappers)		
11 Deep water snapper		
12 Barracudas		
13 Ulavi (parrotfishes)		
14 Grunters		
15 Lobster		
16 Vo (gurgeons)		
17 Keta (silver biddy)		
18 Other (specify)		

ASK IF REEFxFISHxMAX5 = NUQA, SALALA, OR KANACE

	REEFxFISH1xMOS How many months is the season for [REEFxFISH]?	REEFxFISH1xQTY On average, how many KGs of [REEFxFISH] were caught on each trip during the 2012 season?	REEFxFISH1xSHR What proportion of the [REEFxFISH1xQTY] KGs of [REEFxFISH] caught during the average trip during the 2012 season was claimed by members of the household (or what share of the sales)? ENTER A NUMBER BETWEEN 0 and 100.	REEFxFISH1xSOLD Of the [REEFxFISH] caught during the average trip during the 2012 season that your household claimed, what percentage was sold by your household? ENTER A NUMBER BETWEEN 0 and 100.	REEFxFISH1xCOMPARE Was the REEFxFISH1xQTY KGs of [REEFxFISH] caught during the average fishing trip during the 2012 season more or less than was caught on a typical fishing trip during the season 5 years ago? MUCH MORE........1 MORE........2 ABOUT THE SAME........3 LESS........4 MUCH LESS........5

ASK IF REEFxFISHxMAX5 = NUQA, SALALA, OR KANACE

	REEFxFISH2xQTY On average for 2012, how many KGs of [REEFxFISH] was caught on each trip?	REEFxFISH2xSHR What proportion of the [REEFxFISH2xQTY] KGs of [REEFxFISH] caught during the average trip in 2012 was claimed by the household (or what share of the sales)? ENTER A NUMBER BETWEEN 0 AND 100.	REEFxFISH2xSOLD Of the [REEFxFISH] caught during the average trip in 2012 that your household claimed, what percentage was sold by your household? ENTER A NUMBER BETWEEN 0 AND 100.	REEFxFISH2xCOMPARE Was the REEFxFISH2xQTY KGs of [REEFxFISH] caught during the average fishing trip during 2012 more or less than was caught on a typical fishing trip 5 years ago? MUCH MORE........1 MORE........2 ABOUT THE SAME........3 LESS........4 MUCH LESS........5

GLEANING

In 2012, did members of your household glean any mud crabs, mud lobsters, seaweed, sea cucumbers, octopus, bivalves, or prawns for the purpose of consumption or sales? FISHING FOR WAGES SHOULD BE INCLUDED UNDER WAGE WORK, NOT FISHING. __________

YES 1
NO .... 2 **>> FWxFISHING**

	GLEANxFISH	GLEANxFISHxMAX3
	Which of the following species did members of your household glean for the purpose of consumption or sales in 2012? Select all that apply.	Of all the species gleaned in 2012, which 3 are the most important for commercial and consumption purposes?
01 Mud crabs		
02 Mud lobsters		
03 Seaweed		
04 Sea cucumbers		
05 Octopus		
06 Bivalves		
07 Prawns		
08 Other (specify)		

	GLEANxUNIT UNIT OF MEASUREMENT	GLEANxTRIPS How many trips to glean [GLEANxFISH] have members of your household made in the last month?	GLEANxQTY On average for 2012, how many [GLEANxFISHxUNIT] of [GLEANxFISH] were gleaned per trip?	GLEANxSOLD Of the [GLEANxFISH] gleaned during the average trip in 2012, what percentage was sold by your household? ENTER A NUMBER BETWEEN 0 AND 100.	GLEANxCOMPARE Is [GLEANxQTY] [GLEANxUNIT] of [GLEANxFISH] more or less than was gleaned on a typical fishing trip 5 years ago? MUCH MORE .... 1 MORE .... 2 ABOUT THE SAME .... 3 LESS .... 4 MUCH LESS 5

FWxFISHING

In 2012, did any member of this household catch wild fish, crabs, eels, or other life from fresh water for the purpose of sales or consumption? FISHING FOR WAGES SHOULD BE INCLUDED UNDER WAGE WORK, NOT FISHING. __________

YES 1

NO.. 2 **>> FISHINGxINPUT**

FWxFISHINGxTRIPS

How many fresh water fishing trips has your household made in the last month? __________

	FWxFISH	FWxFISHxMAX3
	Which of the following fresh water fish did members of your household catch for the purpose of consumption or sale in 2012? Select all that apply.	Of all the freshwater fish species caught by your household in 2012, which 3 are the most important for commercial and consumption purposes?
01 Eels		
02 Freshwater prawns		
03 Tilapia		
04 Carp		
05 Freshwater clams		
06 Freshwater crabs		
07 Bass		
08 Milkfish		
09 Vo (gurgeons)		
10 Other (specify)		

	FWxQTY On average for 2012, how many KGs of [FWxFISH] were caught per trip?	FWxSOLD Of the [FWxFISH] caught during the average trip in 2012, what percentage was sold by your household? ENTER A NUMBER BETWEEN 0 AND 100.	FWxCOMPARE Is [FWxQTY] KGs of [FWxFISH] more or less than was caught on a typical fishing trip 5 years ago? MUCH MORE ....1 MORE ....2 ABOUT THE SAME..................3 LESS ....4 MUCH LESS............................5

	FISHINGxINPUT	FISHINGxINPUTxAMT
	Which of the following inputs were used by your household in your fishing activities in 2012? Select all that apply. If you used these products for things other than fishing, we'll ask about that later.	How much in total did your household spend on [FISHINGxINPUT] in 2012?
01 Boat hire		
02 Boat maintenance and repair		
03 Fuel for fishing boats		
04 Hook and line		
05 Bait		
06 Hired labour		
07 Fishing taxes or fees		
08 Other (specify)		

Notes07

Form 8. Wages or Salary

ASK FOR ALL HOUSEHOLD MEMBERS AGED 12 AND ABOVE

	LABOUR	LABOURxNOxREASON	LABOURxTYPE	LABOURxMOS	LABOUR1xTIMExUNIT	LABOUR1xWAGE	SECONDxJOB	LABOUR2xMOS	LABOUR2xTIMExUNIT	LABOUR2xWAGE	COMMUTE	COMMUTExAMT
	During 2012, did [NAME] spend 1 month or more working for wages, including as a labourer on another farm? YES........................ **>> LABOURxTYPE** NO	What is the main reason that [NAME] did not work for wages or salary for at least one month in 2012? WORK ON OWN FARM OR FAMILY BUSINESS . ...1 IN SCHOOL / TOO YOUNG ....2 RETIRED / TOO OLD ....3 HOMEMAKER / CHILD CARE ......4 SICKNESS ....5 PRISON..............6	What type of wage / salary work did [NAME] do for his or her main job in 2012? CUT CANE .... 1 RAISE CROPS / LIVESTOCK........ 2 FORESTRY .... 3 FISHING .... 4 VILLAGE ADMIN 5 TEACHER........... 6 CHURCH WORK 7 SHOP.................. 8 CONSTRUCTION9 OFFICE............. 10 GOVERNMENT / SAFETY .... 11 TOURISM 12	How many months did [NAME] work at this job?	What unit of time was [NAME] paid by for this job? HOUR ....1 DAY..................... 2 WEEK .... 3 FORTNIGHT .... 4 MONTH............... 5 YEAR 6	How much did [NAME] receive in wages or salary each [LABOUR1xTIMExUNIT] for this job?	During 2012, did [NAME] spend 1 month or more working a second job for wages or salary? YES............ ...... 1 NO .... 2 **>> COMMUTE**	How many months in 2012 did [NAME] work at this job?	What unit of time was [NAME] paid by for this job? HOUR ....1 DAY..................... 2 WEEK .... 3 FORTNIGHT .... 4 MONTH............... 5 YEAR 6	How much did [NAME] receive in wages or salary each [LABOUR2xTIMExUNIT] for this job?	Did [NAME] pay for public transportation or for petrol for private transportation for commuting to work? YES............ ...... 1 NO .... 2 **>> NEXT PERSON**	How much did it cost [NAME] per day to commute in 2012, on average?

		OTHER...............7 **>> NEXT PERSON**	VILLAGE HEADMAN........ 13 OTHER (specify) 14										
01													
02													
03													
04													
05													
06													
07													
08													
09													
10													

SELFxEMPLOY

Is any member of the household self-employed or does any member of the household own a business, apart from cropping, livestock, forestry, and fishing?

YES...1

NO..2 **>> REMIT**

	SELFxEMPLOYxPERSON Which household members typically participated in this business? Select all that apply.
01	
02	
03	
04	
05	
06	
07	
08	
09	
10	

SELFxEMPLOYxSHARE

What share of the business is owned by household members? __________

SELFxEMPLOYxINCOME

What was the total profit (income minus expenses) for this business in the last year? __________

Ask if REASONxAWAY = 2 or REASONxAWAY = 3

	REMIT Did [NAME] remit part or all of his income to the household during the last 12 months? YES 1 NO 2 **>> SENDxMONEY**	REMITxAMOUNT In total, how much did [NAME] remit to the household during the past 12 months?
01		
02		
03		
04		
05		
06		
07		
08		
09		
10		

SENDxMONEY

In 2012, did any other person send money to this household? __________

YES..1

NO..2 **>> NOTES08**

REMITxOTHER

In total, how much (including the value of both money and durable goods) did other people send to the household in 2012, if any? IF ZERO, ENTER 0. __________

Notes 08

Form 9. Government Assistance and Retirement Income

Now, I would like to ask you about any government assistance that members of this household received in 2012. I will then ask some questions about the material things that your household owns. After that, I will ask about how your household members spend their time.

	ASSISTANCE Which forms of assistance did members of your household receive in 2012? Check all that apply.	ASSISTANCExMOS How many months in 2012 did a member of your household receive [ASSISTANCE]?	ASSISTANCExAMT What was the average amount of [ASSISTANCE] each month it was received in 2012, in dollars?
01 Government Pension (civil servant, military)			
02 Family Assistance Program			
03 Disability benefits			
04 Old age pension (>60 yrs)			
05 Other government support			
06 Private pension			
07 Other private support			
08 School fees and/or school transport			
09 Disaster relief			

ASSISTANCEx09

Did members of your household receive disaster relief in 2012? __________

YES 1

NO .... 2 **>> NOTES09**

ASSISTANCExAMTx09

What was the total value of disaster relief received for disasters that happened in 2012, in dollars? INCLUDE BOTH CASH AND THE VALUE OF DONATED ITEMS. __________

Notes 09

Form 10. Housing, Durable Goods, and Accounts

WALLS

What is the primary building material of the walls of this home? __________

CORRUGATED IRON/METAL.........1

CINDER BLOCK/CONCRETE 2

BRICKS 3

WOOD/WOVEN/REEDS..................4

OTHER (specify) 5

ROOF

What is the primary building material of the roof of this home? __________

CORRUGATED IRON/METAL.........1

THATCH 2

TILES..3

PADANA/PALM LEAVES.................4

OTHER (specify) 5

HOUSExCOMPARE

Is this house worth more, less, or about the same as the average house in this village? __________

MUCH LESS.....................................1

SOMEWHAT LESS 2

ABOUT THE SAME..........................3

SOMEWHAT MORE.........................4

MUCH MORE 5

HOUSExREPLACExVALUE

If you had to replace this dwelling today, how much would it cost to replace as it is, in dollars? __________

HOUSExOWN

Does a member of this household own this dwelling? __________

YES 1

NO .... 2 **>> DURABLES**

HOUSExRENTxINC

Does anyone pay the household head rent to live in this dwelling? __________

YES 1

NO .... 2 **>> DURABLES**

HOUSExRENTxINCxAMT

What is the total amount of rent that you receive (including both cash and the value of goods or services) in rent for this house each month? __________

RENTALxPROPERTY

Does a member of this household own other property (houses or other buildings) that provides rental income? __________

YES 1

NO .... 2 **>> DURABLES**

RENTALxPROPERTYxINC

What is the total amount of rent that you receive (including both cash and the value of goods or services) in rent for other rental properties each month? __________

	DURABLES Which forms of assistance did members of your household receive in 2012? Check all that apply.	DURxVALUE How many [DURABLE] do you own?	DURxVALUE What is the total value of [DURABLE] if you sold all that you have today?
01 Cell phones			
02 Personal computers			
03 Televisions			
04 DVD players			
05 Stereos, radios, tape recorders, mp3s			
06 Cameras or video cameras			
07 Sky Pacific satellite dishes			
08 Electric fans			
09 Gas or electric stoves			
10 Refrigerators			
11 Other kitchen appliances			
12 Automatic washing machines			
13 Sewing or knitting machines			
14 Generators			
15 Bicycles			
16 Trucks (e.g., cane trucks)			
17 Passenger automobile or van			
18 Motorized boats			
19 Non-motorized boats			
20 Tractors			
21 Brushcutters			
22 Chainsaws			
23 Ploughs			

DURxJEWELRY

Does any member of your household own jewellery? __________

YES 1

NO .... 2 **>> DURxOTH**

DURxJEWELRYxVALUE

What is the total value of your household's jewellery? __________

DURxOTH

Does your household own other assets (worth more than $100) not already mentioned? __________

YES 1

NO .... 2 **>> ACCOUNT**

DURxOxDESC

Describe these other assets. __________

DURxOxVALUE

What is the total value of these assets if you sold all that you own today, in dollars? __________

ACCOUNT

Does anyone in your household have a chequing account, a bank account, financial investments, or money saved at home? __________

YES 1

NO .... 2 **>> HIRExDUR**

ACCOUNTxNAME

Select the name of the person answering this question. __________

PERSON 01 1

PERSON 02 2

PERSON 03 3

PERSON 04 4

PERSON 05 5

PERSON 06 6

PERSON 07 7

PERSON 08 8

PERSON 09 9

PERSON 10 10

ACCOUNTxAMT

What is the approximate value of all bank accounts and financial investments combined? __________

LESS THAN $500 1

$500 - $999 2

$1000-$1999 3

$2000-$2999 4

$3000-$4999 5

$5000-$7499 6

$7500-$9999 7

$10,000-$12,499 8

$12,500-$14,999 9

$15,000-$17,499 10

$17,500-$19,999 11

$20,000-$24,999 12

$25,000-$29,999 13

$30,000-$39,999 14

$40,000-$49,999 15

$50,000-$74,999 16

$75,0000-$99,999 17

$100,000-$149,000 18

$150,000-$199,999 19

$200,000-$250,000 20

more than $250,000 21

ASK IF DURABLE = TRUCKS, MOTORISED BOATS, NON-MOTORISED BOATS, OR TRACTORS

	HIRExDUR Did you hire out your [DURABLE] during 2012? YES 1 NO 2	HIRExDURxDAYS How many days in 2012 did you hire out your [DURABLE]?	HIRExDURxAMT What was the average amount of rent received per day?
16 TRUCKS			
18 MOTORISED BOATS			
19 NON-MOTORISED BOATS			
20 TRACTORS			

Notes 10

Form 11. Time Allocation

ASK IF AGE>7

	TIMExSCHOOLxDAYS In the last 7 days, how many days did [NAME] attend school? If CURRENTxSCHOOL =1	TIMExSCHOOLxHOURS On a typical school day, how many hours does [NAME] attend? If CURRENTxSCHOOL =1	TIMExSCHOOLxHW On a typical school day, how many hours does [NAME] do homework? If CURRENTxSCHOOL =1	TIMExSCHOOLxCOMMUTE How long, in hours, does [NAME] spend travelling to school on a typical day (round trip)? If CURRENTxSCHOOL =1	TIMExAG In the last 7 days, did [NAME] work on the household's farm in agriculture or raising livestock? YES .... 1 NO .... 2 ➢Q 9 If CROPPING=1 or LIVESTOCK=1	TIMExAGxDAYS In the last 7 days, how many days did [NAME] work on the household's farm in agriculture or raising livestock? If CROPPING=1 or LIVESTOCK=1	TIMExAGxHOURS How many hours did [NAME] work on a typical day working on the households' farm in agriculture or raising livestock? If CROPPING=1 or LIVESTOCK=1	TIMExAGxCOMMUTE How many hours did it normally take [NAME] to travel to and from this work (round trip) per day? If CROPPING=1 or LIVESTOCK=1	TIMExFOR In the last 7 days, did [NAME] gather firewood, wild foods such as ota, ivi, wild yams, wild pigs, tawarau, and kavika? YES .... 1 NO .... 2 ➢Q 13 If FORESTRY = 1	TIMExFORxDAYS In the last 7 days, how many days did [NAME] gather firewood and/or gather non-timber forest products such as ota, ivi, wild yams, wild pigs, tawarau, and kavika? If FORESTRY = 1	TIMExFORxHOURS In the last 7 days, how many hours did [NAME] gather firewood and/or gather non-timber forest products such as ota, ivi, wild yams, wild pigs, tawarau, and kavika? If FORESTRY = 1	TIMExFORxCOMMUTE How many hours did it normally take [NAME] to travel to and from this work (round trip) per day? If FORESTRY = 1	TIMExFISH In the last 7 days, did [NAME] go fishing? YES.......... NO............ ➢Q 17 If SEAxFISHING = 1 or FWxFISHING=1	TIMExFISHxDAYS In the last 7 days, how many days did [NAME] fish? If SEAxFISHING = 1 or FWxFISHING=1	TIMExFISHxHOURS How many hours did [NAME] fish on a typical day? If SEAxFISHING = 1 or FWxFISHING=1	TIMExFISHxCOMMUTE How many hours did it normally take [NAME] to travel to and from fishing (round trip) per day? If SEAxFISHING = 1 or FWxFISHING=1	TIMExWAGE In the last 7 days, how many days did [NAME] work for wages, including as a labourer on another farm, or in self-employment? If LABOUR = 1	TIMExWAGExHOURS In the last 7 days, how many hours did [NAME] work for wages, including as a labourer on another farm, or in self-employment? If LABOUR = 1	TIMExWAGExCOMMUTE How many hours did it normally take [NAME] to travel to and from this work (round trip) per day? If LABOUR = 1
01																			
02																			
03																			
04																			
05																			
06																			
07																			
08																			
09																			
10																			

	TIMExVWORK In the last 7 days, did [NAME] do work for the village? YES .... 1 NO........... 2 **>> TIMExVMEET**	TIMExVWORKxDAYS In the last 7 days, how many days did [NAME] do work for the village?	TIMExVWORKxHOURS How many hours did [NAME] work on a typical day working for the village?	TIMExVMEET In the last 7 days, did [NAME] attend meetings for the village/community? YES ....1 NO ....2 **>> TIMExCHURCH**	TIMExVMEETxDAYS In the last 7 days, how many days did [NAME] attend meetings for the village/community?	TIMExVMEETxHOURS How many hours did [NAME] attend meetings on a typical day that they are held?	TIMExCHURCH In the last 7 days, did [NAME] attend church, temple, or other religious services? YES......... 1 NO........... 2 **>> TIMExCOMMUNITY**	TIMExCHURCHxDAYS In the last 7 days, how many days did [NAME] attend church, temple, or other religious services?	TIMExCHURCHxHOURS How many hours did [NAME] attend church, temple, or other religious services on a typical day that he or she attended?	TIMExCOMMUNITY In the last 7 days, did [NAME] participate in community groups or other organised activity? YES .... 1 NO........... 2 **>> TIMExSOCIAL**	TIMExCOMMUNITYxDAYS In the last 7 days, how many days did [NAME] participate in community groups or other organised activity?	TIMExCOMMUNITYxHOURS How many hours did [NAME] participate in community groups or other organised activity on a typical day that he or she participated?
01												
02												
03												
04												
05												
06												
07												
08												
09												
10												

	TIMExSOCIAL In the last 7 days, did [NAME] socialise with friends and neighbours, including things like talking with friends, attending weddings and funerals, and drinking grog? YES ....1 NO ....2 **>> TIMExCHORES**	TIMExSOCIALxDAYS In the last 7 days, how many days did [NAME] socialise with friends and neighbours?	TIMExSOCIALxHOURS How many hours did [NAME] socialise with friends and neighbours on a typical day that he or she did so?	TIMExCHORES In the last 7 days, did [NAME] perform household chores such as cooking, cleaning, laundry, chopping firewood, etc.? YES......... 1 NO........... 2 **>> TIMExTYPICAL**	TIMExCHORESxDAYS In the last 7 days, how many days did [NAME] perform household chores?	TIMExCHORESxHOURS How many hours did [NAME] perform household chores when he or she did so?	TIMExTYPICAL Were the last 7 days typical for [NAME] in terms of his or her time allocation? YES......... 1 NO........... 2
01							
02							
03							
04							
05							
06							
07							
08							
09							
10							

Variables that are calculates automatically

TIMExSCHOOLxTOT: Total time spent in school during the last 7 days

TIMExAGxTOT: Total time spent working in agriculture during the last 7 days

TIMExFORxTOT: Total time spent working forestry and gathering forest products during the last 7 days

TIMExFISHxTOT: Total time spent fishing during the last 7 days

TIMExWAGExTOT: Total time spent working for wages during the last 7 days

TIMExVWORKxTOT: Total time spent on work for the village during the last 7 days

TIMExVMEETxTOT: Total time spent in village meetings during the last 7 days

TIMExCHURCHxTOT: Total time spent attending church, temple, or other religious services during the last 7 days

TIMExCOMMUNITYxTOT: Total time spent participating in community groups during the last 7 days

TIMExSOCIALxTOT: Total time spent socialising during the last 7 days

TIMExCHORESxTOT: Total time spent doing chores during the last 7 days

Notes 11

Form 12. Climate and Weather

	CHALLENGE Which of the following challenges has this village/community faced in recent years? Select all that apply.	CHALLENGExRATE Over the last 10 years, has [CHALLENGE] become better, gotten worse, or stayed the same?	CHALLENGExFIRST Among those challenges that you selected, which is the biggest problem facing your community?	CHALLENGExSECOND Among those challenges that you selected, which is the second biggest problem facing your community?	CHALLENEGExTHIRD Among those challenges that you selected, which is the third biggest problem facing your community?
01 Inundation from the sea/storm surge					
02 Declining fish and seafood stock					
03 Coastal erosion					
04 Coral bleaching					
05 Cyclones					
06 Heavy rains					
07 Flooding					
08 Drought					
09 Soil erosion					
10 Landslips and landslides					
11 Lack of drinking water					
12 Fire					
13 Increase of sickness/illness/disease among livestock and crops					
14 Increase of sickness/illness/disease among people					
15 Expiring land leases					
16 African Tulip Tree					
17 Other invasive trees plants, and vines					
18 Taro Beetle					

I will now ask you some hypothetical questions about natural disasters. There are no right or wrong answers; I am just asking for your ideas!

DISxVALxMAX
Think of the worst year for natural disasters that you can. How much do you think it would cost to rebuild and replace everything that you would lose to natural disasters during such a year, in dollars? __________

DISxYEARSx01
Over the next 20 years, how many years do you think you will be affected by natural disasters in some way? For example, if you think that natural disasters will affect you in 10 out of the 20 years, it means that you are just as likely to be affected as not affected in any given year. If you say that natural disasters will affect you in 11 out of the next 20 years, this means that it is slightly more likely to happen than to not happen in any given year. If you say that natural disasters will affect you in 20 out of the 20 years, this means that you are sure it will happen every year. __________

DISxYEARSx02

Out of those [DISxYEARSx01] years, how many do you think your losses and damages will be between $0 and $[DISxVALxMAX]/5? __________

DISxYEARSx03

And in how many of those [DISxYEARSx01] years do you think your losses and damages will be between $[DISxVALxMAX]/5 and 2x$[DISxVALxMAX]/5? __________

DISxYEARSx4

And in how many of those [DISxYEARSx01] years do you think your losses and damages will be between 2x$[DISxVALxMAX]/5 and 3x$[DISxVALxMAX]/5? __________

DISxYEARSx5

And in how many of those [DISxYEARSx01] years do you think your losses and damages will be between 3x$[DISxVALxMAX]/5 and 4x$[DISxVALxMAX]/5? __________

DISxYEARSx6

And in how many of those [DISxYEARSx01] years do you think your losses and damages will be between 4x$[DISxVALxMAX]/5 and $[DISxVALxMAX]? __________

Notes 12

Form 13. Disasters

DISASTERS

In 2012, was any member of your household affected by the January floods, the March floods, Cyclone Evan, or any other significant natural disasters? __________

YES 1

NO 2 **>> FLOODxO**

	DIS Which natural disasters affected your household in 2012? Check all that apply.	DISxALERT How did you first learn about [DISASTER]? Select one. RADIO 1 TV 2 NEWSPAPER 3 INTERNET 4 WARNING FROM GOV'T OFFICIAL 5 IN PERSON BY FRIENDS 6 PHONE CALL FROM FRIENDS 7 TEXT FROM FRIENDS 8 TEXT FROM NETWORK PROVIDER 9 SAW HEAVY RAIN COMING 10 SAW RIVER RISE 11 INCREASED HEAT, HUMIDITY 12 WATER IN THE BUILDING 13 TRADITIONAL INDICATORS/NATURE 14 OTHER (specify) 15	**DISxEVAC** Did you have to evacuate your home during [DISASTER]? YES .... 1 NO .... 2 **>> DISxHOUSE**	**DISxEVACxDAYS** For how many days did you evacuate?	**DISxEVACxAMT** How much did evacuating during because of [DISASTER] cost?	**DISxHOUSE** Was the structure of your house affected by [DISASTER]? YES ....1 NO ....2 **>> DISxDUR**	**DISxHOUSExAMT** How much was the total value of structural damage to your home resulting from [DISASTER]?	**DISxDUR** Did you lose durable goods as a result of [DISASTER]? YES .... 1 NO .... 2 **>> DISxELEC**	**DISxDURxAMT** How much was the total value of durable goods lost as a result of [DISASTER], in dollars?
JFL JANUARY FLOODS									
MFL MARCH FLOODS									
EVAN CYCLONE EVAN									
OTH OTHER (specify)									

	DISxELEC Did your household lose electricity as a result of [DISASTER]? IF VILLAGES DOES NOT NORMALLY HAVE ELECTRICITY FROM FEA, SELECT NOT APPLICABLE YES ....1 NO ....2 **>> DISxFOOD**	DISxELECxDAYS For how many days did your household lose eletricity as a result of [DISASTER]?	DISxFOOD Did members of your household have to purchase packaged foods because self-produced foods (e.g., crops, livestock, and fish) were not available as a result of [DISASTER]? YES ....1 NO ....2 **>> DISxSICK**	DISxFOODxAMT In total, how much did members of your household spend on packaged foods as a result of [DISASTER], in dollars?	DISxSICK Did you or other members of your household suffer any sickness or injury during [DISASTER]? YES ....1 NO ....2 **>> DISxTRAVEL**	DISxSICKxDESC Please describe.	DISxSICKxAMT How much did you pay for medical treatment?	DISxTRAVEL Did members of your household lose the ability to travel to places that they routinely go, such as markets and schools, as a result of [DISASTER]? YES......... 1 NO........... 2 **>> DISxWAGES**	DISxTRAVELxDAYS How many days did members of your household lose the ability to travel to such places as a result of [DISASTER]?
JFL JANUARY FLOODS									
MFL MARCH FLOODS									
EVAN CYCLONE EVAN									
OTH OTHER (specify)									

	DISxWAGES Did your household lose any wages as a result of [DISASTER]? YES ....1 NO ....2 **>> DISxPROTECT**	DISxWAGESx01 Did [PERSON 01] lose wages as a result of [DISASTER]? YES ....1 NO ....2 **>> DISxWAGESx02**	DISxWAGESxDAYSx01 How many days was [Person 01] unable to work as a result of [DISASTER]?	DISxWAGESx02 Did [PERSON 02] lose wages as a result of [DISASTER]? YES..........1 NO ....2 **>> DISxWAGESx03**	DISxWAGESxDAYSx02 How many days was [Person 02] unable to work as a result of [DISASTER]?	DISxWAGESx03 Did [PERSON 03] lose wages as a result of [DISASTER]? YES ....1 NO ....2 **>> DISxWAGESx04**	DISxWAGESxDAYSx03 How many days was [Person 03] unable to work as a result of [DISASTER]?	DISxWAGESx04 Did [PERSON 04] lose wages as a result of [DISASTER]? YES......... 1 NO........... 2 **>> DISxWAGESx05**	DISxWAGESxDAYSx04 How many days was [Person 04] unable to work as a result of [DISASTER]?	DISxWAGESx05 Did [PERSON 05] lose wages as a result of [DISASTER]? YES ....1 NO ....2 **>> DISxWAGESx06**	DISxWAGESxDAYSx05 How many days was [Person 05] unable to work as a result of [DISASTER]?
JFL JANUARY FLOODS											
MFL MARCH FLOODS											
EVAN CYCLONE EVAN											
OTH OTHER (specify)											

	DISxWAGESx06 Did [PERSON 06] lose wages as a result of [DISASTER]? YES .... 1 NO .... 2 **>> DISxWAGESx07**	DISxWAGESxDAYSx06 How many days was [Person 06] unable to work as a result of [DISASTER]?	DISxWAGESx07 Did [PERSON 07] lose wages as a result of [DISASTER]? YES .... 1 NO .... 2 **>> DISxWAGESx08**	DISxWAGESxDAYSx07 How many days was [Person 07] unable to work as a result of [DISASTER]?	DISxWAGESx08 Did [PERSON 08] lose wages as a result of [DISASTER]? YES .... 1 NO .... 2 **>> DISxWAGESx09**	DISxWAGESxDAYSx08 How many days was [Person 08] unable to work as a result of [DISASTER]?	DISxWAGESx09 Did [PERSON 09] lose wages as a result of [DISASTER]? YES .... 1 NO .... 2 **>> DISxWAGESx10**	DISxWAGESxDAYSx09 How many days was [Person 09] unable to work as a result of [DISASTER]?	DISxWAGESx10 Did [PERSON 10] lose wages as a result of [DISASTER]? YES .... 1 NO .... 2 **>> DISxPROTECT**	DISxWAGESxDAYSx10 How many days was [Person 10] unable to work as a result of [DISASTER]?
JFL JANUARY FLOODS										
MFL MARCH FLOODS										
EVAN CYCLONE EVAN										
OTH OTHER (specify)										

	DISxPROTECT Did your household take any measures to protect your property and possessions during [DISASTER]? YES......... 1 NO........... 2 **>> DISxCLEANUPxAMT**	DISxPROTECTxDESC Please describe.	DISxPROTECTxAMT In total, how much did it cost to take these protective measures?	DISxCLEANUPxAMT What were the approximate clean-up costs (such as buying detergent) resulting from [DISASTER]?
JFL JANUARY FLOODS				
MFL MARCH FLOODS				
EVAN CYCLONE EVAN				
OTH OTHER (specify)				

FLOODxO

In the past 10 years, have the members of this household been affected by flooding other than the January 2012 flood, the March 2012 flood, and flooding caused by Cyclone Evan?

YES 1

NO .... 2 **>> NOTES13**

	FLOODxOxYEARS In which of the last 10 years have members of this household been affected by flooding other than the January 2012 flood, the March 2012 flood, and flooding caused by Cyclone Evan? Select all that apply.
2003	
2004	
2005	
2006	
2007	
2008	
2009	
2010	
2011	
2012 (not including January floods, March floods, or Cyclone Evan)	
2013	

Notes 13

Form 14. Resilience to be Completed by the Respondent Himself or Herself

The survey will end soon, but before it does, I would like to ask you about life in $T{Q6}. Unlike the earlier questions, however, I would like to ask you to answer the questions on the tablet yourself!

RESILIENCExNAME

Select the name of the person answering this question. __________

PERSON 01 1
PERSON 02 2
PERSON 03 3
PERSON 04 4
PERSON 05 5
PERSON 06 6
PERSON 07 7
PERSON 08 8
PERSON 09 9
PERSON 10 10

RESILIENCExLANGUAGE

Which language do you prefer for reading?

FIJIAN 1
ENGLISH .... 2 **>> RESILIENCE2x01**

We would like to ask you to help us understand life in this village/community better.

For each of the following statements, please indicate whether you DISAGREE by moving the slider LEFT or AGREE by moving the slider right. Moving the slider all of the way to the left means that you STRONGLY DISAGREE and moving the slider all of the way to the right means that you STRONGLY AGREE. If you are neutral on the statement, you don’t have to move the slider at all.

RESILIENCE1x01
Flooding has led to problems in Ba and Ra provinces in recent years. __________

RESILIENCE1x02

Education is NOT important for the children of today. __________

RESILIENCE1x03
The church, temple, or mosque is an important part of this village/community. ___________

RESILIENCE1x04
People in this village/community work together to solve problems. ___________

ASK IF ETHNICITY=1
RESILIENCE1x05
People in this village/community have clear roles and responsibilities for carrying out tasks. ___________

RESILIENCE1x06
There are conflicts among people of this community. ___________

RESILIENCE1x07
The people of this village/community have a common vision. ___________

RESILIENCE1x08
The village/community holds meetings to deal with issues in the village/community. ___________

RESILIENCE1x09
Village/community members are involved in decision-making about the future of the village/community. ___________

RESILIENCE1x10
Women are involved in making important decisions in the village/community. ___________

RESILIENCE1x11
Young people are NOT involved in making important decisions in the village/community. ___________

ASK IF ETHNICITY=1
RESILIENCE1x12
The leadership of this village is NOT effective. ___________

RESILIENCE1x13
Traditional practices and knowledge are NOT important for solving current problems. ___________

RESILIENCE1x14
The village/community looks for new ways to solve problems. ___________

RESILIENCE1x15
The village/community is able to identify new ways to solve problems. ___________

RESILIENCE1x16
The village/community does NOT have the skills and knowledge to limit the damage from natural disasters such as flooding and drought. ___________

RESILIENCE1x17
The village/community has used new ways to limit the damage from natural disasters such as flooding and drought. ___________

RESILIENCE1x18
I can NOT depend on individuals in this village/community to help me during difficult times. ___________

RESILIENCE1x19
I can rely on groups in this village/community for assistance when times are difficult. ___________

RESILIENCE1x20
I can depend on the government for help during difficult times. ___________

RESILIENCE1x21
Organizations (OTHER THAN GOVERNMENT) outside this village/community can NOT be relied upon for help when I have problems. ___________

RESILIENCE1x22
The people of this village/community have NO control over our future. ___________

RESILIENCE1x23
Taking action now will prevent future problems in the village/community. ___________

RESILIENCE1x24
I am optimistic about the future of this village/community. ___________

RESILIENCE1x25
In general, I am willing to take risks. ___________

>>NOTES14

These questions in Fijian correspond to the English questions above.

RESILIENCE2x01

Na waluvu sa vakavuna e levu na dredre ena yasana ko Ra kei Ba ena vica na yabaki veitaravi sa oti. __________

RESILIENCE2x02

Na vuli e SEGA soti sara ni ka e bibi vei ira na luveda ena siga ni kua. __________

RESILIENCE2x03

Na veivale ni so-Kalou ni veimata-lotu e ka bibi ena tiki ni bula va-koro. __________

RESILIENCE2x04

Ko ira na lewe ni koro era dau cakacakavata me wali kina na veileqa eso. __________

ASK IF ETHNICITY=1

RESILIENCE2x05

E matata tu vei ira na lewe ni koro na nodra dui i tavi kei na kena bibi kina cakacaka rabailevu ka tu me qaravi. __________

RESILIENCE2x06

E tiko na veileti/veilecavi ena loma ni koro. __________

RESILIENCE2x07

E duavata ga vakadua na nodra vunilagi/tatadra/raivotu na lewe ni koro. __________

RESILIENCE2x08

Vakayacori tiko na bose va-koro me veitalanoataki kina na i wali ni veidredre/kauwai ka kovuta na koro. __________

RESILIENCE2x09

Ko ira na lewe ni koro era dau vakaitavi ena kena vakatulewataki na cavu i kalawa ki liu me baleta na koro raraba. __________

RESILIENCE2x10

Ko ira na marama era dau vakaitavi ena kena veitalanoataki kei na vakayacori ni veivakatulewa bibi eso me baleta na koro. __________

ASK IF ETHNICITY=1

RESILIENCE2x11

Ko ira na tabagone era SEGA ni dau vakaitavi ena kena veitalanoataki kei na vakayacori ni veivakatulewa bibi eso me baleta na koro. __________

RESILIENCE2x12

Ko ira na veiliutaki ena loma ni koro e SEGA ni vakavotukana tiko se mana na nodra cakacaka vakaveiliutaki. __________

RESILIENCE2x13

Na veikila vakaitaukei kei na kena veiqaravi e SEGA ni bibi ena kedra wali na veidredre/kauwai dau sotavi. __________

RESILIENCE2x14

Ko ira na lewe ni koro e ra dau vakasaqara na veiwali vovou kina na veidredre/kauwai eso. __________

RESILIENCE2x15

Ko ira na lewe ni koro e tu vei ira na kila me raica ka vakatovolea na i wali vovou ni veileqa eso. __________

RESILIENCE2x16

Ko ira na lewe ni koro e SEGA ni tu vei ira na kila kei na i walewale ni kena vakalailaitaki na vakacaca ka vakavuna na VEILEQA TUBU KOSO ESO (OQO ME VAKA NA: WALUVU, LAUQA NI KAKANA SE WAI, UA LOKA). __________

RESILIENCE2x17

Ko ira na lewe ni koro era sa dau vakayagataka na i walewale vovou ni kena vakalailaitaki na vakacaca ka vuna na VEILEQA TUBU KOSO ESO ena veigauna sa oti (OQO ME VAKA NA: WALUVU, LAUQA NI KAKANA SE WAI, UA LOKA). __________

RESILIENCE2x18

Au SEGA ni rawa ni vakararavi ki vua e dua tale ena loma ni koro ena gauna ni tiko leqaleqa. __________

RESILIENCE2x19

E rawa vei au me'u vakararavitaka na noqu bula kina mataveiwekani e na loma ni koro ena gauna donuya na tiko leqaleqa. __________

RESILIENCE2x20

Au rawa ni vakararavi kina matanitu me vukei au ena gauna ni tiko leqa. __________

RESILIENCE2x21
E SEGA ni tiko na veivakabauti ena veimatailawalawa e so (sega ni wili ki na matanitu levu se soqosoqo tu vakataki ira) ni rawa ni ra veivuke ena gauna ni tiko leqa. __________

RESILIENCE2x22
Ko ira na lewe ni koro e SEGA sara ga ni tu vei ira e dua na vakatulewa lailai me baleta na nodra veisiga ni mataka. __________

RESILIENCE2x23
Na kena vakayacori na veicavu i kalawa eso ni qaravi tavi ni tataqonaki ni kua ena rawa ni tarova se vakalailaitaka na veileqa ena siga ni mataka. __________

RESILIENCE2x24
E tu vei au na vakanuinuitaki ni vinaka me baleta na koro ena veisiga ni mataka. __________

RESILIENCE2x25
Ena rai raraba, au doudou meu vorata na veiririko eso e dau basika ena gauna ni tiko leqa. __________

Notes 14

Variables that are calculates automatically

TIMExINxSEC: Survey duration in seconds

5 CBA SENSITIVITY ANALYSIS ESTIMATES

Table 40. Cost-benefit analysis of adaptation to flood risk in Ba River catchment, base effectiveness (t=100 years, r=4%)

Option	NPV Benefits *(FJ$ million)*	NPV Costs *(FJ$ million)*	Total NPV *(FJ$ million)*	BC Ratio
Current Climate				
Riparian buffers	36.5	12.7	23.7	2.9
Upland afforestation	233.4	224.8	8.5	1.0
Floodplain vegetation	32.1	43.5	(11.5)	0.7
Reinforce riverbanks	60.4	118.3	(57.9)	0.5
Raise houses	0.7	14.4	(13.7)	0.1
River dredging	60.4	89.9	(29.5)	0.7
Mixed Intervention	137.4	122.4	15.1	1.1
Moderate Climate Change				
Riparian buffers	64.2	12.7	51.5	5.0
Upland afforestation	288.9	224.8	64.1	1.3
Floodplain vegetation	54.3	43.5	10.8	1.2
Reinforce riverbanks	116.0	118.3	(2.4)	1.0
Raise houses	1.5	14.4	(12.9)	0.1
River dredging	116.0	89.9	26.0	1.3
Mixed Intervention	220.7	122.4	98.4	1.8
Severe Climate Change				
Riparian buffers	117.3	12.7	104.6	9.2
Upland afforestation	395.0	224.8	170.2	1.8
Floodplain vegetation	96.8	43.5	53.2	2.2
Reinforce riverbanks	222.1	118.3	103.8	1.9
Raise houses	3.1	14.4	(11.3)	0.2
River dredging	222.1	89.9	132.2	2.5
Mixed Intervention	333.2	122.4	210.8	2.7

Table 41. Cost-benefit analysis of adaptation to flood risk in Ba River catchment, base effectiveness (t=100 years, r=12%)

Option	NPV Benefits *(FJ$ million)*	NPV Costs *(FJ$ million)*	Total NPV *(FJ$ million)*	BC Ratio
Current Climate				
Riparian buffers	12.9	4.9	8.0	2.6
Upland afforestation	93.5	93.0	0.4	1.0
Floodplain vegetation	11.6	15.1	(3.5)	0.8
Reinforce riverbanks	20.5	109.9	(89.3)	0.2
Raise houses	0.3	13.4	(13.1	0.0
River dredging	20.5	40.5	(20.0	0.5
Mixed Intervention	50.5	65.9	(15.3)	0.8
Moderate Climate Change				
Riparian buffers	22.3	4.9	17.4	4.5
Upland afforestation	112.4	93.0	19.3	1.2
Floodplain vegetation	19.1	15.1	4.0	1.3
Reinforce riverbanks	39.4	109.9	(70.5)	0.4
Raise houses	0.5	13.4	(12.9)	0.0
River dredging	39.4	40.5	(1.1)	1.0
Mixed Intervention	78.8	65.9	13.0	1.2
Severe Climate Change				
Riparian buffers	40.4	4.9	35.4	8.2
Upland afforestation	148.4	93.0	55.4	1.6
Floodplain vegetation	33.5	15.1	18.5	2.2
Reinforce riverbanks	75.5	109.9	(34.4)	0.7
Raise houses	1.1	13.4	(12.3)	0.1
River dredging	75.5	40.5	35.0	1.9
Mixed Intervention	113.2	65.9	47.4	1.7

Table 42. Cost-benefit analysis of adaptation to flood risk in Ba River catchment, low effectiveness (t=100 years, r=4%)

Option	NPV Benefits *(FJ$ million)*	NPV Costs *(FJ$ million)*	Total NPV *(FJ$ million)*	BC Ratio
Current Climate				
Riparian buffers	18.4	12.7	5.6	1.4
Upland afforestation	197.1	224.8	(27.7)	0.9
Floodplain vegetation	20.0	43.5	(23.5)	0.5
Reinforce riverbanks	36.3	118.3	(82.1)	0.3
Raise houses	0.7	14.4	(13.7)	0.1
River dredging	36.3	89.9	(53.7)	0.4
Mixed Intervention	107.2	122.4	(15.1)	0.9
Moderate Climate Change				
Riparian buffers	29.5	12.7	16.7	2.3
Upland afforestation	219.3	224.8	(5.5)	1.0
Floodplain vegetation	31.1	43.5	(12.4)	0.7
Reinforce riverbanks	69.6	118.3	(48.7)	0.6
Raise houses	1.5	14.4	(12.9)	0.1
River dredging	69.6	89.9	(20.4)	0.8
Mixed Intervention	162.7	122.4	40.4	1.3
Severe Climate Change				
Riparian buffers	50.7	12.7	37.9	4.0
Upland afforestation	261.8	224.8	36.9	1.2
Floodplain vegetation	52.3	43.5	8.8	1.2
Reinforce riverbanks	133.3	118.3	14.9	1.1
Raise houses	3.1	14.4	(11.3)	0.2
River dredging	133.3	89.9	43.3	1.5
Mixed Intervention	222.1	122.4	99.8	1.8

Table 43. Cost-benefit analysis of adaptation to flood risk in Ba River catchment, low effectiveness (t=100 years, r=12%)

Option	NPV Benefits *(FJ$ million)*	NPV Costs *(FJ$ million)*	Total NPV *(FJ$ million)*	BC Ratio
Current Climate				
Riparian buffers	6.8	4.9	1.8	1.4
Upland afforestation	81.2	93.0	(11.9)	0.9
Floodplain vegetation	7.4	15.1	(7.6)	0.5
Reinforce riverbanks	12.3	109.9	(97.6)	0.1
Raise houses	0.3	13.4	(13.1)	0.0
River dredging	12.3	40.5	(28.2)	0.3
Mixed Intervention	40.3	65.9	(25.6)	0.6
Moderate Climate Change				
Riparian buffers	10.5	4.9	5.6	2.1
Upland afforestation	88.7	93.0	(4.3)	1.0
Floodplain vegetation	11.2	15.1	(3.8)	0.7
Reinforce riverbanks	23.6	109.9	(86.2)	0.2
Raise houses	0.5	13.4	(12.9)	0.0
River dredging	23.6	40.5	(16.9)	0.6
Mixed Intervention	59.1	65.9	(6.7)	0.9
Severe Climate Change				
Riparian buffers	17.7	4.9	12.8	3.6
Upland afforestation	103.1	93.0	10.1	1.1
Floodplain vegetation	18.4	15.1	3.4	1.2
Reinforce riverbanks	45.3	109.9	(64.6)	0.4
Raise houses	1.1	13.4	(12.3)	0.1
River dredging	45.3	40.5	4.8	1.1
Mixed Intervention	75.5	65.9	9.6	1.1

Table 44. Cost-benefit analysis of adaptation to flood risk in Ba River catchment, high effectiveness (t=100 years, r=4%)

Option	NPV Benefits *(FJ$ million)*	NPV Costs *(FJ$ million)*	Total NPV *(FJ$ million)*	BC Ratio
Current Climate				
Riparian buffers	54.6	12.7	41.9	4.3
Upland afforestation	257.5	224.8	32.7	1.1
Floodplain vegetation	38.1	43.5	(5.4)	0.9
Reinforce riverbanks	96.7	118.3	(21.6)	0.8
Raise houses	0.7	14.4	(13.7)	0.1
River dredging	96.7	89.9	6.7	1.1
Mixed Intervention	167.6	122.4	45.3	1.4
Moderate Climate Change				
Riparian buffers	99.0	12.7	86.3	7.8
Upland afforestation	335.3	224.8	110.4	1.5
Floodplain vegetation	65.9	43.5	22.3	1.5
Reinforce riverbanks	185.5	118.3	67.2	1.6
Raise houses	1.5	14.4	(12.9)	0.1
River dredging	185.5	89.9	95.6	2.1
Mixed Intervention	278.7	122.4	156.4	2.3
Severe Climate Change				
Riparian buffers	184.0	12.7	171.2	14.4
Upland afforestation	483.9	224.8	259.1	2.2
Floodplain vegetation	119.0	43.5	75.4	2.7
Reinforce riverbanks	355.4	118.3	237.1	3.0
Raise houses	3.1	14.4	(11.3)	0.2
River dredging	355.4	89.9	265.4	4.0
Mixed Intervention	444.2	122.4	321.9	3.6

Table 45. Cost-benefit analysis of adaptation to flood risk in Ba River catchment, high effectiveness (t = 100 years, r = 12%)

Option	NPV Benefits *(FJ$ million)*	NPV Costs *(FJ$ million)*	Total NPV *(FJ$ million)*	BC Ratio
Current Climate				
Riparian buffers	19.1	4.9	14.1	3.9
Upland afforestation	101.7	93.0	8.7	1.1
Floodplain vegetation	13.6	15.1	(1.4)	0.9
Reinforce riverbanks	32.9	109.9	(77.0)	0.3
Raise houses	0.3	13.4	(13.1)	0.0
River dredging	32.9	40.5	(7.6)	0.8
Mixed Intervention	60.8	65.9	(5.0	0.9
Moderate Climate Change				
Riparian buffers	34.2	4.9	29.2	6.9
Upland afforestation	128.1	93.0	35.1	1.4
Floodplain vegetation	23.0	15.1	8.0	1.5
Reinforce riverbanks	63.0	109.9	(46.8)	0.6
Raise houses	0.5	13.4	(12.9)	0.0
River dredging	63.0	40.5	22.5	1.6
Mixed Intervention	98.5	65.9	32.7	1.5
Severe Climate Change				
Riparian buffers	63.0	4.9	58.1	12.8
Upland afforestation	178.6	93.0	85.6	1.9
Floodplain vegetation	41.1	15.1	26.0	2.7
Reinforce riverbanks	120.8	109.9	10.9	1.1
Raise houses	1.1	13.4	(12.3)	0.1
River dredging	120.8	40.5	80.3	3.0
Mixed Intervention	150.9	65.9	85.1	2.3

Table 46. **Cost-benefit analysis of adaptation options of flood mitigation in Penang River catchment, base effectiveness (t = 100 years, r = 4%)**

Option	NPV Benefits *(FJ$ million)*	NPV Costs *(FJ$ million)*	Total NPV *(FJ$ million)*	BC Ratio
Current Climate				
Riparian buffers	FJ 11.2	1.6	9.6	7.0
Upland afforestation	42.0	29.3	12.7	1.4
Floodplain vegetation	10.4	7.8	2.6	1.3
Reinforce riverbanks	21.2	29.4	(8.2)	0.7
Raise houses	0.0	4.8	(4.8)	0.0
River dredging	21.2	11.7	9.6	1.8
Mixed Intervention	37.7	20.0	17.7	1.9
Moderate Climate Change				
Riparian buffers	20.5	1.6	18.9	12.9
Upland afforestation	60.6	29.3	31.3	2.1
Floodplain vegetation	17.9	7.8	10.0	2.3
Reinforce riverbanks	39.8	29.4	10.4	1.4
Raise houses	0.0	4.8	(4.8)	0.0
River dredging	39.8	11.7	28.1	3.4
Mixed Intervention	65.5	20.0	45.6	3.3
Severe Climate Change				
Riparian buffers	37.8	1.6	36.2	23.7
Upland afforestation	95.1	29.3	65.8	3.2
Floodplain vegetation	31.7	7.8	23.8	4.0
Reinforce riverbanks	74.3	29.4	44.9	2.5
Raise houses	0.1	4.8	(4.7)	0.0
River dredging	74.3	11.7	62.6	6.4
Mixed Intervention	111.4	20.0	91.5	5.6

Table 47. Cost-benefit analysis of adaptation options of flood mitigation in Penang River catchment, base effectiveness (t = 100 years, r = 12%)

Option	NPV Benefits *(FJ$ million)*	NPV Costs *(FJ$ million)*	Total NPV *(FJ$ million)*	BC Ratio
Current Climate				
Riparian buffers	3.9	0.6	3.3	6.4
Upland afforestation	16.4	12.1	4.2	1.3
Floodplain vegetation	3.7	2.7	1.0	1.4
Reinforce riverbanks	7.2	27.3	(20.1)	0.3
Raise houses	0.0	4.5	(4.5)	0.0
River dredging	7.2	5.3	2.0	1.4
Mixed Intervention	13.4	12.0	1.4	1.1
Moderate Climate Change				
Riparian buffers	7.0	0.6	6.4	11.6
Upland afforestation	22.7	12.1	10.5	1.9
Floodplain vegetation	6.3	2.7	3.5	2.3
Reinforce riverbanks	13.5	27.3	(13.8)	0.5
Raise houses	0.0	4.5	(4.5)	0.0
River dredging	13.5	5.3	8.3	2.6
Mixed Intervention	22.9	12.0	10.9	1.9
Severe Climate Change				
Riparian buffers	12.9	0.6	12.3	21.3
Upland afforestation	34.4	12.1	22.3	2.8
Floodplain vegetation	11.0	2.7	8.2	4.0
Reinforce riverbanks	25.2	27.3	(2.1)	0.9
Raise houses	0.0	4.5	(4.4)	0.0
River dredging	25.2	5.3	20.0	4.8
Mixed Intervention	37.9	12.0	25.9	3.2

Table 48. Cost-benefit analysis of adaptation options of flood mitigation in Penang River catchment, low effectiveness (t=100 years, r=4%)

Option	NPV Benefits *(FJ$ million)*	NPV Costs *(FJ$ million)*	Total NPV *(FJ$ million)*	BC Ratio
Current Climate				
Riparian buffers	4.9	1.6	3.3	3.1
Upland afforestation	29.3	29.3	0.0	1.0
Floodplain vegetation	6.2	7.8	(1.6)	0.8
Reinforce riverbanks	12.7	29.4	(16.7)	0.4
Raise houses	0.0	4.8	(4.8)	0.0
River dredging	12.7	11.7	1.1	1.1
Mixed Intervention	27.1	20.0	7.1	1.4
Moderate Climate Change				
Riparian buffers	8.6	1.6	7.0	5.4
Upland afforestation	36.7	29.3	7.4	1.3
Floodplain vegetation	9.9	7.8	2.1	1.3
Reinforce riverbanks	23.9	29.4	(5.5)	0.8
Raise houses	0.0	4.8	(4.8)	0.0
River dredging	23.9	11.7	12.2	2.0
Mixed Intervention	45.6	20.0	25.7	2.3
Severe Climate Change				
Riparian buffers	15.5	1.6	13.9	9.7
Upland afforestation	50.5	29.3	21.2	1.7
Floodplain vegetation	16.8	7.8	9.0	2.1
Reinforce riverbanks	44.6	29.4	15.2	1.5
Raise houses	0.1	4.8	(4.7)	0.0
River dredging	44.6	11.7	32.9	3.8
Mixed Intervention	74.3	20.0	54.3	3.7

Table 49. Cost-benefit analysis of adaptation options of flood mitigation in Penang River catchment, low effectiveness (t=100 years, r=12%)

Option	NPV Benefits *(FJ$ million)*	NPV Costs *(FJ$ million)*	Total NPV *(FJ$ million)*	BC Ratio
Current Climate				
Riparian buffers	1.7	0.6	1.1	2.8
Upland afforestation	12.0	12.1	(0.1)	1.0
Floodplain vegetation	2.3	2.7	(0.4)	0.8
Reinforce riverbanks	4.3	27.3	(23.0)	0.2
Raise houses	0.0	4.5	(4.5)	0.0
River dredging	4.3	5.3	(0.9)	0.8
Mixed Intervention	9.8	12.0	(2.2	0.8
Moderate Climate Change				
Riparian buffers	3.0	0.6	2.4	4.9
Upland afforestation	14.6	12.1	2.4	1.2
Floodplain vegetation	3.6	2.7	0.8	1.3
Reinforce riverbanks	8.1	27.3	(19.2)	0.3
Raise houses	0.0	4.5	(4.5)	0.0
River dredging	8.1	5.3	2.9	1.5
Mixed Intervention	16.1	12.0	4.1	1.3
Severe Climate Change				
Riparian buffers	5.3	0.6	4.7	8.8
Upland afforestation	19.3	12.1	7.1	1.6
Floodplain vegetation	5.9	2.7	3.2	2.2
Reinforce riverbanks	15.1	27.3	(12.1)	0.6
Raise houses	0.0	4.5	(4.4)	0.0
River dredging	15.1	5.3	9.9	2.9
Mixed Intervention	25.2	12.0	13.2	2.1

Table 50. **Cost-benefit analysis of adaptation options of flood mitigation in Penang River catchment, high effectiveness (t=100 years, r=4%)**

Option	NPV Benefits *(FJ$ million)*	NPV Costs *(FJ$ million)*	Total NPV *(FJ$ million)*	BC Ratio
Current Climate				
Riparian buffers	17.6	1.6	16.0	11.0
Upland afforestation	50.5	29.3	21.2	1.7
Floodplain vegetation	12.6	7.8	4.7	1.6
Reinforce riverbanks	34.0	29.4	4.6	1.2
Raise houses	0.0	4.8	(4.8)	0.0
River dredging	34.0	11.7	22.3	2.9
Mixed Intervention	48.3	20.0	28.4	2.4
Moderate Climate Change				
Riparian buffers	32.5	1.6	30.9	20.4
Upland afforestation	76.5	29.3	47.2	2.6
Floodplain vegetation	21.9	7.8	14.0	2.8
Reinforce riverbanks	63.7	29.4	34.3	2.2
Raise houses	0.0	4.8	(4.8)	0.0
River dredging	63.7	11.7	52.0	5.5
Mixed Intervention	85.4	20.0	65.5	4.3
Severe Climate Change				
Riparian buffers	60.0	1.6	58.5	37.7
Upland afforestation	124.8	29.3	95.5	4.3
Floodplain vegetation	39.1	7.8	31.3	5.0
Reinforce riverbanks	118.9	29.4	89.5	4.0
Raise houses	0.1	4.8	(4.7)	0.0
River dredging	118.9	11.7	107.2	10.2
Mixed Intervention	148.6	20.0	128.6	7.4

Table 51. Cost-benefit analysis of adaptation options of flood mitigation in Penang River catchment, high effectiveness (t=100 years, r=12%)

Option	NPV Benefits *(FJ$ million)*	NPV Costs *(FJ$ million)*	Total NPV *(FJ$ million)*	BC Ratio
Current Climate				
Riparian buffers	6.0	0.6	5.4	10.0
Upland afforestation	19.3	12.1	7.1	1.6
Floodplain vegetation	4.5	2.7	1.7	1.6
Reinforce riverbanks	11.5	27.3	(15.7)	0.4
Raise houses	0.0	4.5	(4.5)	0.0
River dredging	11.5	5.3	6.3	2.2
Mixed Intervention	17.0	12.0	5.0	1.4
Moderate Climate Change				
Riparian buffers	11.1	0.6	10.5	18.3
Upland afforestation	28.1	12.1	16.0	2.3
Floodplain vegetation	7.6	2.7	4.9	2.8
Reinforce riverbanks	21.6	27.3	(5.7)	0.8
Raise houses	0.0	4.5	(4.5)	0.0
River dredging	21.6	5.3	16.4	4.1
Mixed Intervention	29.6	12.0	17.6	2.5
Severe Climate Change				
Riparian buffers	20.5	0.6	19.9	33.8
Upland afforestation	44.5	12.1	32.4	3.7
Floodplain vegetation	13.5	2.7	10.7	4.9
Reinforce riverbanks	40.4	27.3	13.1	1.5
Raise houses	0.0	4.5	(4.4)	0.0
River dredging	40.4	5.3	35.1	7.7
Mixed Intervention	50.5	12.0	38.5	4.2

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