A comparative analysis of ecosystem-based adaptation and engineering options for Lami Town, Fiji

Synthesis report

UNEP SPREP PROEP ian umces edu LAMI TOWN COUNCIL CONSERVATION INTERNATIONAL Regional Seas UN HABITAT FOR A BETTER URBAN FUTURE

FRONT COVER

Informal settlement along the river in Lami Town, Fiji © SCOPE Pacific Limited

BACK COVER

Climate awareness meeting in Lami Town, Fiji © Lami Town Council.

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Synthesis report

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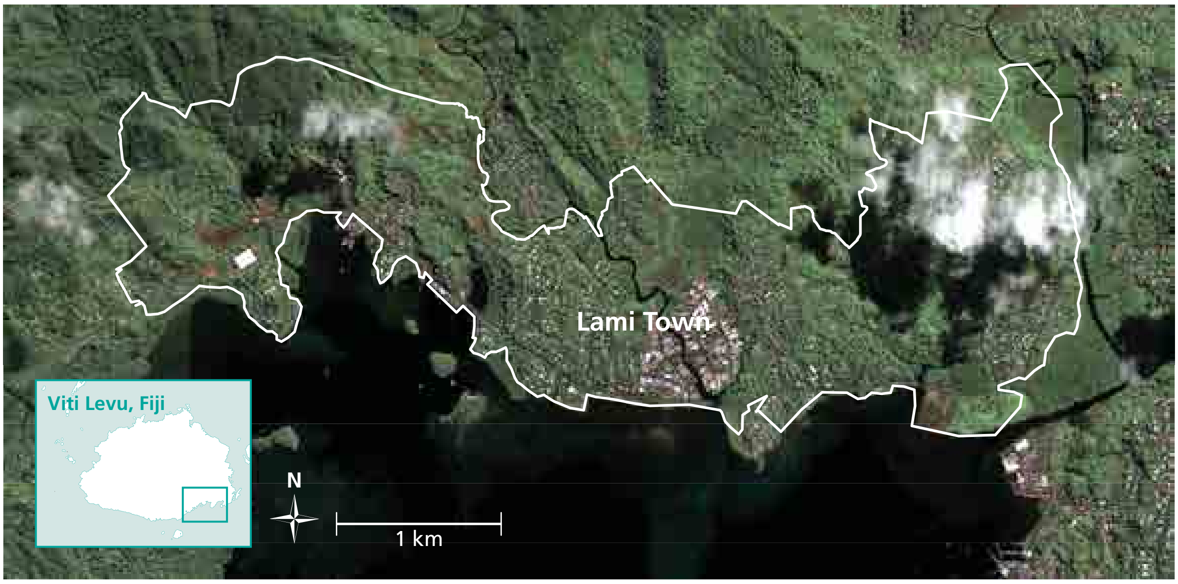
Contents

Context

This report builds on a vulnerability and adaptation assessment,[1] which provided information on key threats to natural resources and the socio-political context of Lami Town, Fiji, and identified potential adaptation options to climate change. To further analyse these adaptation options, this synthesis report presents a cost-benefit assessment of four adaptation scenarios. These scenarios represent the spectrum of ecosystem-based and engineering adaptation options to reduce vulnerability to storms, which was identified by the Lami Town Council as the principal vulnerability concern. This report is intended to be used as the basis for development of a full adaptation plan for Lami Town.

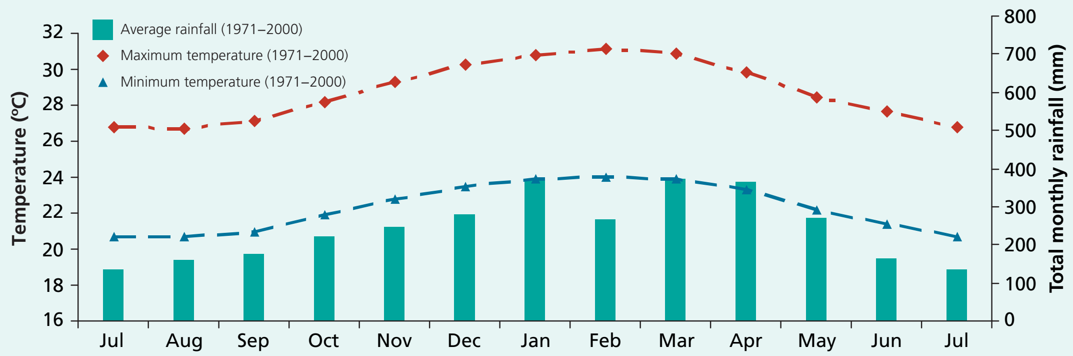
1. UN-Habitat. 2011. Cities and Climate Change Initiative: Lami Town Climate Change Vulnerability Assessment. 121pp.

An urban centre and its periphery in the wet tropics



Location of Lami Town on Viti Levu, Fiji.

Lami Town is located in Rewa Province, on the south east coast of Viti Levu, Fiji. It is directly west of Suva, being considered part of the greater Suva area, and occupies the inshore coastline of Suva Harbour. Lami Town and adjacent peri-urban areas comprise a mixture of formal and informal settlements. Approximately half of Fiji's population of 861,000 live in the greater Suva area; in 2007 the population of Lami town was 20,529. Peri-urban areas such as those adjacent to Lami Town currently have the greatest population growth in Fiji, as they provide an inexpensive option for living with easy access to urban employment opportunities. Land elevation ranges from 10–150 m above sea level, and while Lami Town is predominantly built over limestone, shallow soils susceptible to erosion characterise many of the upslope areas.



Maximum and minimum temperature ranges, and average rainfall records for Laucala Bay (Suva) from 1971–2000. Adapted from Fiji Islands Climate Summary Nov 2011.

Annual average rainfall for Lami Town ranges from 3,000–5,000 mm. The dry season is from May to October and the wet season from November to April. With a warm tropical climate, maximum annual temperatures range between 26°C and 31°C, with just 2–4°C difference between the warmest months (January – February), and the coolest months (July – August).

Protective natural resources

MANGROVE FOREST

Lami Town has 88 ha of intact coastal mangrove forest that limits shoreline erosion, reduces coastal flooding from storm surges, and supports both commercial and subsistence fisheries.

CORAL REEF

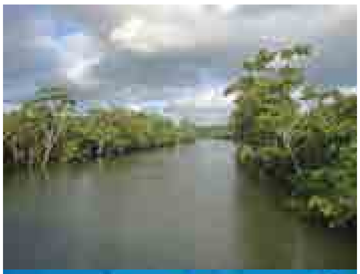
The entrance to Suva Harbour is framed by large coral reefs (1,387 ha), with some reef areas spreading throughout the harbour. These reefs influence water flows, providing coastal protection along some sections of the shoreline, as well as supporting diverse fisheries.

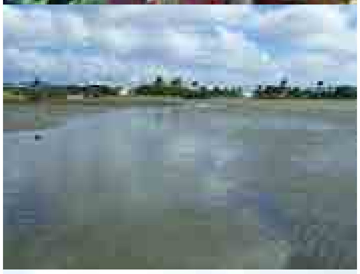
SEAGRASS AND MUDFLATS

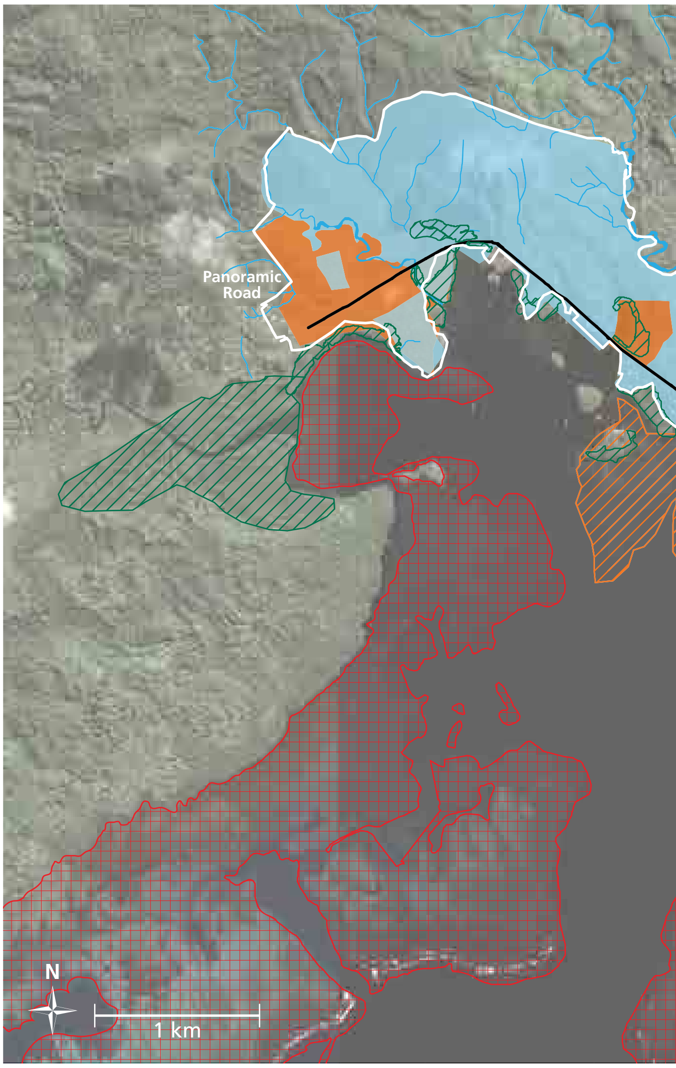
The 330 ha of mudflats occurring offshore along the large central region of Lami Town have the potential to reduce storm wave size. These mudflats are stabilised by extensive seagrass meadows, which additionally assist in accumulating further sediment.

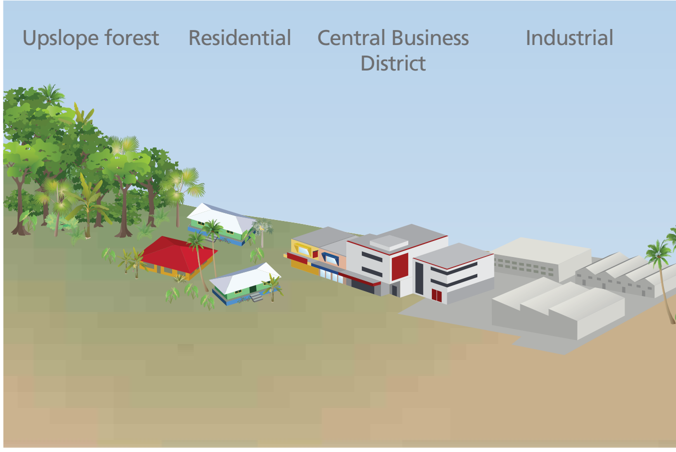
UPSLOPE FOREST

Intact forest in upslope areas of the Lami Town watershed assist in retaining the shallow surface soils in place, limiting hill slope erosion and river flooding. Lami Town still has large areas of intact forest on its northern boundary.

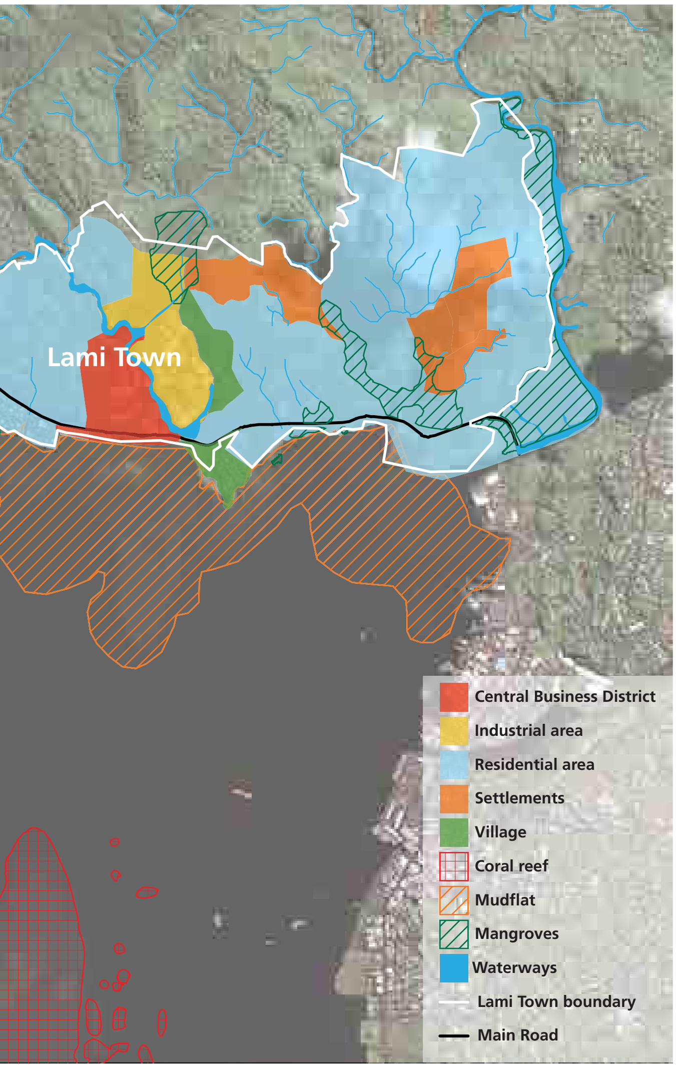


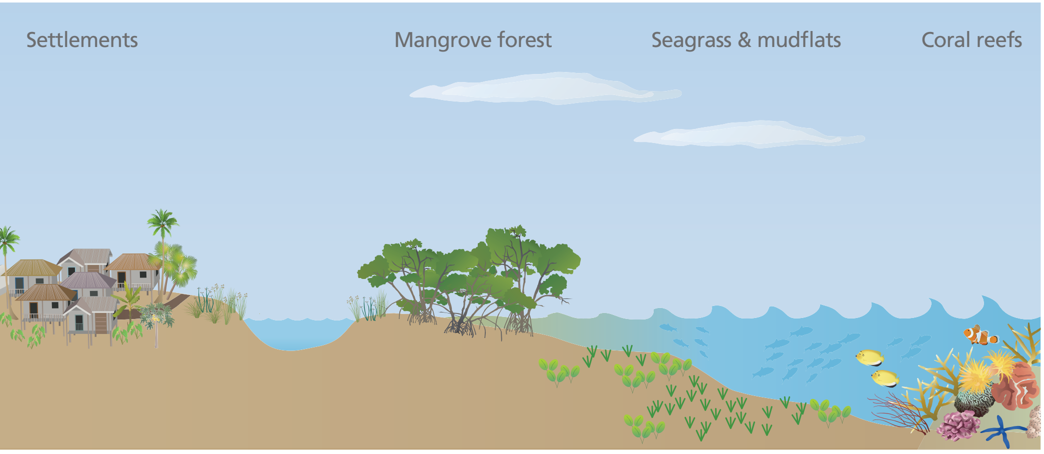






Threats from flooding are predicted to increase with climate change. Preserving intact natural ecosystems will assist in protecting Lami Town from current and future flooding.





CENTRAL BUSINESS DISTRICT

Situated on Queens Highway, the major westerly exit route from Suva, the Lami Town business district provides essential services to a large residential area as well as many informal communities.

INDUSTRIAL

Industry within Lami Town is primarily general industry such as warehouses, packaging and food processing, and garment making, with some heavy industry including paint making, battery processing, gas and chemical storage, and cement manufacturing.

RESIDENTIAL

There are seven main residential areas within the urban area of Lami Town, with a total population of approximately 10,700 people. These are mostly permanent homes with septic tanks, owned by middle to high income earners.

SETTLEMENTS

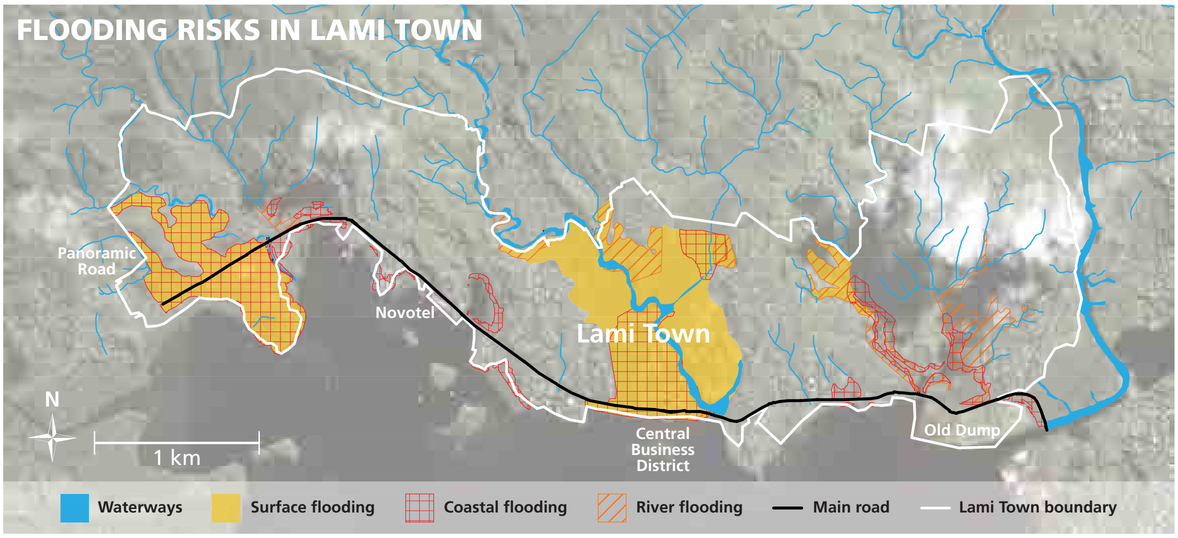
There are eight informal settlements in urban Lami Town. These areas have no formal security of tenure, but are based on communal land use by agreement (or illegal in some cases). The houses are temporary or permanent and are occupied by low to middle income earners.

There are also two traditional villages within Lami Town, Lami village and Suvavou village, with permanent houses occupied by iTaukei landowners and their families.

Vulnerability of Lami Town

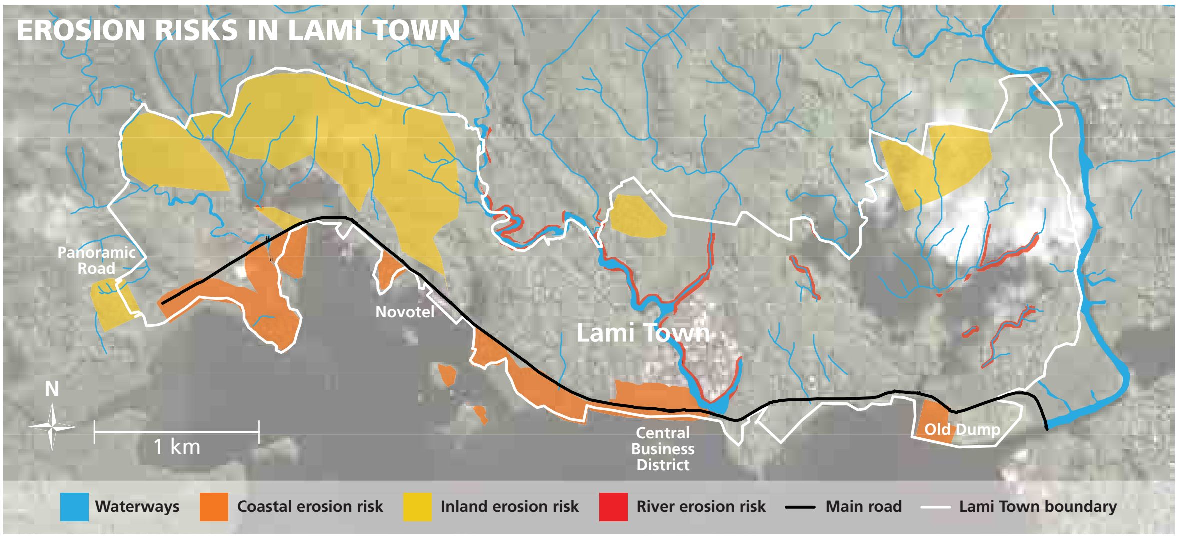
Vulnerability to flooding

The narrow coastal area of Lami Town is surrounded by steep hills, and includes three rivers flowing to the ocean. As a result, three types of flooding can occur: 1) coastal flooding as a result of storm surges or large waves from Suva Harbour; 2) flash flooding from rapidly rising rivers, especially where hillslopes have been cleared of vegetation; and 3) surface flooding where high rainfall pools in low lying areas. The coastal, riverbank, and low lying areas vulnerable to flooding are where many of the residential, industrial, and urban areas are located.



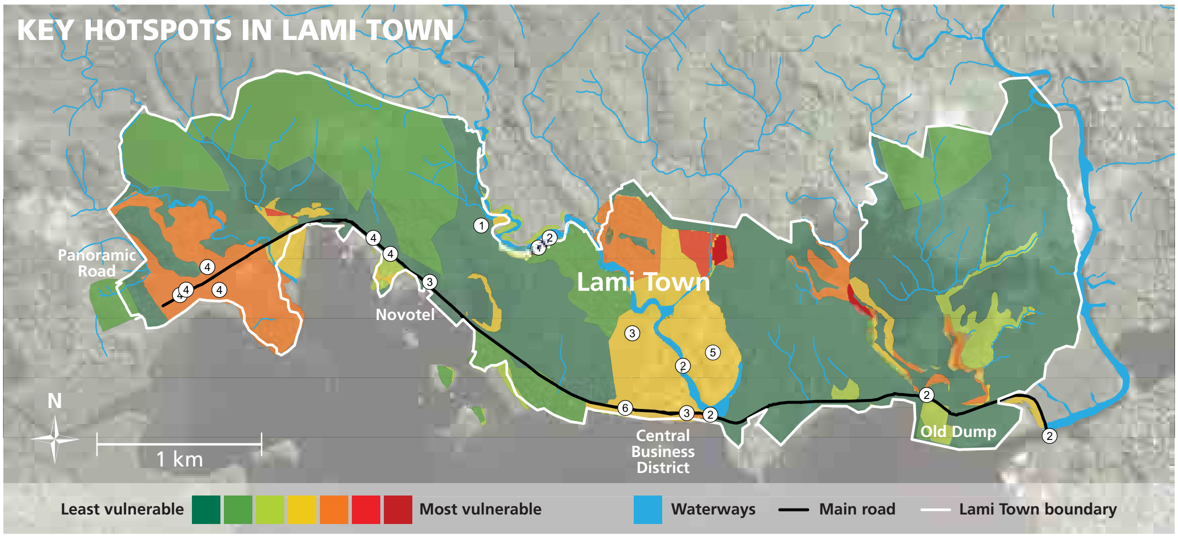
Vulnerability to erosion

Erosion in Lami Town can occur in three main ways, as a result of the proximity of a sandy coastline to steep hills drained by three meandering rivers: 1) Shoreline erosion is possible during storms from surge, waves, or longshore drift of sediment; 2) Riverbank erosion risk is present where rivers flow rapidly through the hills and where the shape of the river has been constrained by engineering; and 3) Upslope or inland erosion occurs on hill-slopes, especially after forest clearing. Due to the widespread susceptibility to erosion throughout the watershed, potential impacts on people and development are high.



Hotspots of vulnerability in greater Lami Town

Combining all flood and erosion threats shows three areas within Lami Town that are particularly vulnerable. The western region is vulnerable to coastal and surface flooding as well as coastal erosion; the region inland, including the central business district, is vulnerable to coastal, river and surface flooding as well as coastal and inland erosion; and the upper reaches of the Lami River are vulnerable to river and surface flooding and river erosion.



1. River bank erosion

These locations (including Powell Crescent, Nasevou Street, Wailada Industrial area, and Johnny Singh park) show severe river bank and soil erosion, or localised flooding with large rains and strong river flow.

2. Vulnerable bridges

Many of the strategic bridges throughout Lami Town have evidence of riverbank erosion exacerbated by being either too low (e.g., Quaiya Bridge) or being undergraded for the size and quantity of traffic (e.g., Lesi Bridge).

3. Coastal erosion

Evidence of coastal erosion resulting from storms and extreme tides is common along the Lami Town shoreline, but extreme in some areas such as Tikaram Park and the Bay of Islands Park.

4. Coastal flooding

Many of the informal settlements in and around Lami Town are particularly vulnerable to coastal flooding. These settlements are often located in mangroves, wetlands, or flood plains.

5. Wailada industrial subdivision

Being located on a flood delta region previously surrounded by mangroves, this area is highly vulnerable to flooding and erosion both from the rivers and the ocean.

6. Lami Town business district

This area is highly vulnerable, with sand overwash from the coast onto both commercial and residential properties along the Queens Highway, in addition to flooding and erosion. Very high impervious surface and low lying topography limit ability for water to dissipate.

CLIMATE CHANGE IS PROJECTED TO INCREASE FLOODING AND EROSION THREAT

- Sea level in Fiji has been rising 6 mm per year since 1993 and is projected to continue rising.
- The intensity and frequency of extreme rainfall is projected to increase.
- Total annual rainfall is projected to be similar, but more concentrated in the wet season.
- Tropical cyclones are projected to be fewer in number, but more severe.

Australian Bureau of Meteorology and CSIRO, 2011. Climate Change in the Pacific: Scientific Assessment and New Research. Volume 1: Regional Overview. Volume 2: Country Reports.

Adaptation options to reduce coastal vulnerability

A wide range of possible adaptation options are available to reduce vulnerability to negative impacts from extreme weather conditions. Many of these focus on engineering-based solutions, such as improving infrastructure or building structures to directly increase protection from waves and flooding. Historically, these are the solutions that have been predominantly used. However, additional approaches are increasingly recognised as having additional benefits beyond solely reducing the identified threat. Ecosystem-based solutions focused on preserving key habitats that offer natural protection, such as mangroves, coral reefs, and forests can additionally support ecosystem services, including fisheries and tourism. Social and policy options, including zoning and early warning systems, can also increase human well-being.

Adaptation options used to calculate cost comparisons for this report are identified as either engineering or ecosystem-based.

Example ecosystem-based options

Mangroves provide a natural barrier to storm waves and help maintain good water quality by trapping sediment and limiting coastal erosion.

REPLANT MANGROVES

Mangroves provide an effective natural barrier to storm waves. They also stabilise sediment (limiting coastal erosion), help to maintain good water quality in coastal areas, and support coastal fisheries. Maintaining intact mangrove areas may limit access to the coast for other development and infrastructure.

REPLANT STREAM BUFFER

Preserving intact vegetation along riverbanks by limiting disturbance, as well as replanting where necessary, can reduce riverbank erosion and assist in slowing river flow. Re-establishing these wetland areas is not always successful and protecting these areas may result in limited access for some purposes.

REDUCE UPLAND LOGGING

Preserving remaining upland forests by reducing clearing and upland logging, and revegetating where possible, can assist in reducing hillslope erosion, flash flooding, and reduced water quality, particularly in instances where an extreme storm event is isolated.

REDUCE CORAL EXTRACTION

Coral reef areas have the potential to provide some local protection and provide multiple ecosystem resources including sustaining fisheries, supporting tourism, and influencing local sediment processes (including beach nourishment). Limiting extraction can assist in maintaining these services, potentially reducing the need for more expensive engineering options.

MONITORING & ENFORCEMENT

Once areas have been preserved and damaging practices have been curtailed, monitoring and enforcement are required to ensure these positive actions continue.

Example policy and social options

REGULATING LAND TENURE—INFORMAL SETTLEMENTS

The Department of Housing has a National Housing Policy action plan which provides for an upgrading programme that includes regulating land tenure for informal settlements. This can improve provision of basic services to informal communities, including emergency services during extreme events.

REZONING LAND USE

Where areas have historical zonings that are now recognised for placement of new infrastructure in highly vulnerable situations, such as industrial zones in areas with high vulnerability to flooding, rezoning can assist in reducing property losses. This process needs strong evidence and, potentially, effective conflict resolution.

RELOCATION OF HIGHLY VULNERABLE HOUSEHOLDS

Households over the water amongst the mangroves or directly adjacent to the river are highly vulnerable to flooding effects. Mechanisms to move this small number of households to higher ground, even within the same settlement, could increase human well-being while improving the ecosystem services and natural protection afforded by mangroves and natural river bank vegetation. This process would need extensive consultation and community support.

FLOOD WARNING SYSTEMS AND MAPPING

Systems to provide more accurate prediction of areas likely to flood and warning mechanisms to alert communities of impending threats could have the ability to limit loss of both property and life. However they require capital expenditure, constant maintenance, training/awareness on evacuation drills, and strong links with meteorological services.

Informal settlements amongst the mangroves are highly vulnerable to coastal flooding.

Example engineering options

TOP: River bank reinforcement such as this 'gabion' basket can reduce erosion.

MIDDLE: Sea walls may interfere with natural sediment movement processes.

BOTTOM: Example of roadside drainage.

REINFORCE RIVERS

Protect river banks

Techniques to reduce river bank erosion include placing rock-filled wire 'gabion' baskets along river banks, or spall-filled reno mattresses. Reducing erosion minimises loss of property, and also limits potentially negative effects on downstream water quality. Construction and repairs are highly labour intensive, and the result is often not aesthetically pleasing.

Dredge rivers

Targeted dredging of river channels is often useful near infrastructure that constricts water flow, such as bridges. Dredging increases the capacity of the river to absorb increased flow during storm events, thereby reducing flooding. Continued investment in maintenance is required.

River realignment

In some instances, allowing water to flood into areas that currently are protected can alleviate vulnerability either for a larger area or for an area with more infrastructure and human settlements. While having positive potential benefits for protected infrastructure and ecosystems, relocation of some infrastructure may be required.

BUILD SEA WALLS

Rock, concrete, or tyre sea walls placed along vulnerable shorelines can provide protection against storm surges and coastal flooding. Due to dynamic nearshore processes, sea walls can become undercut and may interfere with natural sediment movement processes. Continued investment in maintenance is required, especially after storm events.

INCREASE DRAINAGE

Removing vegetation and debris from roadside and storm drains increases flow rates during storm events, helping to reduce flooding and vulnerability to water-borne diseases. Continued investment in maintenance is required.

IMPROVE BRIDGES

Raising and strengthening bridges can assist in maintaining access for evacuation and passage of emergency services. High capital investment and continued maintenance are required.

LAND RECLAMATION

Deposition of sediment into coastal areas below high tide can establish new land for development and infrastructure. While protection of current infrastructure may be increased, these new areas often require much stronger protection and there can be negative impacts on water quality and loss of ecosystem services from displaced habitats.

STORM SURGE BARRIERS

These solid and removable barriers are generally placed across river mouths or inlets and can be highly effective in reducing coastal flooding from storm surges. As well as being very expensive to build and maintain, they have the potential to exacerbate river flooding and to change coastal ecosystem function.

BEACH NOURISHMENT

Beach areas often experience significant erosion, due to either storm events or structures that interrupt natural sediment flow processes (for example, rock walls, piers, bridges). Addition of sand in these areas provides increased protection to property and infrastructure from future storms. Periodic replenishment is likely to be required and there can be localised reductions in water quality. Protecting reefs can contribute to beach nourishment.

BUILD SEA DYKES

Direct protection from building wide and low barriers can be highly effective in preventing damage from storm surge and high waves, without the effects of scouring. Requiring high volumes of building material as well as continual maintenance, dykes can also potentially interfere with natural coastal processes and ecosystem function.

ELEVATION OF INFRASTRUCTURE

Flood proofing can be provided by raising buildings, or using innovative building designs and materials. This approach allows infrastructure to remain in place with modification, however it is only effective in some instances where velocity of flood waters is low.

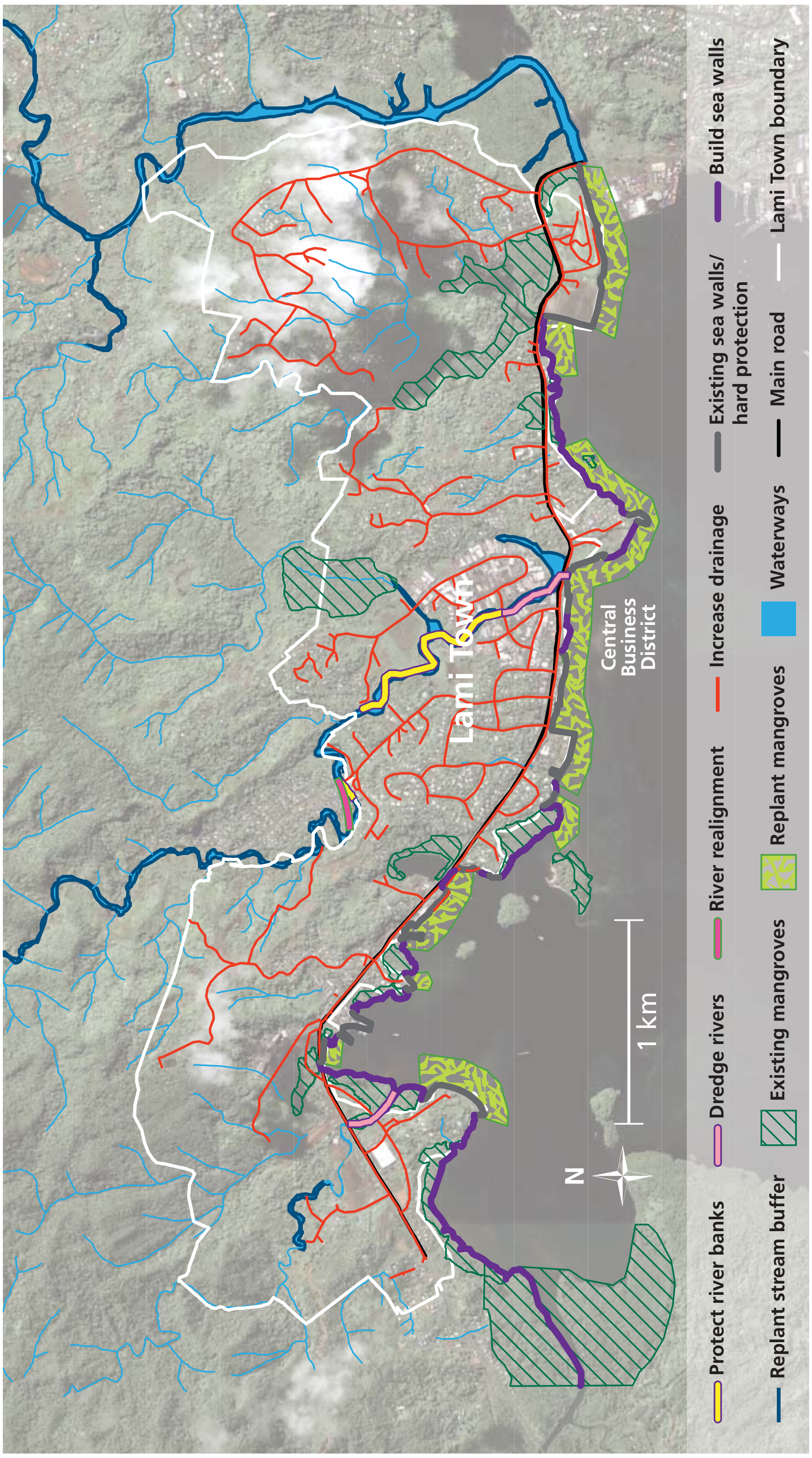
TOP: Bridge improvement is often needed to maintain emergency and evacuation access.

MIDDLE: Land reclamation can have negative impacts on water quality and reduce ecosystem services by displacing habitats.

BOTTOM: Flooding from a tidal sea wave on the foreshore at Lami Town.

Location of proposed adaptation options

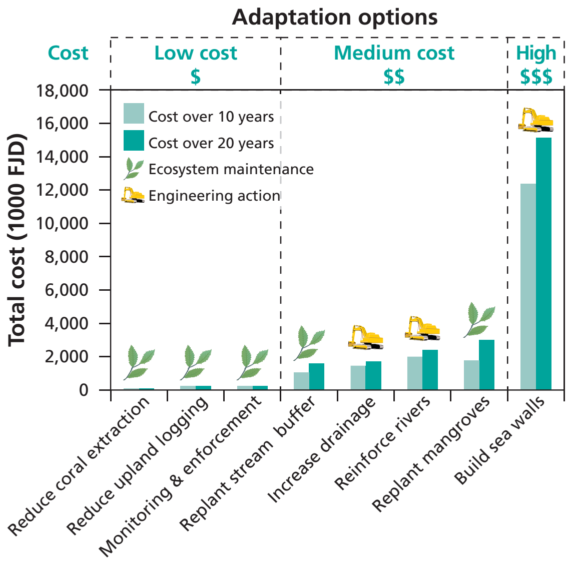
Before comparing costs of the different adaptation options throughout the Lami Town area, all possible sites for each adaptation option were identified. In some cases, multiple actions could be carried out at one site; however, in many cases it may be more appropriate to select the most effective adaptation action for a specified location.



Cost comparison of adaptation options

The least-cost analysis is an assessment of the total cost of implementing adaptation options within Lami Town. The assessment includes initial costs as well as maintenance costs over a 10- and 20-year timeframe (calculated discount rate of 3% over time). These options are grouped into low, medium, and high cost for implementation at all identified potential sites to reduce coastal vulnerability.

While the cost of some different options, such as replanting mangroves and reinforcing rivers, is comparable for full implementation across Lami Town (see graph to right), the costs per unit area (m²) or per unit length (m) are vastly different (see table below). As a cost over 20-years, replanting mangroves or streamlines costs less than FJ$5 per m², while building seawalls or reinforcing river banks costs more than FJ$2,000 per metre.



Total cost to implement adaptation options for all identified sites throughout Lami Town.

Adaptation options	Unit cost	Cost in FJD 10y	20y
Replant mangroves	m²	$2.76	$4.67
Replant stream buffer	m²	$2.88	$4.87
Increase drainage	m	$16.29	$20.00
Build sea walls	m	$1,670.00	$2,050.00
Reinforce rivers			
Protect river banks	m	$1,144.00	$1,404.00
Dredge rivers	m³	$18.52	$22.72
River realignment	m	$923.00	$1,133.00

Unit cost of adaptation options. Note that "reinforce rivers" is broken down into its three constituents: protect river banks, dredge rivers, and river realignment.

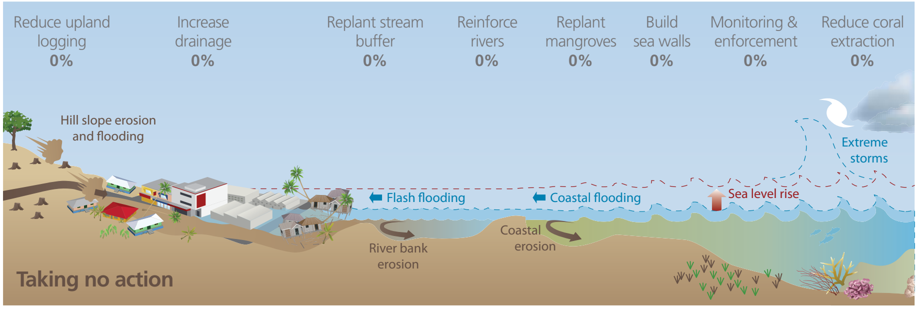
On a unit area or length basis, ecosystem-based options are orders of magnitude cheaper than engineering options; however, protection effectiveness also needs to be taken into consideration.

Estimating damages if no action is taken

DO NOTHING

Faced with high vulnerability to extreme weather events, one scenario is to take no action.

Percentage implementation of adaptation options



Avoided damages are calculated as the damages that could be incurred when no action is taken. This 'Do Nothing' scenario estimates the potential damages incurred if no action is taken, and can therefore be used as an indication of the benefits of taking action. The estimates of potential damages in Lami Town were based on studies carried out after floods in Ba and Nadi, Fiji, and included losses to businesses and households, as well as health costs. The costs of repairing government structures and provision of flood relief supplies and services were unavailable and not included in this report. Calculated over a 20-year timeframe (with a discount rate over time of 3%), potential damages were estimated at FJ$463 million. As it is recognised that some incurred damages may be less in Lami Town than in Nadi or Ba, due to differences in business type and infrastructure, 50% of this value was the maximum potential damage avoidance presented.

Taking action: comparing costs to benefits

An estimate of the dollars saved by avoiding damage for every dollar spent on implementing an adaptation option. For example, if replanting a stream buffer is assumed to provide 25% damage avoidance, for every $1 spent replanting the stream buffer, $73 dollars are saved in avoided damages.

Comparing the costs of implementing different adaptation options to the costs of damages that could potentially be avoided by implementing these options, clearly shows that the benefits of taking action outweighs the costs, in all cases. The specific amount of damages that might be avoided by any one option will be dependent on how and where options are implemented, as well as the characteristics of the storm surge event. It cannot be assumed that all options are equally effective in damage avoidance as some options rely on physical processes that are known to be less effective at dispersing wave energy. Some of the less expensive options (e.g., curtailing coral extraction or logging) would most likely avoid less than 10% of damages, while the more expensive options (e.g., planting mangroves or building sea walls) could potentially avoid more than 25% of damages.

Cost of damage avoided per dollar spent (FJD)

	Assumed % damage avoided		
Adaptation options	**50%**	**25%**	**10%**
Replant mangroves	$77	$38	$15
Replant stream buffer	$146	$73	$29
Monitoring & enforcement	$1,498	$749	$300
Reduce upland logging	$2,035	$1,018	$407
Reduce coral extraction	$2,988	$1,494	$598
Build sea walls	$15	$8	$3
Reinforce rivers	$96	$48	$19
Increase drainage	$140	$70	$28

For all adaptation options under consideration, the benefit of taking action outweighs the cost.

Estimating the value of natural ecosystems

The tropical ecosystems that surround Lami Town, including coral reefs, mangrove forest, mudflats and seagrass meadows, and upland forest, support a diverse range of ecosystem services (direct and indirect use), such as fisheries and storm protection, as well as non-use values which includes the potential for use by future generations.

Use values	Use values	Non-use values
Direct values	**Indirect values**	**Existence & bequest values**
Fishing	Nutrient retention	Cultural heritage
Aquaculture	Nutrient recycling	Resources for future generations
Transport	Flood control	Existence of specific, important species
Water supply	Storm protection	Existence of wild places
Recreation	Habitat for species	
Genetic material	Nursery ground for fisheries	
Scientific opportunities	Shoreline stabilization	
Wild resources		

Values and services provided by the natural ecosystems surrounding Lami Town.

Ecosystem	Type of value	Value (FJD)	Unit/year Hectare	Unit/year Household	Benefits (FJD year^{-1})
Mangroves	Direct	$41	-	200	$8,200
	Indirect	$471	320	-	$150,720
			Ecosystem benefits of mangroves		$158,920
Coral reefs	Direct	$521	-	10	$5,210
	Indirect	$471	1,387	-	$653,277
			Ecosystem benefits of coral reefs		$658,487
Mudflats/seagrasses	Direct	$123	-	200	$24,600
	Indirect	$139	330	-	$45,870
			Ecosystem benefits of mudflats/seagrasses		$70,470
Upland forests	Indirect	$7	1,151	-	$8,057
			Ecosystem benefits of upland forests		$8,057
Streams	Direct	$60	32.5		$1,950
			Ecosystem benefits of streams		$1,950
			Total ecosystem benefits for Lami Town		**$897,884**

Value of ecosystem services (per household or per hectare, and overall) for Lami Town over a one-year time frame.

Evaluating ecosystem services is challenging. It is important to recognise that these valuations, while significant, only contain estimates from a small number of all the ecosystem services provided and therefore are a very conservative estimate (or underestimate) of the true economic value of the ecosystems surrounding Lami Town.

Ecosystem-based adaptation options not only provide coastal protection from storms, but also help maintain significant services provided by intact coastal ecosystems.

Developing scenarios for adaptation options

Given all possible adaptation options, a relevant subset that could be fully costed were analysed to provide guidance on the best overall adaptation approaches. To assess the suite of potential adaptation options for Lami Town, the benefits and costs of four different combinations were compared with taking no action. The scenarios had a different balance of ecosystem-based and engineering options, with Scenario 1 comprised of all ecosystem-based options, Scenario 4 all engineering options, and the other two scenarios a combination of these.

Scenario 1
ECOSYSTEM-BASED OPTIONS

Focuses on maintaining the current natural protection from coral reefs, mangrove forest, mud flats and seagrass meadows, and upland forest, as well as working to preserve and re-establish these habitats to reduce vulnerability of the community. Specific adaptation options include replanting mangroves and stream buffer, reducing upland logging and coral extraction, and monitoring and enforcement.

Scenario 2
EMPHASIS ON ECOSYSTEM-BASED OPTIONS

Includes a wide range of adaptation options, however the predominant choices are for ecosystem-based rather than engineering options.

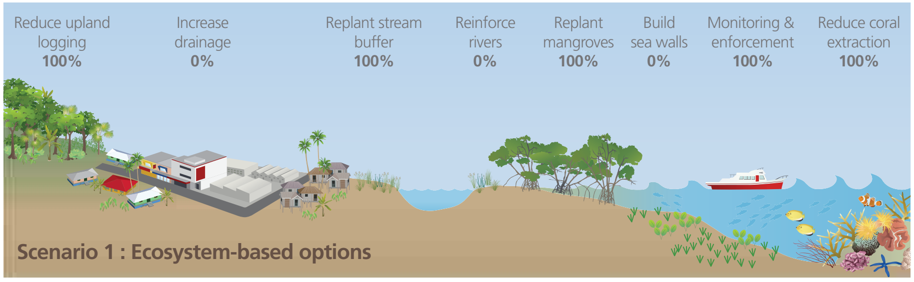
Scenario 3
EMPHASIS ON ENGINEERING OPTIONS

Includes a wide range of adaptation options, however the predominant choices are for engineering rather than ecosystem-based options.

Scenario 4
ENGINEERING OPTIONS

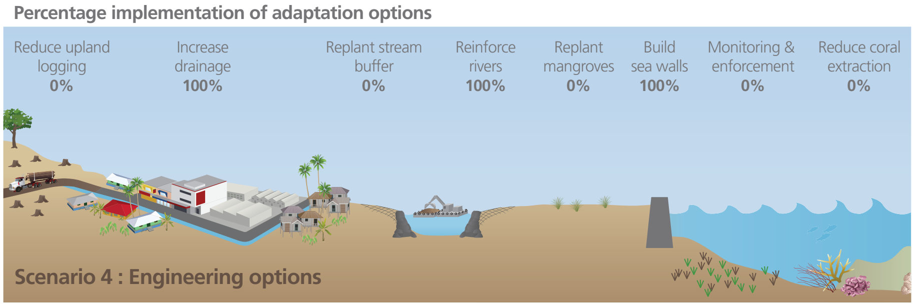
Focuses on engineering options targeted to improve current infrastructure, taking actions to limit the effects of severe weather on that infrastructure and the building of protective barriers in streams and along the shoreline. Specific adaptation options include building sea walls, reinforcing rivers (dredging, river realignment, and protecting river banks with gabion baskets or spall-filled reno mattresses), and increasing drainage.

Percentage implementation of adaptation options



Percentage implementation of adaptation options				
	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Adaptation options	Ecosytem-based options	Emphasis on ecosystem-based options	Emphasis on engineering options	Engineering options
Replant mangroves	100%	75%	25%	0%
Replant stream buffer	100%	75%	25%	0%
Monitoring & enforcement	100%	40%	20%	0%
Reduce upland logging	100%	50%	20%	0%
Reduce coral extraction	100%	50%	20%	0%
Build sea walls	0%	25%	75%	100%
Reinforce rivers	0%	25%	75%	100%
Increase drainage	0%	25%	75%	100%

Percentage implementation of adaptation options



Greatest benefits? Focus on ecosystem-based options

For all four scenarios of adaptation options, implemented at suggested locations throughout Lami Town, estimated benefits ranged from FJ$8 to FJ$19.50 for every dollar spent on coastal adaptation. Results were based on a 20-year time horizon (and 3% discount rate – where benefits in the future count as less important than immediate benefits). The benefits included avoided damages in terms of health costs and potential damage to businesses and households, as well as ecosystem services maintained or enhanced. The highest ratio of benefit-to-cost was for ecosystem-based options, with a benefit of $19.50 for every dollar spent, with an assumed damage avoidance of 10–25%.

Scenario	Benefit-to-cost ratio (FJD)	Assumed damage avoidance
Ecosystem-based options	$19.50	10–25%
Emphasis on ecosystem-based options	$15.00	25%
Emphasis on engineering options	$8.00	25%
Engineering options	$9.00	25–50%

Benefit-to-cost ratio for each scenario of adaptation options, and assumed damage avoidance.

Effectiveness of adaptation options at avoiding damages

While there is no agreed method for quantifying how effective each adaptation option is at reducing potential damage from a storm surge, it should be acknowledged that appropriately designed hard infrastructure will, in most circumstances, be more effective in reducing potential damages than ecosystem-based alternatives. There are few studies that specifically document actual or predicted effectiveness of adaptation options; however, one study of the Indian Ocean tsunami in Aceh suggested that shorelines with some protection had 2–30% reduction in structural damage, and another study has suggested that for every metre of intact vegetation, wave height can be reduced by 0.26–5.0%. As such, for coarse analyses it is suggested that hard infrastructure interventions would be more likely to approximate 25–50% effectiveness in damage avoidance, and ecosystem-based options would generally be more likely to provide 10–25% damage avoidance.

Benefits are increased when ecosystem-based adaptation options are included, attaining ecosystem maintenance in addition to coastal protection.

Socio-political implications of adaptation options

Option	Details of the option	Social
ENGINEERING OPTIONS		
Bridge improvements	Raise and upgrade bridges.	• Public consultation and awareness, particularly for those residing near bridges and high-users.
Reinforce river bank	Reinforce river bank using gabion baskets.	• Public consultation and awareness, particularly for those residing near bridges and high-users.
Dredge river	Remove extra sediments.	• Public consultation and awareness, particularly for those residing near the river.
Increase drainage	Clear out any blocked drains.	• Public awareness on littering and securing loose soil.
Build sea walls	Build sea walls with concrete, rock, or tyres.	• Community awareness and engagement of private sector and schools.
ECOSYSTEM-BASED OPTIONS		
Coastal revegetation	Replant mangroves, forests.	• Needs community support in order to be successful. Lami Town residents are largely dependent on mangroves for subsistence so should be supportive of any replanting schemes. Some settlements have piggeries located in mangroves—these may need to be relocated.
Conservation of mangroves, seagrasses/ mudflats, coral reef, forests, river buffer areas	Protect natural systems through monitoring and surveillance to limit extractive activities.	• Needs strong communication to engage community in recognising the benefits (e.g., shoreline protection, maintenance of inshore fisheries, erosion control) and the benefits of keeping these habitats intact and healthy.
POLICY AND SOCIAL OPTIONS		
Rezoning areas	Rezone areas such that building industrial or residential areas in vulnerable zones would not occur.	• Needs strong engagement from land trustees and descendants.
Regulating land tenure of informal settlements	Implement Fiji national housing policy that addresses the need to formalise the informal settlements in order to provide assistance.	• Community consultations to integrate settlements into disaster response plan.
Coastal relocation	Relocate people from vulnerable, coastal settlements to higher, drier areas.	• Initiate discussions with vulnerable communities and leaders to increase awareness of risk and improve understanding of the need to relocate.
River relocation	Relocate people from vulnerable riverine settlements to drier areas.	• Initiate discussions with vulnerable communities and leaders to increase awareness of risk and improve understanding of the need to relocate.
Disaster response planning	Develop a disaster response plan involving the community and the private sector.	• Public consultation and awareness.

Institutional	Governance
• The Fiji Roads Authority is responsible for maintenance of all roads and bridges.	• National – Fiji Roads Authority.
• Department of Environment is responsible for replanting and erosion control. National Disaster Management Office also has funding to assist with controlling river bank erosion.	• National – Department of Environment and National Disaster Management Office.
• The Ministry of Agriculture is responsible for all dredging works in Fiji.	• National – Land and Water Resource Management Department, Ministry of Agriculture.
• Lami Town council is responsible for inlets and Fiji Roads Authority is responsible for outlets.	• National – Fiji Roads Authority in consultation with Lami Town Council, and private sector on industrial sites.
• Multiple options including revegetation, tyres through to concrete seawalls.	• National – Department of Lands, Department of Environment, Lami Town Council with the private sector.
• The mangrove sub-committee under the National Integrated Coastal Management Committee is responsible for sustainable mangrove management at the national level.	• National – working with Department of Environment, Lami Town Council and the public/community.
• The Departments of Fisheries, Forests, and Lands have been working together to stregthen conditions for licenses to cut mangroves.	• National – working with Department of Environment on community and public awareness and with the Department of Fisheries, Forests, and Lands with mangrove licenses.
• Department of Town and Country Planning and Lami Town Council to review Lami Town's Planning Scheme to incorporate climate impacts and climate projections.	• National – Department of Town and Country Planning, Ministry of iTaukei Affairs, and Lami Town Council.
• Department of Housing is engaged in upgrading and regulating land tenure for informal settlements.	• National – Department of Housing and the national housing policy implementation action plan.
• Department of Housing has settlement upgrading and relocation funds to provide basic services to relocated households.	• National and local – Department of Environment with awareness raising; Lami Town Council and National Disaster Management Office developing local disaster preparedness and response time; Department of Lands and Department of Housing for relocation.
• National Disaster Management Office (NDMO) cannot offer assistance for informal settlements during flooding events; the national Climate Change policy recognises need to address impacts in regards to the urban development and housing sector.	• National and local – Department of Environment with awareness raising; Lami Town Council and National Disaster Management Office developing local disaster preparedness and response time; Lands and Housing for relocation.
• Lami Town Council has taken the initiative to work directly with NDMO in developing a disaster response plan that involves the community and private sector, has liaised with SPC–SOPAC Community Risk programme for tsunami mapping and secured through them signage and early warning system (AusAID).	• National and local – Lami Town Council in conjunction with NDMO, SPC–SOPAC, and AusAID.

Conclusions and recommendations

Conclusions	Recommendations
• Intact mangroves, forests, seagrass, mud flats, and coral reefs provide natural capital, by reducing flood and erosion potential while providing secondary ecosystem services, such as supporting inshore artisanal fisheries.	• **Protect and maintain** intact mangroves, forests, seagrass, mud flats, and coral reefs as a priority action, representing the cheapest options with greatest benefit-to-cost ratios.
• Lami Town has high vulnerability to flooding and erosion of industrial, commercial and residential buildings.	• **Target engineering options** to protect priority areas of built capital.
• An adaptation plan focused on ecosystem-based options, including targeted engineering options, will provide a high benefit-to-cost return in terms of avoided damages as well as provision of secondary ecosystem services.	• **Include social and policy initiatives** into an integrated adaptation plan, to complement ecosystem-based and targeted engineering options.
• Potential damages in Lami Town were estimated to be up to FJD 232 million, while implementation of all costed adaptation options was estimated to cost approximately FJD 24 million over 20-years.	• **Support planning** and prioritising of adaptation action strategies by determining the recipients of benefits from the different options, as well as identifying potential co-benefits (such as local employment).
• Built capital in Lami Town is very high in the most vulnerable areas, in close proximity to the coast and rivers.	• **Develop** a high resolution elevation map of Lami Town (including bathymetry) as a basis to further identification of priority sites for adaptation action, enable storm surge and flood modelling, and development of a specific flood height-Damage curves to inform a site-specific adaptation action plan.
• There are some large data gaps regarding both costs and effectiveness of different adaptation options, limiting support of informed decision making.	• **Examine assumptions** on the relative effectiveness of ecosystem-based and engineering adaptation options in order to determine which benefit-to-cost ratios to use as a part of decision-making, alongside other non-economic analyses of vulnerability, risk, social and political issues.
• The current analysis, focused on coastal and river areas, could be enhanced with expanded consideration and costings of watershed, policy and social options.	• **Refine economic analysis** using flood height-damage curves, elevation maps, watershed analysis, and costs for policy and social options as estimated by local economists.

Process for decision making

This cost-benefit analysis aimed to guide adaptation planning and implementation decisions within Lami Town Council. The following decision-making process illustrates the role of this report in the context of the broader adaptation planning process. The process for decision-making in other sites could follow the planning process used for Lami with modifications as necessary.

1

Identify key areas of vulnerability and possible adaptation options through a vulnerability assessment process.

Involves: Assessment of climate exposure.

2

Conduct a cost-benefit assessment of adaptation options identified in step one.

Involves: Least-cost analysis; benefit-cost assessment using avoided damage assessment; sensitivity analysis.

3

Detailed assessment and design of preferred adaptation options.

May involve: Visual inspection by experts, spatial analysis, storm surge modelling, flood modelling. Requires coastal engineering and restoration expertise.

4

Implementation of preferred adaptation options.

May involve: Partnerships between communities, government officials, and/or local and international contractors.

5

Monitoring and evaluation.

May involve: Assessment of community awareness, community participation, and effectiveness of adaptation options.

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More information

For more information, please see the full technical report:

Rao N.S., Carruthers T.J.B., Anderson P., Sivo L., Saxby T., Durbin, T., Jungblut V., Hills T., Chape S. 2012. **An economic analysis of ecosystem-based adaptation and engineering options for climate change adaptation in Lami Town, Republic of the Fiji Islands.** A technical report by the Secretariat of the Pacific Regional Environment Programme.

Both of these publications are available electronically at: **www.sprep.org** and **ian.umces.edu**

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