Fiji

TECHNOLOGY NEEDS ASSESSMENT REPORT ADAPTATION

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FOREWORD

As a Small Island Developing State, Fiji is severely impacted by both the slow and sudden onsets of climate change induced by global dependence on unsustainable fossil fuels. Rising sea levels engulfing low-lying coastal communities, saltwater intrusion reducing arable land, changing weather patterns impacting food security, and catastrophic cyclones reversing years of development progress while threatening fiscal stability are major climate-induced adversities Fiji faces. These adversities tremendously impact sustainable livelihoods, security and well-being and contribute to an increased incidence of poverty and undue pressure on social services.

These vulnerabilities present the apparent need for enhanced climate adaptation and resilience. While Fiji's National Adaptation Plan provides the strategy to reduce climate vulnerability, the need to identify relevant technologies to facilitate the implementation of this plan has never been so urgent. Fiji is also committed to transitioning towards a low-carbon future in line with its 5-year and 20-Year National Development Plan, its NDC commitments under the Paris Agreement and its Low Emission Development Strategy 2018-2050. Enhancing investments in resilient renewable solutions now will reduce the need for increased climate adaptation in the future. Additionally, minimum dependence on non-renewable energy would ultimately free up fiscal resources for investments in climate adaptation and socio-economic development while improving macro-economic stability.

Urgent climate action is imperative for Fiji to achieve its development aspirations. However, this is hindered by slow technological mobilisation coupled with inadequate knowledge transfer and limited financial capacity, all of which exacerbate systemic failures in addressing key drivers of climate vulnerability and inaction. This Technology Needs Assessment (TNA) process is fundamental in helping to bridge this gap and ascertain the technological needs for transformative climate adaptation and mitigation initiatives at the national and sub-national level.

In this regard, the Fiji TNA has been developed through extensive stakeholder engagements with Government agencies, private sector, financial institutions, academia, project developers and local technology experts. This collaborative approach enabled the identification of various technology needs for the agriculture sector and low-lying coastal communities that, according to the National Adaptation Plan and Fiji's Climate Vulnerability Assessment, are amongst the most climate-vulnerable sectors in Fiji. From a mitigation perspective, the Fiji TNA takes a two-pronged approach of increasing access to renewable energy and reducing economy-wide dependence on fossil fuels to identifying rural electrification and greening domestic maritime shipping as priority sectors for Fiji's TNA.

Fiji is proud to have completed its TNA as a proactive step towards effective resource mobilisation for climate action. We look forward to undertaking further assessments to identify technological gaps and operationalise Fiji's TNA by developing sectorial Technology Action Plans as the next important step in the process. Technology is regarded as humankind's greatest enabler against perils, and Fiji stands ready to harness this potential in order to address the adversities of climate change.

Makereta Konrote
Permanent Secretary for Economy

LIST OF ACRONYMS

ACIAR	Australian Center for International Agriculture Research
ABM	Australian Bureau of Meteorology
CCICD	Climate Change and International Cooperation Division
CMIP5	Coupled model Inter-comparison Project (Phase 5)
CSA	Climate Smart Agriculture
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CVA	Climate Vulnerability Assessment
ENSO	El- Niño Southern Oscillation
FFS	Farmers Field School
GDP	Gross Domestic Product
GGF	Green Growth Framework
HIES	Household Income and Expenditure Survey
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management
INM	Integrated Nutrient Management
LEDS	Low Emission Development Strategy
MCA	Multi-Criteria Analysis
NAP	National Adaptation Plan
NCCP	National Climate Change Policy
NCD	Non-Communicable Diseases
NDP	National Development Plan
PACC	Pacific Adaptation to Climate Change
RCP	Representative Concentrations Pathway
SALT	Sloping Agricultural Land Technology
SC	Steering Committee
SLR	Sea Level Rise
SPC	Pacific Community
SPCZ	South Pacific Convergence Zone
TNA	Technology Needs Assessment
UNFCCC	United Nations Framework Convention on Climate Change
UNEP	United Nations Environment Programme

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EXECUTIVE SUMMARY

A Technology Needs Assessment (TNA) is a set of activities that identify and analyse technology priorities for mitigation and adaptation of developing countries such as Fiji. The TNA project has allowed Fiji to identify climate technology pathways that assist in the implementation of the Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC). The process is country-driven, requiring heavy stakeholder engagement and local capacity building. The scope and depth of the Fiji TNA is well aligned to our national development objectives and allows national stakeholders to explore synergies with other national processes, striving towards the implementation of Nationally Determined Contributions and National Adaptation Plans.

The TNA is entailed in a three-stage process and has three key objectives:

a) To identify and prioritise mitigation and adaptation technologies for selected sectors;

b) To identify, analyse and address barriers hindering the deployment and diffusion of the prioritised technologies, including the enabling framework for these technologies;

c) To conduct a Technology Action Plan, which is a medium/long-term plan for increasing the implementation of identified technologies, based on the inputs obtained from the previous two steps. The Technology Action Plan outlines actions to be undertaken.

Fiji's TNA is focused on agriculture and coastal communities as priority sectors under the adaptation component of the project. On the mitigation forefront, the sectors selected to undergo a needs assessment included domestic maritime shipping and rural electrification. The sectors undergone assessment were informed by national policies and selected by the technical team at the Climate Change and International Cooperation Division (CCICD). CCICD has the responsibility of mainstreaming development in Fiji that is related to climate change mitigation and adaptation. As part of this first deliverable of the three in this process, the national consultants prepared technology factsheets (TFS) for several technologies with the assistant of sectoral experts. Technologies were streamlined by the technical working group before being presented before a wider national stakeholder audience. Three technologies prioritised under each sector underwent a thorough selection and scoring process. This selection process was referred to as the Multiple Criteria Analysis (MCA). The MCA is an 8-step process involving: (1.) providing decision context on the sectors; (2.) identifying technologies; (3.) identifying objectives and criteria; (4.) scoring; (5.) weighting of criteria; (6.) combing scores and weights; (7.) examination and validation of results; and (8.) sensitivity analysis based on the social, economic and environmental aspects needed for the successful implementation of the technology. To validate the results, the outcomes of the MCA underwent a sensitivity analysis repeating steps 4 to 7 of the MCA.

Fiji is a group of 332 or so islands dispersed over 1.3 million km^2 of the Ocean, with a national population of 884, 887 people, 55.9% of whom live in urban areas and 44.1% of whom reside in rural communities including islands and highlands. Fiji's contribution to global greenhouse-gas emissions is insignificant in comparison to our level of vulnerability due to climate change. Some of our key challenges as an archipelago country include inter-island travelling, food security, rising tides and sea levels, and providing Fijians living in remote areas with basic electricity. Hence the choice of sectors for our TNA.

A comprehensive stakeholder engagement process was required to undertake the country-driven technology needs assessment. The heart of this stakeholder engagement process lay in bilateral between stakeholders on the TFS, email exchanges, and workshops to enhance understanding and transfer vital information about the sector plans and priorities. While the comprehensive reports on the TNA for mitigation and adaptation have been presented as two separate reports, this summary will shed light on the technologies that have been prioritised by the people of Fiji. The technologies will contribute to and enhance the Fijian Government's ongoing efforts in ensuring a resilient and low-carbon economy.

In order to address the vulnerability areas under the Climate Vulnerability Assessment (CVA) and achieve the adaptation goals of the National Adaptation Plan (NAP), national stakeholders prioritised Agro-forestry; Integrated Nutrient Management and Improved Crop varieties for making a resilient agricultural sector. Similarly, the technologies prioritised for protection coastal communities included: Construction of Sea Wall with Gryones; Mangrove Rehabilitation; and Flood hazard mapping.

The results and outcomes from the prioritisation exercise will next undergo a barrier assessment in the implementation of prioritised technologies and the preparation of technology action plans for the deployment of these technologies.

CHAPTER 1: INTRODUCTION

1.1 ABOUT THE TNA PROJECT

The Technology Needs Assessment (TNA) process originated from the Poznan Strategic Programme on Technology Transfer established at the Fourteenth Conference of the Parties (COP 14) to the United Nations Framework Convention on Climate Change (UNFCCC), with the purpose to scale up investment in technology transfer thus empowering developing countries to address their requirements for environmentally sound technologies.

A TNA is a country-driven process, grounded in national sustainable development plans, building national capacity and facilitating the analysis and prioritisation of climate technologies to support the implementation of the UNFCCC Paris Agreement. TNAs are central to the work of Parties to the Convention on technology transfer and present an opportunity to track on evolving needs for new equipment, techniques, and practical knowledge and skills, which are necessary to mitigate greenhouse gas emissions and reduce the vulnerability of sectors and livelihoods to the adverse impacts of climate change. The enhancement of technology development, its transfer, deployment and dissemination is a key pillar of the international response to climate change.

The Cabinet officially endorsed Fiji to participate in the third phase of the Technology Needs Assessments (TNA Phase III) Project (GEF-6, 2017) in January 2019. This was followed by the signing of a Memorandum of Understanding with UNEP DTU Partnership (UDP) for conducting a Technology Needs Assessment Project in Fiji in February 2019. The scope and depth of the TNA is well aligned to national development objectives and allows national stakeholders to explore synergies with other national processes, striving towards the implementation of Fiji's Nationally Determined Contributions and National Adaptation Plan.

The TNA is a three-stage process and has three key objectives:

a) To identify and prioritise mitigation and adaptation technologies for selected sectors;

b) To identify, analyse and address barriers hindering the deployment and diffusion of the prioritised technologies, including the enabling framework for these technologies;

c) To conduct, based on the inputs obtained from the previous two steps, a Technology Action Plan, which is a medium/long term plan for increasing the implementation of identified technologies. The Technology Action Plan outlines actions to be undertaken.

1.2 EXISTING NATIONAL POLICIES RELATED TO TECHNOLOGICAL INNOVATION, ADAPTATION TO CLIMATE CHANGE AND DEVELOPMENT PRIORITIES

1.2.1 National Circumstances

Fiji consists of some 332 islands dispersed over 1.3 million km^2 of the Ocean, with a total land area of 18,300square kilometres. Only 110 islands are inhibited, and the settlements and developments are generally along the coast, mostly because mountainous terrain makes the interior inaccessible in the larger two islands. In addition, the small inland population does not justify significant development investments in rural zones. Fiji has a characteristically tropical climate. The country has two distinct climatic seasons – a warm and wet season from November to April and a cooler and dry season from May to October. The mountain ranges are also responsible for the wet and dry sides of the main islands, Viti Levu and Vanua Levu. Rainfall pattern is highly variable in Fiji, with the eastern side of Viti Levu and Vanua Levu receiving more rain. The eastern side of each island receives 3 – 5 meters of annual rainfall as compared to 2 – 3 meters of rainfall on the western side (GoF, 2017a). On the west side of Viti Levu, South East trade winds generally prevail. The movement of the South Pacific Convergence Zone (SPCZ) also affects the rainfall pattern in the country (GoF, 2017a). Generally, the average temperature is around 25°C and reaches about 30°C during the hotter and wetter season. Fiji's climate is mostly controlled by a natural climate driver called the El Niño Southern Oscillation (ENSO). There are two extreme phases of ENSO: El Niño (drier and cooler than normal) and La Niña (wetter than normal), and obviously a neutral phase. The major droughts in the country that occurred in 1987, 1992, 1997 – 1998, 2003 and 2010 were all associated with the El Niño events (GoF, 2017a).

The population of the country is 884, 887 (2017 Census). According to the 2017 national census, the population grew by 0.6% as compared to the earlier census in 2007. An alarming revelation is that the rural-urban drift has grown by 16.3%, with a subsequent decrease of 5.3% in rural population. The urban area holds 55.9% of the total population, while 44.1% resides in rural communities. The census also revealed that the median age of the population in the country is 27.5 years. According to the 2013 – 2014 Household Income and Expenditure Survey (HIES), 19.8 % of the urban households were below the basic-needs poverty line as compared to 36.7 % of the rural households.

Fiji is classified as a developing-country economy, with a GDP of 5.524 billion. The GDP growth rate is forecasted to be 2.7 % in 2019 and + 2.9 % for 2020 (before the onset of the coronavirus pandemic). The economy is one of the fastest-growing and dynamic among the neighbouring Pacific Islands, as it is endowed with agriculture, forest, mineral and fish resources. The country has a large subsistence agriculture sector generally contributing 18% of GDP. The sugarcane industry was traditionally the backbone of the national economy, but has declined since 1990 largely due to land tenure issues. On the other hand, the tourism sector has risen to become the country's most powerful earner of foreign reserves. To strengthen economic growth, a 5-year and 20-year National Development Plan was devised, with the main objective to quadruple per capita GDP by 2036. Nonetheless, natural hazards and climate change are real challenges in achieving significant increase in GDP. For example, Tropical Cyclone Winston, a category 5 cyclone that struck Fiji in February 2016, caused damage of approximately FJD $2 billion, which is equivalent to 20% of 2017 national GDP (Mansur et al., 2017). It is anticipated that future GDP growth would be hampered by increases in urbanisation and development along the coastlines, which would increase Fiji's vulnerability to the impacts of climate change such as sea level rise, coastal flooding due to storm surges, ocean acidification and increased risk of flooding, which all have dire consequences for national economic development.

1.2.2 National Strategies, Policies and Actions Related to Climate Change

5-Year and 20-Year National Development Plan

The National Development Plan (NDP), with the title "Transforming Fiji," consists of a 20-year plan (2017 – 2036) and a more comprehensive 5-year plan (2017 – 2021) to charter a way forward for the national economy to be more progressive, vibrant, inclusive and climate resilient (GoF, 2017b). The plan adopts two approaches, that is, Inclusive Socio-Economic Development and Transformational Strategic Thrusts. The NDP sets ambitious objectives for the country such as:

1. Fourfold increase in GDP per person by sustaining annual real GDP growth average of 4 – 5 %.
2. Reducing government debts to 35% of GDP
3. Reducing the unemployment rate to below 4 %
4. Eradicating poverty
5. Providing affordable housing.
6. Ensuring 100% access to infrastructure services such as water, electricity, health and education.
7. Promoting food and nutrition security
8. Protecting culture, Heritage and Natural Environment
9. National Security
10. Nurturing New and Emerging Growth Sectors
11. Improving Transport and Digital connectivity
12. Embracing Appropriate and New Technology for productivity improvement.
13. Building vibrant cities and towns and a stronger rural economy.

The NDP highlights innovative technologies needed for sustainable development, particularly in the water, electricity and agriculture sectors. The NDP highlights that all water infrastructure should be climate-resilient and adopts innovative technologies for industrial recycling, rainwater harvesting and storage techniques, storm water and aquifer management and development of ground water sources, and desalination plants powered by renewable energy in maritime region. For the energy sector, the NDP highlights that future electricity infrastructure is to be more climate resilient, and therefore underground cables for electricity distribution should be explored and implemented where feasible.

The NDP clearly states that the agriculture sector needs to incorporate climate-smart agriculture practices to enhance production and thereby improve food and nutrition security. It also highlights the need to manage our natural systems such as mangroves, forests and coral reefs, which are critical for food and nutrition. Some of the climate-related technologies mentioned for the agriculture sector in the development plan are specific to the following:

- Land-use planning and better soil management practices to prevent soil erosion and increase soil fertility.
- Strengthened research into the development of new varieties of crops that are climate-resilient.
- Improved crop breeding infrastructure and seed storage facilities
- Irrigation
- Promoting the enhancement of traditional farming skills and knowledge through farmers' field school and crop extension services.

The NDP is also committed to expanding the rural economy and highlighting strategies to improve productivity by forging functional linkages between the agriculture sector and market. The development plans also aim to increase the climate resilience of rural communities by developing the following strategies:

- National Strategic Plan for climate change and disaster resilience.
- Incorporating flood resilient designs and construction in the National Building Code
- Developing hazard maps and models for all potential hazards including sea level rise, storm surge, flood and tsunami.
- Undertaking vulnerability assessments for all communities
- Developing climate and disaster resilience plans for rural communities.
- Ensuring that every rural community have at least one school building that is category 4 cyclone resilient
- Providing capacity building to communities that have been identified as vulnerable to rising sea-levels and in need of relocation.

Green Growth Framework 2014

The impacts of climate change hinder development therefore, there is a compelling need for a rigorous sustainable development that favours a climate resilient economy. The 2014 Green Growth Framework (GGF) supports and complements NDP and the 2010 – 2014 Roadmap for Democracy and Sustainable Socio-Economic Development and shares the same vision as the Roadmap, "A better Fiji for all" (GoF, 2014). The implementation of the framework is supported by 8 guiding principles and has 10 thematic areas in the development agenda. The GGF is regarded as a tool to accelerate integrated and inclusive sustainable development at all levels and enhance economic growth by encouraging resilience to adverse impacts of climate change. One of the thematic areas identified under the GGF is to build resilience to climate change and disasters. This is seen as the primary indicator for sustainable development and attracts climate financing in the range of FJD75 billion to 100 billion/ yr. for a temperature rise of 2 – 4 °C. Technology and Innovation are also embedded in the GGF, and the key challenge identified was the lack of research and innovation in green technologies and services. This barrier could be resolved by developing a national framework that promotes innovation, research and development of green technologies. More research funding to universities and research institute involved in the development of sustainable green technologies could be an effective implementing strategies.

National Climate Change Policy 2018 – 2030

The Fijian Government is immensely committed to protecting Fiji's people, environment and economy from the impacts of climate change and is undertaking ambitious climate action through international agreements such as the Paris Agreement. The intention of NCCP is largely defined by Vision 2050, the objective of which states that "A *resilient and prosperous Fiji, in which the wellbeing of current and future generations is supported and protected by a socially inclusive, equitable, environmentally sustainable, net- zero emissions economy*". The National Climate Change Policy (NCCP) is an overarching policy that involves mainstreaming climate change activities in all sectors. The NCCP is the principal policy mechanism to safeguard national development priorities from climate change risk.

The NCCP takes a woven approach to resilient development and takes into consideration the technology needed to achieve its vision. As per the structure of NCCP, objectives and strategies are in three pillars: (1) Foundation, (2) Dimensions, (3) Pathways. These three pillars provide guidance to improve linkages between the cross-sectoral government plans, policies and strategies that address climate change challenges. The NCCP provides the basis for the national adaptation process and the Low Emission Development Strategy (LEDS) and would be instrumental in the formation of the National Climate Change Act. Climate Change Adaptation and Mitigation are the dimensions of the Policy. An extract of the NCCP below highlights specific objectives under the Climate Change Adaptation and Resilient Development dimension (GoF, 2019):

- *To integrate the consideration of climate change projections, articulation of risk reduction responsibilities, and formulation of resilience-building objectives across all sector plans and strategies.*
- *To increase ecosystem protection, natural resource redundancy and environment resilience.*
- *To secure equal and sustainable access to produce, products, resources and services that support human health and well being.*
- *To implement climate change adaptation solutions which are inclusive, equitable and locally driven.*

The NCCP recognises technology transfer as the key element to create an enabling environment for adaptation, mitigation and risk reduction activities. The Objective 5.2 of NCCP clearly states "To *invest strategically in human and technological capacity building for climate resilient development*". One of the strategies under this objective is to enhance technology transfer and diffusion by incorporating technology needs assessment with relevant sector plans. The focus of the capacity building is through exchange and sharing of knowledge and data collection to boost innovation and technology transfer.

National Adaptation Plan

The National Adaptation Plan (NAP) was launched at COP 24 and was a result of multi-stakeholder consultation workshops and bilateral meetings with experts, regional Pacific organisations and national civil societies. The NAP is to lead ongoing adaptation initiatives in the country to reduce vulnerability to climate change. The NAP is aligned to the Cancun

Adaptation Framework of the UNFCCC to improve adaptive capacity to accelerate national climate- resilient developments.

A total of 160 adaptation measures have been prioritised over a period of 5 years (GoF, 2018) by using local context framework and multi-criteria analysis and are distributed across 10 systems and sectoral components. The systems component deals with implementing changes to system processes to enable climate resilient development. The sectoral components are the socio-economic indicators vulnerable to the impacts of climate change such as Food and Nutrition Security, Health, Human Settlements, Infrastructure and Biodiversity and the Natural Environment.

1.3 VULNERABILITY ASSESSMENTS IN THE COUNTRY

The Fijian Government, with support from the World Bank and Global Facility for Disaster Reduction and Recovery (GFDRR) produced Fiji's first Climate Vulnerability Assessment (CVA) report (GoF, 2017). Because the methodology to assess vulnerability is not very straightforward, wider stakeholder consultations were carried out to gather information on how current climate change is impacting respective sectors and how these impacts would worsen with future climate projections. The report highlights Fiji's exposure to large natural hazards such as floods and tropical cyclones, which historically have caused losses of approximately FJD500 million per year, representing generally more than 5% of Fiji's GDP. Climate change is likely to amplify these risks and threatening the development objectives of NDP. The climate models suggest an increased occurrence of high-intensity storms and higher storm surges in the Pacific region (IPCC, 2014). The impact of climate change on future droughts in Fiji is highly uncertain (ABM & CSIRO, 2011), but the impacts of drought as observed during the 1997/1998 El Niño event are associated with a decrease in agricultural productivity, the mortality of livestock and reduced supplies of drinking water. The lack of availability of drinking water leads to health risks such as typhoid in local communities.

The CVA highlights 5 areas where adaptation measures need to be implemented to reduce the vulnerability but require a climate-proofing investment estimated at FJD9.3 billion over 10 years. The five areas of interventions prescribed in CVA are:

1. *Resilient towns and cities*
   With increasing urbanisation, people tend to establish informal settlement in flood-prone areas. These settlements do not meet the Building Standard Code, which further elevates the vulnerability risk. The CVA recognises the need for urgent action in land-use planning to identify areas free from flooding for future developments and to upgrade informal settlements so to be more climate-resilient.

2. *Improving infrastructure services*
   A key feature of the 20 year NDP is 100% access to basic amenities, and these infrastructures have to be resilient to climate change and natural hazards in order to ensure their sustainability. Figure 1.1 shows the asset loss in different sectors due to cyclones and floods in Fiji and clearly illustrates that the transport sector is most vulnerable, followed by residential areas and other types of building.

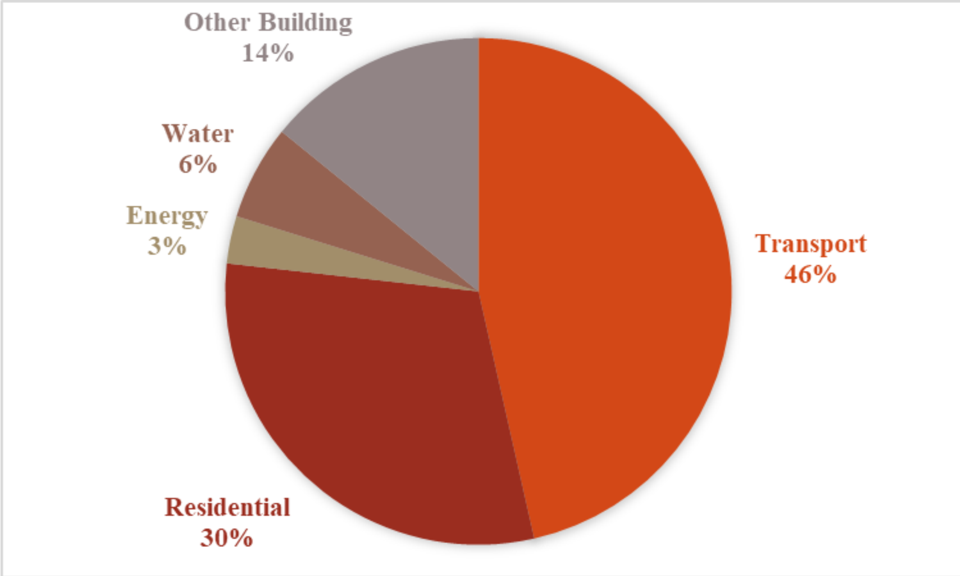

Figure 1.1: An Illustration of percentage asset loss due to the impact of natural hazards such as flood and cyclones. (Source: GoF, 2017a)

The study revealed that the transport sector is particularly vulnerable to increased rainfall intensities, sea-level rise, storm surges and riverine flooding. The vulnerability in this sector stems from the fact that the major road network is along the coast. The hazards can washout low-lying coastal roads and cause landslip and landslide on roads due to loosely held soil causing temporary road network disruptions. The vulnerability is further enhanced because there are limited alternative routes in the road network. The vulnerability assessment of the major road network was carried in the CVA, and some roads identified as at-risk and were being prioritised for strengthening and maintenance.

Residential and non-residential buildings are also at risk from climate change and natural hazards. The CVA recognises that insurance can absorb some shocks incurred by climate hazards. After TC Winston, the insurance industry faced claims of FJD155 million, which is equivalent to 7% of the total loss caused by TC Winston.

The water sector is also vulnerable to flooding and drought events. The vulnerabilities in the water sector are due to inadequate protection of infrastructures from run-off intrusion in water pumping stations, soil erosion and landslides. The high dependency on surface-water sources in the urban areas creates greater vulnerability in drought-stricken areas, so diversification of water sources should be considered to make the water sector more climate-resilient in the future. Hydropower contributes 45- 60 % of Fiji’s energy generation and this could be negatively impacted by droughts. Similarly, wind power stations and solar home systems are affected during the high-intensity winds. Implementation of some early-warning systems could be beneficial in safeguarding these structures before the onset of cyclones.

3. *Supporting agriculture and fisheries development that is smart for climate, the environment and the economy.*

Fiji's traditional crops are relatively resilient to climate variability; however, the traditional farming practices have declined due to increased demand for commercial production. Consequently, the agriculture sector has become more vulnerable to climate variability, which affects food security and income generated from farming. Fiji's agriculture and fisheries sectors are under threat from current and future climate change indicators such as extreme rainfall, flooding, cyclones, sea-level rise, temperature rise and droughts. All these have negative impacts on the growth cycles, and productivity, meaning loss of livelihoods for many Fijians. A large number of people living below the poverty line depend on agricultural income, and a recent modelling study suggests that even a minor shock resulting in a 1 % loss in agricultural income would push an additional 1,000 people into poverty.

The increase in sea-surface temperatures will cause coral bleaching, which may affect fish stocks due to loss of fish habitat, migration or changes in spawning times for tuna. With increased rainfall, there will be greater run-off, which may smother reefs due to sedimentation. Ocean acidification will lead to lower productivity of invertebrates due to reduction in aragonite concentration.

The fisheries sector is vital for Fiji's economy and for local food security. The sector comprises offshore the tuna fishery, commercial coastal fisheries and subsistence coastal fisheries. The coastal fisheries are not well managed, and habitat destruction caused by climate change and increased pollution would cause a decline in the coastal fisheries subsector.

4. *Conserving ecosystems and the local environment to protect valuable development assets.*

   Ecosystems are critical assets to sustain livelihoods, fisheries, forestry, agriculture and tourism but are at risk of degradation due to direct or indirect impacts of climate change. Good-governance mechanisms are required to conserve ecosystems and should be driven mainly by local communities to manage natural resources, reduce degradation and contribute to diversification of livelihoods.

5. *Building socioeconomic resilience by taking care of the poor and keeping economic growth inclusive and through actions on early warning and preparedness, social protection and health care.*

   To reduce the vulnerability of the poor to the impacts of climate change, it is imperative to have effective and efficient early warning systems regarding natural hazards so people are well prepared in advance for such extreme events. This incorporates stocking food and clean drinking water.

1.4 SECTOR SELECTION

1.4.1 An overview of Expected Climate Change and its Impact in Sectors Vulnerable to Climate Change

A. Past Observed Trends in Climate Variables

The measurements of ambient air temperatures at both Suva and Nadi Airport since 1942 suggest that temperatures have been increasing. The night-time temperature trends were stronger than the daytime trends. The long-term measurements also show that cool days and cool nights decreased while warm days have increased at Suva with no discernible trends observed for Nadi (Mataki et al., 2006 and Kumar et al., 2013). It was noted that the high positive trend in air temperatures at Suva is unprecedented for this part of the Pacific region (CSIRO, 2011). The trend observed in air temperature is consistent with the global warming trend reported by IPCC (2011). Kumar et al. (2003) highlighted that the increase in maximum and minimum temperatures was 0.08 to 0.23°C per decade but escalated to 0.18 – 0.69 °C per decade from 1989 to 2008. Such observation strongly supports warming and is consistent with the global trend reported by IPCC (2013). On the contrary, the rainfall data for the same period does not show any statistically significant trend. The variability observed is associated with the ENSO cycles and cyclonic activit.

The tropical cyclone season is normally from November to April, but some off-season cyclones have occurred in October and May associated with El Niño years. A total of 117 tropical cyclones crossed the Fiji Exclusive Economic Zone (EEZ) between 1969 and 2011, equating to an average of 28 cyclones per decade (ABM & CSIRO, 2011). The inter-annual variability in the frequency of tropical cyclones is large, ranging from 0 – 6 cyclones per year. There is no significant relationship between the occurrence of cyclones with El Niño, La Niña and neutral years. Approximately 32 % of the cyclone occurrences between the 1981/82 and 2010/11 seasons became stronger, that is, category 3 or stronger. The strongest category 5 (TC Winston) hit the country in 2016, affecting 540,000 people. (Mansur et al., 2017)

B. Climate Projections

i. Temperature

The climate projection in Pacific Climate Change Science Program (PCCSP) report was derived from the new 24 Global Climate Models (GCMs) in the available Coupled Model Inter-comparison Project (Phase 5) (CMIP5) database (ABM and CSIRO, 2011). Different emission scenarios or Representative Concentrations Pathway (RCP) such as RCP 2.6, 4.5, 6.0 and 8.5 were used. RCP 8.5 is a very high emission scenario, and RCP 2.6 is a low emission scenario. There is very high confidence in model results (shown in Figure 1.2) that temperature will rise by 1.9 – 4.5 ˚C for the RCP 8.5 scenario as compared to the projection of 0.3 – 1.1 °C for RCP 2.6. The model projections also suggested that temperature rises maybe about 0.4 °C greater over land than over the ocean. It was also highlighted that temperature on extremely hot days would increase, projected at 0.7 °C for RCP 2.6 and 3 ° for RCP 8.5 by 2090. It should be cautioned that there were biases in the projection of sea-surface temperatures associated with biases in the movement of SPCZ, which affect both temperature and rainfall projections.

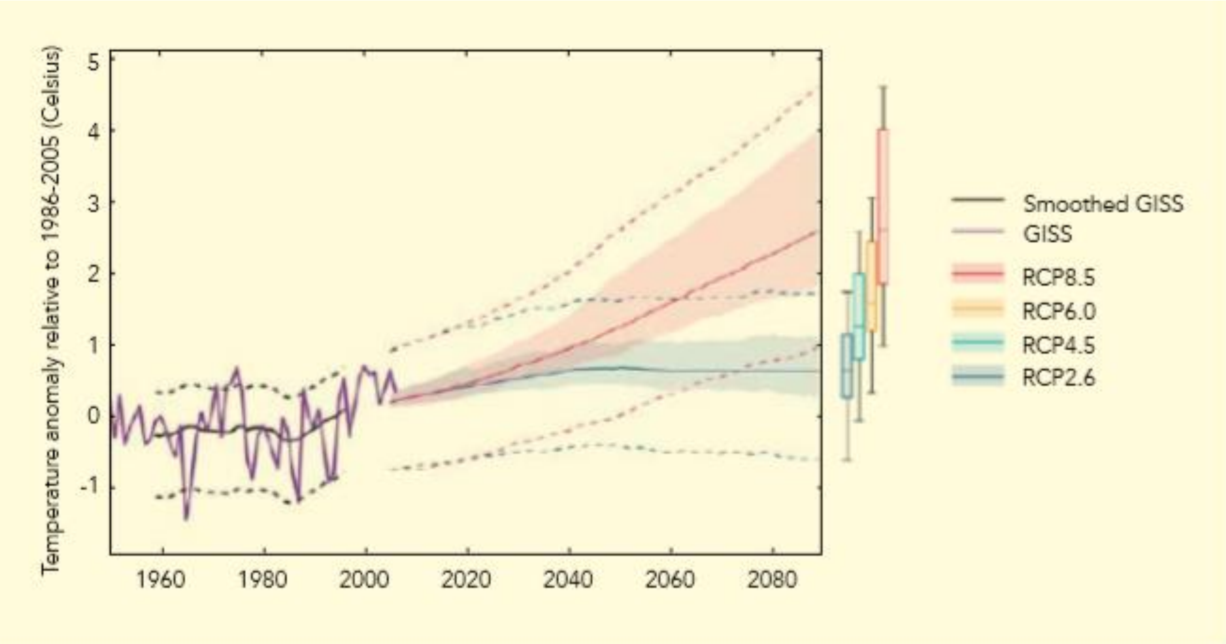

Figure 1.2 Historical and simulated mean annual surface air temperature anomaly under different emission scenarios (ABM & CSIRO, 2011).

ii. Rainfall

The CMIP5 models show that there is a large variability in rainfall projections, but very little change in the model average (shown in Figure 1.3). The model suggests an increase in November to April rainfall in the Fiji region, and little change in the May to October rainfall. Due to large natural variability in rainfall, the effect of climate change on rainfall will not be apparent on short or medium timescales. An interesting feature of the model study is the change in rainfall pattern during the November - April season; rainfall may increase more than the average in the western half of the two main islands (Viti Levu and Vanua Levu), but increase less or even decrease in the eastern halves. There is low confidence in the model projection of little change in average annual rainfall. This is attributed to changes in SPCZ position and the fact that the model projection does not show consistent direction of change. Some simulations show an increase in rainfall, while others show a decrease. A subset of CMIP5 models indicates that the frequency and intensity of extreme rainfall events are projected to increase, a conclusion that was further supported by an in-depth analysis of extreme rainfall events in the SPCZ (Cai et al., 2012), boosting the confidence in the model projections.

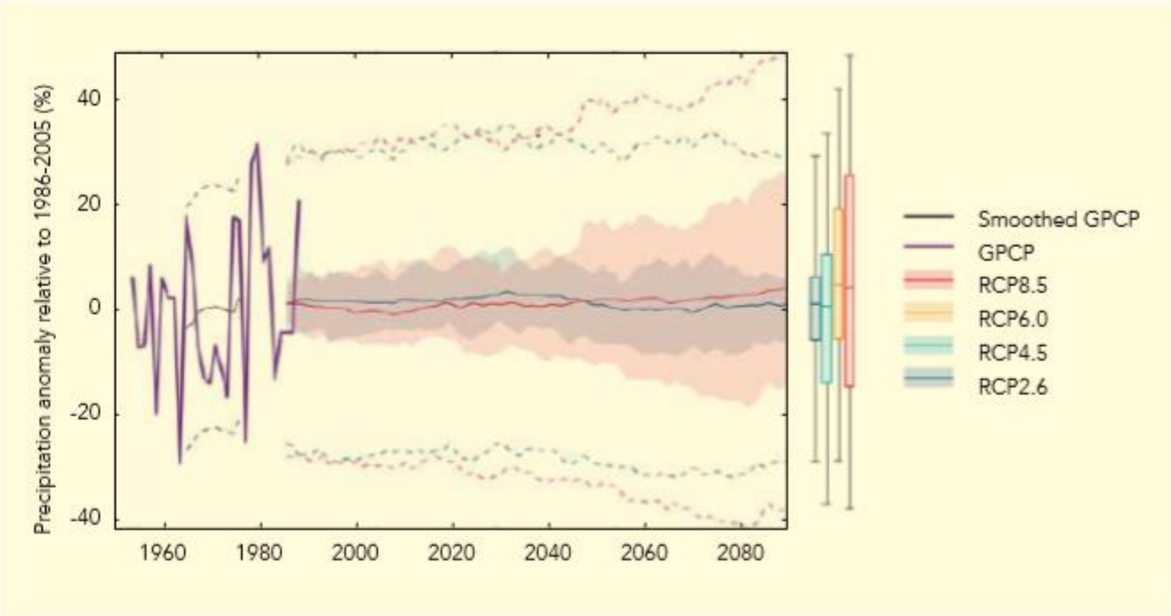

Figure 1.3: An illustration of the model projection of precipitation anomaly relative to 1986 – 2005 under different scenarios (ABM and CSIRO, 2011).

iii. Drought

The projections for drought in the Fiji Islands is highly uncertain but shows that the proportion of time spent in drought is expected to decrease under all emission scenarios. Under RCP 2.6 the frequency of mild and moderate drought events may decrease, while the frequency of severe and extreme events is projected to stay the same. The low confidence in drought projection is related to the fact that there is no simulation for direction changes in ENSO, which influences drought events.

iv. Tropical Cyclones

On a global scale, it is projected that the frequency of tropical cyclones will decrease by the end of the 21stcentury. The agreement among models highlights that there will be an increase of 2 – 11% in the mean maximum wind speed of cyclones and a 20% increase in rainfall closer to the cyclone centre (Knutson et al., 2010).

v. Sea Level Rise

The mean sea level is projected to rise, as shown in Figure 1.4 below. The CMIP5 simulates an increase of 8 – 18 cm by 2030 under the RCP 2.6 scenario and 41 – 88 cm by 2090 under the RCP 8 scenario. There is an inter-annual variability of sea level of about 18 cm, and the uncertainty associated with Antarctica ice sheet contraction gives medium confidence in sea-level projection. At the Lautoka SEAFRAME station for the period 1993 to 2015, the sea level is increasing at +4.7mm/year. Such a short record is prone to biases from natural variability. The observational record is relatively short in climate terms, and therefore still prone to the effects of shorter-term ocean variability (such as El Niño and Pacific decadal oscillations).

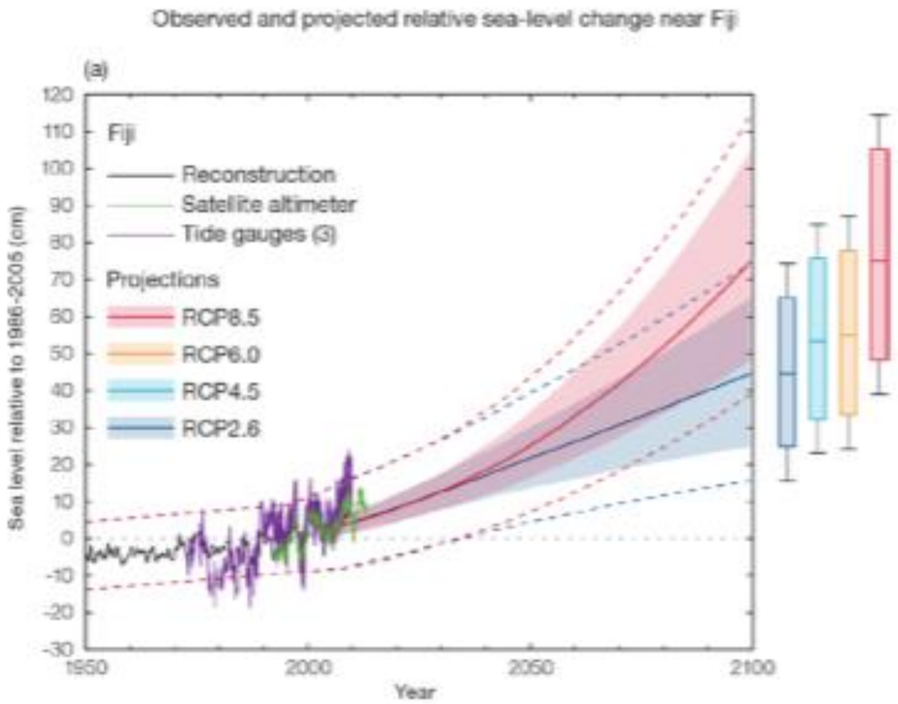

Figure 1.4: Observed and projected relative sea-level change near Fiji (Source: ABM & CSIRO, 2011)

vi. ***Ocean Acidification***

Due to the increases in the concentration of atmospheric CO_2, the ocean acidification phenomenon will rise. Ocean acidification is expressed in terms of aragonite saturation state, and it was noted that it declined from about 4.5 in the late 18th century to approximately 3.9 ± 0.1 by 2000 (Kuchinke et al., 2014). The CMIP5 as per figure 1.5 indicates that in RCP 8.5, the aragonite saturation state continues to decline to values where corals have not historically been found. Under RCP4.5, the aragonite saturation plateaus at around 3.2, and conditions for healthy coral growth are maintained in RCP 2.6 (very low emissions).

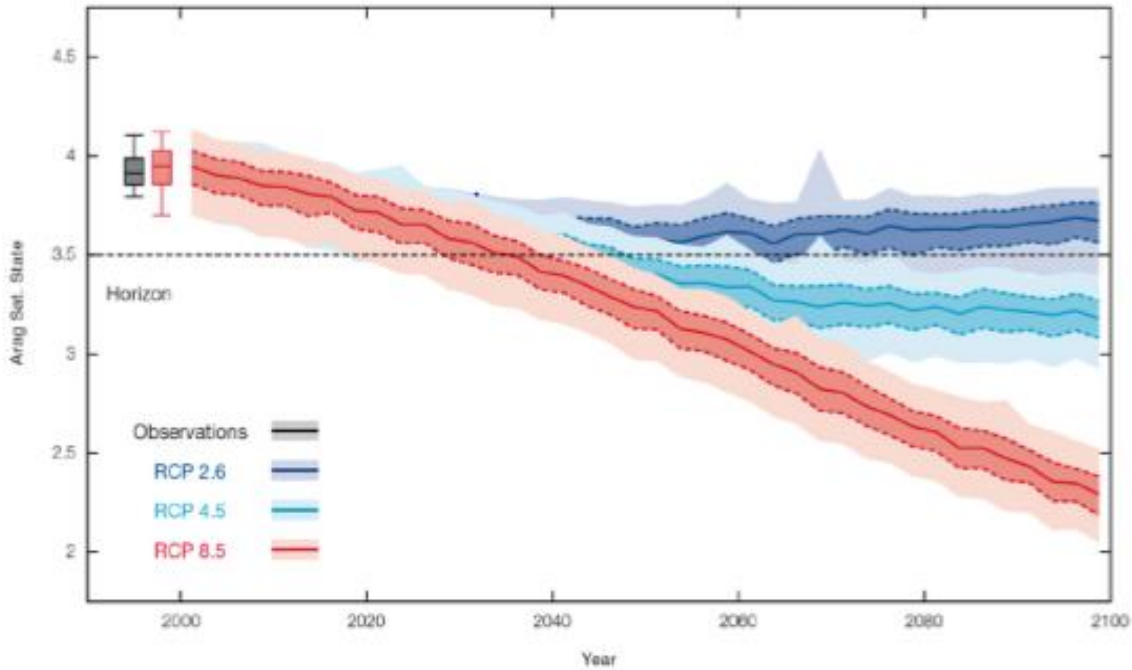

Figure 1.5: Projected decrease in aragonite saturation state for Fiji from CMIP5 models under different scenarios. (Source: ABM & CSIRO, 2011).

1.4.2 Overview of Climate Change Vulnerability and its Impact in Sectors Vulnerable to Climate Change

A. Water Resources and Water Infrastructure

A slight decrease in the projection of rainfall on the eastern side of the islands could impact potable and non-potable water supply, and in some parts of the country the sea-level rise could contaminate drinking water sources due to saltwater intrusion. Extreme rainfall events could result in water contamination and overflow of dams. The extreme rainfall events have the potential to impact storm water drainage. The storm-water drainage networks are unable to cope with extreme rainfall events, leading to urban flash flooding. Cyclones, droughts, storm surges and other extreme events could damage storm-water infrastructure and disrupt drainage through blockage or excessive water. Increases in high-intensity cyclones could damage water supply infrastructure and disrupt water treatment and distribution, leading to shortages of clean, safe drinking water. The extreme events could also impact the functioning of wastewater treatment plants and would lead to overflowing of wastewater treatment ponds, resulting in contamination of water supply and waterways.

B. Tourism Sector

More high-intensity cyclones in future will mean damage to buildings and infrastructure in addition to damages due to sea-level rise, storm surges, floods, coastal erosion and landslides. The CVA projects a decrease in tourism revenues by 18 percent in 2030 due to increased natural hazard events. Modes of transportation are affected during natural extreme events, leading to a further decrease in tourist numbers. The eco-tourism sector will be affected by changing weather conditions leading to degradation of pristine coral reefs, rainforest and surroundings. Increasing costs to implement adaptation measures for the tourism sector would be borne by tourists and related service providers, which would increase costs and undermine Fiji's competitiveness as a tourist destination. Growth in the tourism sector would be hindered by the need for increased capital investments in other priority sectors (such as infrastructure, agriculture and health) due to climate-related challenges.

C. Urban development and housing

Extreme events such as flooding and cyclones cause economic losses, particularly for poor people who live in inadequate housing that is more prone to damage. Land loss and reduction in arable land due to sea-level rise could lead to migration to urban centres, causing overcrowding. Overcrowding will put immense pressure on services and utilities to cope with the demands resulting from heat waves, water shortages and disease outbreaks. Cyclones, floods and storm surges can damage houses and other residential buildings and endanger the occupants.

D. Agriculture and Forestry

The projected climate change will have an impact on the agro-forestry economy of the country. Land arability could be reduced due to soil-water intrusion, inundation, coastal and riverbank erosion, exposure to salt-water spray and heat stress on soils. Saltwater intrusion could create a hostile environment for root crops to thrive, which could constrain both agricultural and economic development. This is expected to increase in the future. Extreme events such as heavy rainfall, floods and droughts could affect livestock production and management. The projected climate change could also increase the incidence of pests and diseases. Farming in the low-lying areas could be seriously hampered by flooding, causing damage to crops due to long periods of inundation. In addition to floods, droughts and cyclones could also physically damage crops, farm equipment and infrastructure. As a consequence, there would be reduced food security in terms of food production, food quality, nutritional value, affordability and access. Loss of soil fertility could result from extreme rainfall, which could alter soil structure and trigger erosion, which would accelerate nutrient loss due to nitrogen leaching. Loss of soil fertility could also result from over cultivation without any fallow periods.

Extreme drought events will make forests more vulnerable to forest fires and land desertification, leading to loss of biodiversity. Forest health could be reduced due to higher temperatures and changes in rainfall patterns, which in turn would lead to an increased occurrence of invasive species and pests. Droughts could also reduce soil moisture and put stress on soil water availability. Changing temperature and rainfall patterns may cause shifts in habitats and boundaries of certain tree species, pollinators and seed dispersers as well as the flowering behaviour of certain tree species. Loss of arable land due to climatic stress such saltwater intrusion and landslides would place added pressure on forest areas for development and subsistence agriculture economy.

E. Health Sector

The projected climate change will increase the incidence and severity of vector-borne, zoonotic and infectious diseases. Water-borne diseases and diseases transmitted through mosquitoes are also affected by climate change. Sensitivity to climatic conditions is not only limited to the duration of transmission but may also affect geographical distribution. The social and environment determinants of health, such as access to clean and safe drinking water, sufficient food, secure shelter and hygiene and sanitation are also exposed to climate threats. Fiji is highly susceptible to climate-sensitive diseases such as dengue fever, leptospirosis, typhoid fever and diarrhoea, which become widespread after floods and cyclones. In the Pacific, La Niña conditions have been strongly associated with dengue outbreaks (GoF, 2017a)

There is strong evidence that climate change has a indirect impact of on health sector, specifically an increase in Non-Communicable Disease (NCD). Currently in Fiji, mortality due to NCD is very high and would be exacerbated by increasing temperatures, which could discourage people from engaging in physical activities. Local fruits and vegetables will be more expensive and less affordable for poor people during climate-related food shortages, which would cause a large portion of the population to depend on processed food with high sugar and salt content. All this will lead to obesity, which is directly correlated with NCDs. Lack of food could also lead to malnutrition. There could be psychological impacts as well due to population displacement and income loss.

1.4.3 Sector Selection

An extensive review and analysis of policy documents and other documents pertaining to climate change and adaptation actions were carried out in conjunction with wider stakeholder engagement by the Ministry of Economy, Government of the Republic of Fiji, to identify sectors that are most vulnerable to climate change at the Inception Workshop held on Thursday 13 September 2018. As the Ministry responsible for mainstreaming climate change adaptation and mitigation into the economy, the technical team at the Ministry of Economy's Climate Change and International Cooperation Division acted as an Advisory team. It informed the sector prioritisation process based on the mitigation, adaptation and development priorities of the country. The prioritisation of sectors for the TNA project primarily depended on the outcomes of Fiji's Climate Vulnerability Assessment and Fiji National Adaptation Plan. The criteria chosen for sector selection are as follows:

- Increasing resilience of the sector will support the objectives of the NDP and will eventually lead to a climate resilient economy and sustainable development.
- The vulnerability of the sector to the projected climate change is extremely high and requires intervention such as climate financing and innovative technologies to reduce vulnerability.
- Size of the population affected by climate change hazards and enhancing or upscaling adaptation options in these sectors will safeguard the livelihoods of our local people.

The CVA strongly highlights that Fiji's economy is more vulnerable to natural hazards such as floods, tropical cyclones, storm surges and to some extent, drought and as a result the following sectors, which were broadly identified in CVA, were considered for prioritisation:

- Agriculture
- Urban Development and Housing
- Infrastructure (transport, water and energy)
- Coastal Zones (coastal communities and fisheries)
- Health
- Biodiversity

Based on the development priorities and criteria for sector selection, with compelling evidence from CVA, the two priority sectors retained through the consultation process carried out by the Ministry of Economy for the TNA process are:

1. Agriculture

2. Coastal zones

The agriculture sector plays a key role in the Fijian economy and is regarded as a transformational thrust for Fiji's development (GoF, 2017b). Agriculture supports livelihoods of 118, 801 households (61% of all households) either directly or indirectly (GoF, 2017a). The annual export earnings from the agriculture sector over the last 5 years amounts to FJD 194.2 million. The CVA report highlighted estimated damage of FJD 791 million in the agriculture sector from natural climate hazards over a period of 16 years. Although the future costs, losses or damages are highly uncertain, it is anticipated that projected conditions of climate change and more high-intensity cyclones could only increase our economic losses and create more poverty. Hence, there is a need for technology transfer and climate financing to reduce the vulnerability of the agriculture sector and promote the economic growth of the country.

The coastal communities are vulnerable to sea-level rise, storm surges and coastal flooding. It was reported that shoreline retreats of 15 – 20 m over recent decades had been observed in Fiji, and that this was partly attributed to the loss of mangroves (World Bank, 2000). In 2013, the village of Vunidogoloa was the first village to be relocated (McNamara and Des Combes, 2015) with an additional 42 communities identified to be at risk from rising sea level. Hence, some interventions in adaptation measures in safeguarding the coastal communities from climate hazards and long-term climate change impacts are of paramount national importance.

CHAPTER 2: INSTITUTIONAL ARRANGEMENT FOR THE TNA AND THESTAKEHOLDER INVOLVEMENT

The CCICD acts as the coordinating agency for the implementation of the 2018-2030 NCCP. CCICD is responsible for the coordination of climate finance and the implementation support and reporting associated with Fiji's NDP, LEDS, NDC-IR and NAP. CCICD is responsible for liaising with and reporting to the UNFCCC as well as providing national reports of SDGs, ensuring transparency, integrity, and consistency of reporting. As the Coordinating Agency for NCCP, CCICD supports climate-change knowledge management by developing communications strategies, developing and maintaining data repositories, and supporting functions and knowledge products designed to raise awareness of key climate-change issues in government, the private sector, and civil society. CCICD works to provide support to government ministries in national efforts to mainstream climate change into development planning, sectoral planning and strategies, decision making, and policy.

As the UNFCCC National Designated Entity and Focal Point, CCICD is also the National Contracting Entity for the TNA Project. Through the Technology Needs Assessment Project, CCICD aims to uphold the principals of the NCCP to achieve a resilient and prosperous Fiji, in which the well-being of current and future generations is supported and protected by a socially inclusive, equitable, environmentally sustainable, net-zero emissions economy. The TNA will allow Fiji to assess technologies that are vital for a resilient and low carbon Fiji. A TNA is a solution for developing countries such as Fiji that struggle to secure climate finance to address their development needs.

2.1 NATIONAL TNA TEAM

The country-driven nature of the TNA required an inclusive and participatory process that ensured that the prioritised technologies were a true reflection of the national needs. The Ministry of Economy is the designated national institution, and it leads and coordinates the TNA process in Fiji. The Ministry of Economy is also the Focal Point for the United Nations Framework Convention on Climate Change (UNFCCC).

The key elements of the institutional setup of the national TNA process include the Cabinet, the TNA Project Steering Committee (SC), the TNA Coordinator, the National Consultants and the Sectoral Working Groups. Figure 2.1 maps out the institution arrangement for the TNA project in Fiji.

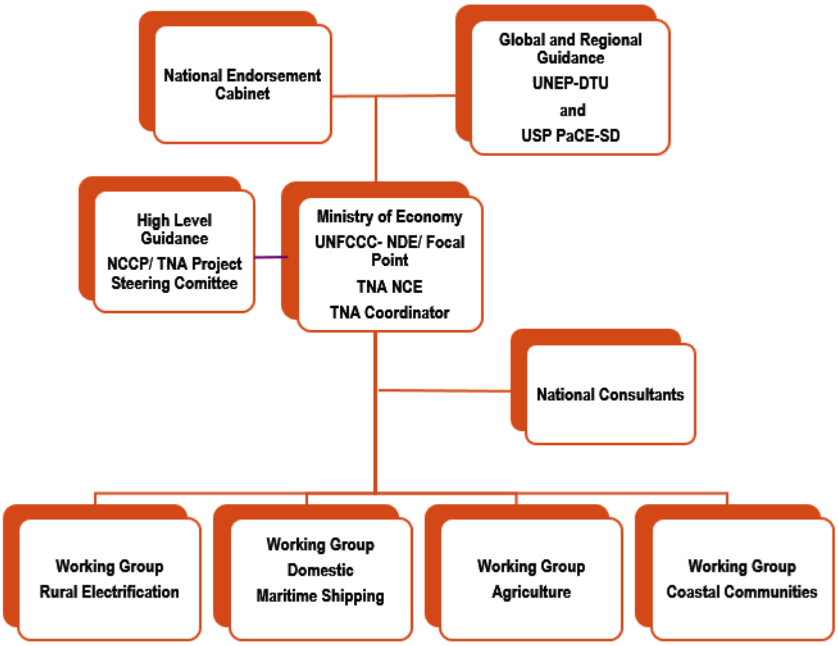

Figure 2.1: National Institutional Arrangement

2.1.1 Cabinet

The Cabinet's role is to provide political endorsement for the National TNA Deliverables.

2.1.2 TNA Project Steering Committee

The NCCP Steering Committee was appointed as the TNA project Steering Committee. The role of the Steering Committee is to provide high-level guidance and approval for the TNA process and the outcomes. Representation on the Steering Committee is at a senior government officer levels, and the members include:

1. Permanent Secretary for Economy
2. Permanent Secretary for the Ministry of Health
3. Permanent Secretary for the Ministry of Agriculture
4. Permanent Secretary for the Ministry of Forestry
5. Permanent Secretary for the Ministry of Fisheries
6. Permanent Secretary for Local Government, Housing and Community Development
7. Permanent Secretary for Waterways and Environment
8. Director Meteorology
9. Director Energy
10. Director National Disaster Management Office
11. Solicitor General

The National TNA Coordinator

The role of the National TNA Coordinator is to act as a focal point for the Ministry of Economy guiding the development and progress of the TNA within the country. The National TNA Coordinator Ms Deepitika Chand, was appointed from the CCICD at the Ministry of Economy. Ms Chand is the Climate Change Officer (Mitigation) has a Master of Science Degree in Chemistry focused on the evaluation of methane emissions from the agriculture sector and high-precision ambient methane measurements in Fiji.

The CCICD plays a central coordinating role in implementing Fiji's NCCP 2018-2030 that envisions a resilient and prosperous Fiji, in which the well-being of current and future generations are supported and protected by a socially inclusive, equitable, environmentally sustainable, net-zero emissions economy.

National TNA Consultants

TNA in Fiji was performed with the involvement of local mitigation and adaptation experts. The lead national consultants were selected by the National TNA coordinator in close consultation with UDP and the Pacific Regional TNA Hub, following an open and transparent selection process.

The Mitigation Consultant is Dr Ramendra Prasad, a Senior Lecturer in Physics at the University of Fiji. Dr Prasad has contributed to many studies pertaining to renewable energy and energy modelling and forecasting in Fiji. The Adaptation Consultant is Dr Francis Mani, a Senior Lecturer in Chemistry and Associate Dean for Teaching and Learning at the Faculty of Science Technology and Environment at the regionally owned University of the South Pacific (USP). Dr Mani has experience in preparing the Fiji Greenhouse Gas Inventory for the SNC and TNC and is the lead consultant on the work on the waste sector for the Fiji LEDS.

National expert consultants are responsible for finalising the TNA Report after thoroughly identifying and prioritising technologies for the two sectors identified under climate change adaptation and mitigation after exhaustive consultation with the relevant stakeholders and experts. The National Consultants lead the process of the multiple criteria analysis, along with the national stakeholder groups, and facilitate the process of technology prioritisation addressing the barriers and developing an enabling framework.

TNA Sectoral Working Groups

A Sectoral Working Group (WG) was established for each sector assessed in the Fiji TNA. Each group consisted of five to six experts from academic institutions, private companies, and non-governmental organisations. The WG contributed towards the development and furnishing of the technology factsheets.

2.2 STAKEHOLDER ENGAGEMENT PROCESS FOLLOWED IN THE TNA – OVERALL ASSESSMENT

The stakeholder consultation process for the TNA work in Fiji followed the principles of sustainable wellbeing, inclusivity, social cohesion, partnership, agility, urgency, transparency, and communication and integrated learning as deliberated by Fiji's NCCP 2018-2030. Stakeholders include government agencies, private sector, non-government organisations, civil-service organisations and academic institutions (See Annex II for the list of stakeholders consulted).

The TNA Report was prepared after an extensive stakeholder process. The key and successful stakeholder engagement methods included:

- Email correspondence and exchanges on the Technology Factsheets (TFS), which allowed the stakeholders to become well versed in the technologies and provide meaningful feedbacks during the stakeholder consultation workshops.
- Bilateral engagement, which proved a very useful way to engage experts in a particular field, especially when the stakeholder was not able to attend the workshops.
- Awareness workshop for selected sectors that facilitated formation of technical working group; and
- National stakeholder consultation of key stakeholders for technology prioritisation.

2.3 CONSIDERATION OF GENDER ASPECTS IN THE TNA PROCESS

Fiji developed a National Gender Policy in 2014 to promote gender equity, equality, social justice, and sustainable development. At the twenty-third Conference of Parties hosted by Fiji, the Gender Action Plan under the Lima work programme on gender was finally adopted. Gender responsiveness is also a key pillar of the 2018-2030 NCCP. Women play a unique role in natural-resource management. Women are vulnerable to climate change, but women are also the agents of change in societies. Improving and enhancing the incorporation of women's knowledge, skills, participation, and leadership into planning processes at the local and national level creates opportunities to maximise both women's and men's contributions to environmental sustainability.

The TNA work on Fiji builds with the guidance of the NCCP and Sustainable Development Goal 5. Women civil society representatives have been included in the technical working groups and the stakeholder consultations. The technologies prioritised were evaluated for gender sensitivity, which was included as included as a criterion under the social benefits. Equal opportunities have been provided to both men and women to voice their opinions and standpoints. The Fiji TNA was also inclusive of the disabled and Lesbian, Gay, Bisexual, Transgender and Queer (or questioning) and others (LGBTQ+) groups.

CHAPTER 3: TECHNOLOGY PRIORITISATION FOR AGRICULTURE

3.1 KEY CLIMATE CHANGE VULNERABILITIES IN AGRICULTURE SECTOR

The agriculture sector in Fiji is vulnerable to future prediction of climate hazards such as intense rainfall, extreme temperatures, flooding, drought and saltwater intrusion due to increased sea level rise. Table 3.1 below summarises the expected impact of climate change that could cause huge socioeconomic losses for the agriculture industry. Over the last 16 years, cyclones and floods have caused at least FJD791 million in damages and losses to the agriculture sector—equivalent to around FJD50 million a year on average.

Table 3.1: Expected impact of climate change on Fiji Crops, livestock, and forestry.

HAZARD/ CHANGE	EXPECTED IMPACT
Changes in rainfall pattern	Changes may disrupt planting, flowering patterns, vegetable growth and harvesting patterns, which may affect productivity.
	Heavy, concentrated rainfall can lead to waterlogging and a higher risk of certain plant diseases, leading to higher rates of mortality. It can also lead to erosion.
Changes in temperature	Existing cultivars of crops such as mango, papaya and tomato can be adversely affected by high temperatures at specific stages of their development.
	The incidence of pests and diseases may increase across a range of crops and livestock; increasing minimum night-time temperatures have already been shown to increase the spread of taro leaf blight, which poses a major risk the important local taro industry.
	High temperatures may increase stress on livestock.
	The availability of maize- and soy-based animal feed could be affected by climate change, resulting in increased costs for Fiji's poultry and pig industries, which are heavily dependent on imported feed.
Sea – level rise and sea flooding	The land area available for agriculture may be reduced; the sugar industry has an estimated 5,000 ha of land that is under threat from saltwater intrusion.

Source: GoF (2017a)

The economic loss in agriculture is mostly incurred through natural hazards, which will intensify in future, there are other climatic indicators such as heat stress or droughts that can impact the agriculture sector. Droughts in Fiji are associated with the El Niño phenomenon, and can affect on average 20 – 30 % of Fiji's land area (PACC Report). The impacts of droughts include a decrease in agricultural production due to heat stress and lack of groundwater availability, the mortality of livestock, and the lack of drinking water. A study by the World Bank indicates that droughts under El Niño conditions could decrease sugarcane productions by USD 13.7 million a year by 2050 (PACC Report). It is also anticipated that increases in daily temperatures and severe drought conditions could result in land degradation and desertification particularly in the rain shadow areas of Fiji such as Western Viti Levu and the North-West of Vanua Levu.

Staple foods in the Pacific such as sweet potato, taro and yams will have a moderate to high impact from predicted temperature changes from different Representative Concentration Pathways (RCPs) scenarios (see Table 3.2). The declining crop yield could be due to combination of key climate change indicators resulting in heat stress, prolonged drought, waterlogging, soil erosion or soil fertility and an increase in the incidence of pests and diseases. The farmers at Sigatoka Valley, which is termed as the "Salad Bowl" of Fiji and is one of the largest suppliers of local vegetables to markets in the urban centres, noted that farming has become laborious in these areas because more water needs to be sourced to retain field moisture during dry conditions.

Table 3.2: Impact of temperature rise under different emission scenarios on staple foods, export commodities and livestock.

CATEGORY	PRODUCT	SHORT – TERM IMPACT (TO 2030)[A]	MEDIUM – TERM IMPACT (TO 2050)[B]
Staple Food	Sweet Potato	Moderate	Moderate to high
	Cassava	Insignificant to low	Low to moderate
	Taro	Low to moderate	Moderate to high
	Yams (domesticated)	Moderate to high	High
	Breadfruit	Insignificant to low	Low to moderate
	Rice	Moderate to high	High
	Banana	Low	Low to moderate
Exports	Coconuts	Low	Low to moderate
	Cocoa	Low	Moderate
	Sugar	Low	Moderate
	Papaya	Low to moderate	Moderate to high
Livestock	Cattle	Low	Moderate
	Pigs	Low	Moderate
	Poultry	Moderate	High

Fiji is one of the countries in the Pacific, where taro plays a vital role not only for food and nutritional security but also for income generation as a result of the very significant taro export market. Over the last few years, Fiji has exported around 10,000 tonnes (AUD 9-10 million), with about 65 per cent going to New Zealand and the balance to Australia and the USA (McGregor et al., 2011). Increasing temperature and rainfall is likely to provide optimum conditions that would favour pathogens causing taro leave blight (TLB), which could have dire consequences for the local taro industry. Other agricultural pests and diseases such as anthracnose on chillies and capsicum, bacterial wilting, and agricultural insects such as mealy bugs, aphids and caterpillar pests of leafy vegetables have become a nuisance to farmers due to changing weather patterns. The Asian subterranean termite, which is an invasive species to

Fiji, has already infected the sugar cane fields, and increases in temperature and humidity would allow the termites to become more widespread in the sugar industry (Chand et al., 2018). A recent study investigating the future distribution of termites using RCP 4.5 and a projection year of 2050 revealed potential invasion hotspots to be located in the tropics, which further supports the concerns raised earlier for the Fiji sugar industry (Buczkowski and Bertlsmeier, 2017).

Increasing temperature and rainfall have an impact on the Soil Organic Carbon (SOC) and thereby affects soil fertility. A recent study revealed that climate change has some impact, but the major driver is land-use changes (Zhou et al., 2019). The traditional farming systems that allowed the land to have a period of fallow ensured that the land was able to recover its fertility. Recent changes in weather patterns and a shift to cash cropping that involves permanent cultivation to take advantage of the economic the boom in taro and ginger exports have led to a decline in soil fertility.

3.2 DECISION CONTEXT

The relevant policies and national development plans were discussed in section 1.2 and were used as a basis to prioritise sectors. The NCCP Framework (2018) focuses on streamlining climate change issues in different sectors. Objective 5 of NCCP (2018) is on adaptation to climate change and the adaptation measures proposed in the policy clearly outline the development of sustainable technologies that incorporate traditional knowledge and strongly support an ecosystem-based approach in food security and agriculture. It clearly stipulates building national adaptive capacity in the agriculture sectors to respond effectively to climate-sensitive diseases, particularly in livestock. The GGF further supports Fiji to better integrate sustainable development and climate adaptation strategies into future development planning. The NDP regards the agricultural sector as a transformational thrust for Fiji's economy, and therefore making the agriculture sector more resilient to impacts of climate change is a high national priority. The overarching national climate change document that was used to identify technologies in the agricultural sector was the NAP understands the long-term impact on food and nutrition security and has adopted climate-smart agriculture technologies to support food security by combating threats identified earlier in Fiji's agriculture system.

The NAP clearly outlines 13 adaptation measures for the agriculture sector, and these are highlighted below:

1. Undertake regular climate change assessments, GIS mapping and crop modelling, that could be used as part of the national planning for food and nutrition security.
2. Improve biosecurity efforts to control invasive species, pest and diseases, which can reduce the occurrence of plant and livestock diseases.
3. Strengthen Fiji's disaster preparedness efforts in agriculture by encouraging agronomy, climate-based crop planning, breeding, and cultivation of traditional and improved seed varieties, cultivars and livestock breeds.
4. Strengthen research collaborations with farmers to create a community of practice and to support knowledge networks, which facilitate innovative and climate-adaptive farming practices.

5. Work with diverse stakeholders to ensure that farmers have access to climate information services and hazard maps.
6. Promote and integrate climate-smart agriculture (CSA) into farming, trainings, extension services, policies and plans.
7. Increase adoption of sustainable soil and land management techniques to address soil erosion and desertification, improve soil fertility through nutrient management, enact the Soil Conservation Improvement Bill and enforce the Unplanned Rural and Forest Fire Strategy.
8. Improve water management systems by upscaling low-cost irrigation systems, agronomic practices and developing integrated watershed management plans.
9. Strengthen the resilience of farmers and farming families by encouraging the diversification of agricultural produce for subsistence consumption and market sales.
10. Monitor farm communities' attitudes to climate adaptation options in agriculture.
11. Integrate climate adaptation issues and actions into policy plans
12. Enhance support for irrigation schemes that support agriculture diversification and mitigate increased droughts.
13. Construct and maintain of sea walls and drainage infrastructure to reduce saltwater intrusions due to sea-level rise and storm surges.

It is apparent that the adaptation measures for agriculture proposed in the NAP will improve productivity while also building resilience to future climate change. This is achieved through measures such as climate-resilient crop varieties, and animal breeds, sustainable soil management, irrigation technologies, integrated pest management and agro-forestry, which will strengthen the ability of farmers in Fiji to address the challenges of climate change. The technologies identified for TNA will address these primary issues and will be discussed in section 3.4.

Fiji ratified the Sendai Framework to Disaster Risk Reduction Programme that incorporates climate-related insurance. Agriculture insurance programs can be used to manage the financial cost of disasters to farmers and governments. Such programs transfer the agricultural financial loss due to climate to insurers. Agriculture insurance should be imbedded in the National Disaster Management Plan and should have an active engagement of both the public and private sectors. The Pacific Financial Inclusion Program carried out a pre-feasibility study for weather-based index insurance in Fiji, in consultation with major stakeholders. It was concluded that several issues need to be addressed before piloting such weather-based index insurance, including the lack of agricultural and weather data and the lack of an aggregator that would facilitate insurance sales to farmers[1]. Fiji 2020 Agriculture Sector Policy Agenda also recommended climate insurance under the Fiji Development Bank with a highly efficient premium payment and claim processing system in place.

The Fiji 2020 Agriculture Sector Policy Agenda outlines the strategy to build modern agriculture as an Organised System of Producing, Processing, and Marketing Crops, Livestock, and Aquaculture Products. It incorporates the model of Rural Transformation Centre (RTCs) that would be responsible for disseminating agricultural information and encourages

[1] source: http://www.pfip.org/wp-content/uploads/2016/08/PFIP-focus-weather-index-based-insurance-in-Fiji.pdf

community participation through Farmers Field School (FFS). The AusAid TAROGEN project, funded by the International Climate Change Adaptation Initiative (ICCAI), has been leading the establishment of taro breeding programmes in Fiji, a project led by the Pacific Community (SPC). In addition to this, SPC is now establishing a regional multi-stakeholder CSA network among interested countries and territories for knowledge exchange and sharing information, experiences and technical skills in climate-smart agriculture (CSA) and to be supported by FAO's sub-regional program for CSA. The network will enhance public- and private-sector partnership and could be used as a platform for countries to commit to their NDCs by implementing CSA.

The Development of Sustainable Agriculture in Pacific (DSAP) Fiji was implemented in Fiji from 2003 – 2010 by SPC and focused on making the agriculture sector more resilient to impacts of climate change. The project empowered women groups and devised trainings and technologies for sustainable agricultural production. The Australian Centre for International Agriculture Research (ACIAR) funded a project on enhancing value-added products and environmental benefits from the agro-forestry system in Fiji. The project was implemented by the Ministry of Agriculture (Research & Extension), Ministry of Forestry (Research and Extension), Ministry of iTaukai Affairs, Sunshine Coast University, Adelaide University and Southern Cross University.

3.3 OVERVIEW OF EXISTING TECHNOLOGIES IN AGRICULTURE SECTOR

The issue of food security and increasing agricultural productivity is enshrined in different national policies and plans. As a consequence, some efforts in developing CSA technologies have been trialled or promoted in the country. There have been "no-regret" measures (actions that would be worthwhile to implement even in the absence of climate change) such as climate-resilient crop varieties and animal breeds, which are a key adaptation strategy in agriculture sector and have immense stakeholder and political acceptability in terms of both research and investment. In addition to modern technology, there is a strong commitment to technological interventions incorporating traditional knowledge, particularly in sustainable soil management. There has been a significant amount of training and capacity building to promote sustainable soil management, irrigation technologies, integrated pest management, and agro-forestry that will build the resilience of the local farming community and reduce vulnerability to the projected impacts of climate change.

Some of the existing technologies in the Agriculture Sector are:

- Improved crop varieties such as new taro varieties that are resistant to taro leaf blight tolerant varieties ("Tarova Loa" and "Tarova Vula" and new Kumara variety ("Golden Brown") which is drought-tolerant and resistant to Kumara scrub disease. The Pacific Adaptation to Climate Change (PACC) Programme is the one of the initial climate change initiatives implemented in Fiji through SPREP to improve crop resilience to extreme events such as flooding by improving drainage systems in lowland farming areas in the Tailevu-Rewa and Serua-Namosi Province. The project also tested staple root crops (taro, cassava and sweet potatoes) for saltwater and waterlogging-tolerant varieties at two pilot sites.

- Drip irrigation in sugar-cane field trials in Drasa, Lautoka to decrease the vulnerability of the sugarcane to water stress during the early plant development stages.

- Livestock disease surveillance centres in the country to boost the cattle industry.

- Animal breeding either using artificial insemination or embryos to produce cattle that are more tolerant to heat stress and improve the genetics in animals for better meat and milk production.

- Farmers Field School (FFS): A classic example of FFS is the Tutu Regional Training Centre in Taveuni, which provide non-formal education to young farmers to become self-employed in the agriculture sector. The DSAP project established demonstration farms and provided training to youth to incorporate inter-cropping farm systems to increase livelihoods. It provided technical information on managing soil health using vetiver cultivation together with cash crops to avoid soil erosion by using locally available organic residues such as coco peat and biochar to increase soil organic matter.

- Pest and disease control using the Integrated Pest Management (IPM). The English cabbage industry is at threat from increasing pests such as *Plutella xylostella* (Diamondback Moth) and *Crocidolomia binotalis*. An IPM method was developed using the trap crop of Brassica Juncea (Indian Mustard) in conjunction with the 'biocide' *Bacillius thuringiensis*, which is harmless to introduce or natural enemies of these pests. To avoid the use of harmful pesticides such as organophosphates, more plant-derived products such as neem, derris, pyrethrin and chilli combination to soap water should be used. At the Farmer Field School (FFS) conducted in Fiji, it was advised that insecticides need to be applied only once in the early life stages of the diamond black moth (DBM) so that it does not develop resistance.

- Allowing a fallow period after intense farming and planting "Mucuna" re-establishes soil health or fertility.

- A low-cost biochar facility at Tei Tei Taveuni produces charcoals from coconut woods and husk and multipurpose trees that are incorporated into the soil to increase its fertility.

- Composting facilities established around the country to produce compost from waste organic matter such yard and green market refuse.

- Agro-forestry demo plot and nursery in Nabou and Vanua Levu, and various workshop promoting agro-forestry around the country. The ACIAR project was to identify multipurpose agro-forestry crops with market potential and to enable enhanced and gender-equitable small-holder participation in agro-forestry crop production

- Sloping Agricultural Land Technology (SALT) to prevent soil erosion during episodes of heavy rainfall. SALT technology has been practised in sugarcane farms, and vetiver hedgerows have been planted to reduce soil erosion and increase productivity. This technology is widely accepted in agro-forestry as well.

3.4 ADAPTATION TECHNOLOGY OPTIONS FOR AGRICULTURE AND THEIR MAIN ADAPTATION BENEFITS

Table 3.3 gives the long list of technology options for the agriculture sector the stakeholders agreed were relevant for agriculture and would reduce the sectors vulnerability to the impacts of climate change listed in Table 3.1. Table 3.3 also highlights the linkages of the technologies to national policy and planning documents such NAP and NCCP and is useful to demonstrate the political acceptability of the technology. The technology factsheet for each of these technologies is attached in Annex I, which contains a brief description of the technology, application potential in the country, and costs, technical aspects, and environmental impact.

Table 3.3: Adaptation Technology options for Agriculture and their main adaptation benefits and linkages to national policies and planning documents

Technology	Linkages to Policy and Planning Documents	Climate Change Adaptation benefits for Agriculture
Drip Irrigation	Adaptation measure #12.A.8 of NAP	This technology will reduce the vulnerability of the food crop sector such as root crops, sugar cane and cash crops due to climate-related or drought-related water scarcity. It will deliver the exact amount of water needed by plants at the root zone and therefore avoids evaporation of water. This technology also helps avoid overexploitation of water resources and fertiliser usage. The fertiliser distributed by such technique also helps to address the loss of soil fertility due to climate change.
Integrated Pest Management	Adaptation measure #12.A.2 of NAP. Mentioned in CVA	Infestation by pests such as termites, and diamond black moth is affecting the agriculture sector and causes a huge loss. The pest infestation is driven by effects of climate change such as rainfall, and increasing temperatures, which create optimum conditions for pests to thrive. IPM is an environmental technology that integrates the diversity of crops, conservation of soil fertility and protection of beneficiary insects and predators, and thus increases the resilience of the crops and farmers to climate change.
Integrated Nutrient Management	Adaptation measure #12.A.7 of NAP. Highlighted in GGF and NCCP.	Soil organic matter (SOM) decreases much faster with warmer temperatures leading to soil infertility. This technology particularly takes into account incorporation of organic supplements such as compost and biochar to increase soil nutrient and moisture retention. By and large, it contributes to the reduction

Technology	Linkages to Policy and Planning Documents	Climate Change Adaptation benefits for Agriculture
		of vulnerability to climate change through improvements in soil resources and increases in productivity.
Selective Breeding via controlled mating	Adaptation measure #12.A.3 of NAP; also highlighted in CVA.	Breeds that are resilient to effects of climate change such as heat, adapted to local context and are most productive. Greenhouse gas emissions would decrease and herders would have access to carbon market.
Sustainable Livestock Management	Adaptation measure #12.A.3 of NAP; CVA	Of the diseases related to climate change that affect livestock, the ones with the greatest impact are vector-borne. Changes in rainfall patterns can influence an expansion of vectors during wetter years and can lead to large outbreaks. Climate change could also influence disease distribution indirectly through changes in the distribution of livestock.
Agro-forestry	Adaptation Measure #12.A.3 and 12.A.9 of NAP; also highlighted in NDP and GGF	Agro-forestry or use of trees in the cropping system, helps farmers to reduce their vulnerability to climate change. The trees are less vulnerable to heat stress and are able to reduce the heat stress of crops, hold the soil during episodes of extreme rainfall and help in the maintenance of soil nutrient. This technique strengthens the REDD+ program to reduce its carbon footprint.
New Improved Crop varieties	Adaptation measure #12.A.3 of NAP; also highlighted in CVA	The technology involves plant-breeding techniques by selecting specific rootstocks such as yams, taro, kumara and vegetables with increased drought tolerance, thus reducing water consumption by plants; pest-tolerant varieties such as those resistant to Taro Leaf Blight and Banana TR4; or even producing salt-tolerant cassava and sugarcane varieties
Climate Index Insurance	DRRP and also highlighted in CVA	The intensity of cyclones is expected to increase in future and would cause huge financial loss in the agriculture sector. Climate-index insurance pays the holder of the insurance contract when a certain value in an index is realized (e.g. a percentile of the rainfall is realized). Indemnities to farmers will decrease their vulnerability to climate change. It has been demonstrated that index insurance for excessive rainfall could be beneficial for sugar cane producers (Kath, 2018).

3.5 CRITERIA AND PROCESS OF TECHNOLOGY PRIORITISATION

In the first national TNA awareness workshop, organised on 29th July, 2019 a long list of technologies was discussed with the relevant stakeholders forming the Agriculture TNA working group (See Annex II). Feedback was sought on the details of the factsheets, and some new technologies were suggested. During this workshop, stakeholders expressed their consensus on the applicability and the relevance of the technologies. There were many bilateral meetings with concerned organisations to finalise these TFS. The Multi-Criteria Analysis framework developed by the MCA4Climate project (UNEP, 2011) was used as a basis to develop the objective and subjective criteria for prioritising technologies. The objective criteria were the costs (including both capital and operational cost), whereas the subjective criteria were those that were based on expert opinions drawing on the knowledge and experience of working group members. Table 3.4 shows the criteria, indicators, and scoring scale used in the prioritizing exercise by the stakeholders.

Table 3.4: The criteria, indicators and scoring scale used in the prioritisation of technologies in the agriculture sector.

Criteria		Indicators	Scoring Scale
Cost	1	Cost to set up and operate the technology (resources, skills, infrastructure, maintenance costs)	USD/yr Lowest value preferred
Implementation Considerations	2	Ease of implementation (timeframe, part of strategic plan of implementing agent, local availability and maturity of technology and existing expertise in Fiji)	1 – Very Difficult 2 – Difficult 3- Moderately difficult 4 – Easy 5 – Very Easy (preferred value)
Climate-Related	3	Enhancing resilience against climate change (i.e. to what extent the technology will contribute to reducing the vulnerability of the agriculture sector to climate change impacts).	1 – Very low 2 – low 3- Medium 4 – High 5 – Very High (preferred value)
	4	Potential to reduce GHG emissions. The factor considered for scoring used will the proven ability of technology to reduce carbon footprint.	1- very low 2 – low 3 – medium 4 – high 5 – very high (preferred value)
Economic Benefits	5	Creation of new jobs. A factor to consider is number of new jobs created.	1- very low 2 – low 3 – medium

Criteria		Indicators	Scoring Scale
			4 – high 5 – very high (preferred value)
	6	Increasing farmers' revenue and the ability to re-invest. Factors to consider an increase in productivity, increase in income/livelihoods and decrease in avoided damage due to drought, rain, heat, pest and poor soil nutrient.	1- very low 2 – low 3 – medium 4 – high 5 – very high (preferred value)
Social Benefits	7	Contribution to social and sustainable development (gender-sensitive and inclusive such as the enhanced role of women and women leadership in decision making, education or dissemination of knowledge, improvement in health due to enhanced livelihood and access to better health facilities and community engagement.	1- very low 2 – low 3 – medium 4 – high 5 – very high (preferred value)
Environment Benefits	8	Protects and safeguards the environment from pollution of air, water and soil. It improves the habitat for wildlife.	1- very low 2 – low 3 – medium 4 – high 5 – very high (preferred value)
Political Acceptability	9	Coherence with national development policies and priority.	1- very low 2 – low 3 – medium 4 – high 5 – very high (preferred value)

The stakeholders determined the weightings for each indicator. Table 3.5 shows the weightings used in the MCA analysis. Weighting 1 represents the primary weighting agreed by stakeholders' consensus and the other two weightings, which were decided by the consultants to take into account the difference in opinions amongst the stakeholders during the national workshop, were used for the sensitivity analysis to evaluate the robustness of the MCA analysis. If the same three technologies are prioritised as first, second and third in all three weighting scenarios, the MCA can be considered valid.

Table 3.5: Weightings used for prioritisations and sensitivity analysis.

Criteria		Weighting 1		Weighting 2		Weighting 3	
Level 1	Level 2	Level 1	Level 2	Level 1	Level 2	Level 1	Level 2
Cost		20%		15%		25%	
Implementation Consideration		5%		5%		3%	
Climate Related	Enhancing Resilience	25%	70%	30%	70%	20%	60%
	Potential to reduce GHG		30%		30%		40%
Economic	Creation of Jobs	15%	40%	15%	40%	20%	30%
	Income generation		60%		60%		70%
Environmental		20%		20%		15%	
Social		10%		10%		10%	
Political Acceptability		5%		5%		7%	

3.6 RESULTS OF TECHNOLOGY PRIORITISATION

The results of the MCA exercise to prioritise technologies for agriculture adaptation is shown in Table 3.6. The TFS of technologies, identified relevant for Fiji, were finalised through bilateral meetings with the stakeholders before the prioritisation workshop organised on 13th September 2019. The following working group members participated in the prioritisation workshop:

1. Mr Saimone Johnson Sugar Research Institute
2. Mr Viliame Waqa Ministry of Lands
3. Ms Tavaita Tamani Ministry of Agriculture
4. Mr Adriano Tabualevu Ministry of Agriculture
5. Dr Ashnita Prasad Ministry of Agriculture
6. Mr Romuluse Rajale Ministry of Agriculture
7. Mr Shalendra Prakash Sugar Cane Growers Council
8. Ms Adi Loraini Baleilomaloma SPC Land Resources Department
9. Ms Deborah Sue Ministry of Forestry
10. Ms Noelenen NabulivouDIVA for equity
11. Ms Nazeea Bano Sugar Research Institute

These TFS were used by stakeholders to assess the criteria and come to a consensus score.

The scores were normalised using the formulas and then the final scores given are the summation of the product of the normalised scores and weights.

The top three ranked technologies for the agriculture sector are:

1. Agro-forestry
2. Integrated Nutrient Management
3. Improved Crop Varieties.

Table 3.6: Results of the prioritisation exercise using Weighting 1 are given in Table 3.5. The performance and scoring matrix is given in Annex III.

Criteria	Cost	Implementation Considerations	Climate Related		Economic Benefits		Social Benefits	Environment Benefits	Political Acceptability	Total Scores	Rank
Level 1 weighting	**20%**	**5%**	**25%**		**15%**		**10%**	**20%**	**5%**		
			Enhancing Resilience	Potential to Reduce GHG emissions	Creation of Jobs	Increasing Revenue					
Level 2 weighting			70%	30%	40%	60%					
Technology											
Option 1: Drip Irrigation	0.0	0.0	11.7	3.8	6.0	6.8	10.0	20.0	0.0	58.2	5th
Option 2: Integrated Nutrient Management	20.0	2.5	11.7	5.6	6.0	6.8	0.0	20.0	3.3	75.9	2nd
Option 3: Selective Breeding via controlled breeding	16.5	1.3	5.8	3.8	6.0	6.8	10.0	0.0	5.0	55.1	6th
Option 4: Agro-forestry	14.1	3.8	17.5	7.5	6.0	9.0	10.0	20.0	3.3	91.2	1st
Option 5: Improved Crop Varieties	20.0	2.5	11.7	1.9	6.0	6.8	10.0	10.0	0.0	68.8	3rd
Option 6: Integrated Pest Management	18.8	2.5	11.7	3.8	6.0	4.5	10.0	0.0	3.3	60.6	4th
Option 7: Sustainable Livestock Management	18.8	2.5	5.8	5.6	6.0	6.8	0.0	0.0	5.0	50.5	7th
Option 8: Index Insurance	20.0	5.0	0.0	0.0	0.0	0.0	10.0	0.0	1.7	36.7	8th

The ranking of the top three technologies did not change in the sensitivity analysis when different weightings, as indicated in Table 3.5, were applied. The fact that there was no change in the sensitivty analysis shows the robustness of the MCA. This was further supported by benefit Vs cost graph (see Figure 3.1), which shows that technologies with low costs and high benefits were prioritised. It can be seen that Option 4 (Agro-forestry) had only the second-highest score in terms of cost but was most preferred overall because its obvious benefits made it cost-effective, whereas Option 1 (Drip Irrigation) had high acceptability amongst the stakeholders, but its high cost for implementation made it less cost-effective, and less favourable overall, according to MCA.

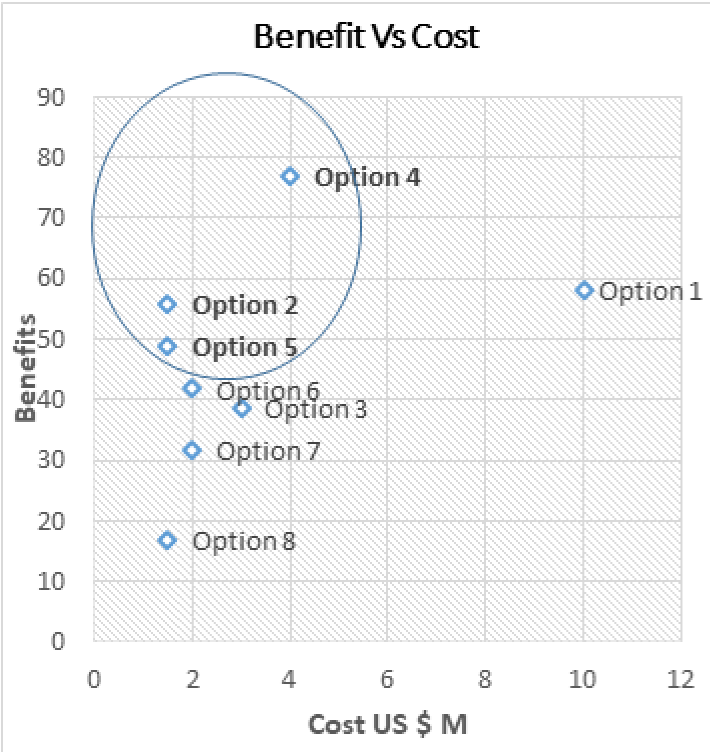

Figure 3.1: Cost-Benefit illustration for technologies in the agriculture sector. The overall score for prioritisation is based on criteria in addition to costs and benefits, such as implementation considerations and political acceptability. However, this chart illustrates that the technologies prioritised also have a high ratio of benefits to costs.

CHAPTER 4: TECHNOLOGY PRIORITISATION FOR COASTAL ZONE

4.1 KEY CLIMATE CHANGE VULNERABILITIES IN THE COASTAL ZONE SECTOR

Most of the infrastructure development, such as roads, and economic activities, are concentrated along the coastline and therefore highly vulnerable to sea-level rise (SLR). The urban drift, or migration of people from rural to urban areas along the coast and living in informal settlements, mostly in low-lying vulnerable areas, further exacerbates the risk posed by SLR and flooding. The primary risk of SLR is increased coastal flooding and inundation, coastal erosion, saltwater intrusion and changes in sediment deposition (Mimura, 1999). Although SLR is the greatest long-term threat to low-lying coastal developments, the coastal areas have experienced huge loss and damage due to intense rainfall and flooding and due to storm and tidal surges associated with cyclonic activities.

The rate of sea-level rise by 6 millimetres per year since 1993 in Fiji is greater than the global average and has dire consequences for settlements along the coast (GoF, 2017a). The risk of coastal flooding and inundation associated with SLR and storm and tidal surges has forced the relocation of 3 villages. The first village was Vunidagaloa, where 26 homes were relocated to higher ground, and more than 40 villages are earmarked to be relocated in future. Haigh (2017) suggested that the mean sea-level increase by 2100 at 87 – 135 cm. A high-emission scenario projects water levels of 3.2 m above sea level at Lautoka every other year by 2100, as compared to current estimates of once every 100 years (Haigh, 2017). This tends to suggest that northwest Viti Levu and Vanua Levu are more vulnerable to storm surges associated with future predictions of high-intensity cyclones.

Corals are very sensitive to increases in sea-surface temperatures and are tolerant to temperature increases by 1°C to 2°C. The prediction of increases in sea surface temperatures in future will amplify the magnitude and the frequency of coral bleaching events. A massive coral bleaching was observed in Fiji in 2000 during the strong La Niña event, and almost 100% coral bleaching was observed in some sites of the Great Astrolabe Reef. The threshold temperature for coral bleaching in Fiji is within the range of 29.5 – 30°C. In addition to increasing SSTs, intense cyclones can also damage corals. Cyclone Winston, a category 5 cyclone, damaged coral reefs up to 30 m below the surface of Vatu-i-ra passage (Mangubhai, 2016). Ocean acidification due to increases in CO_2 decreases growth rates and causes structural damage to corals, and increases in rainfall associated with future climate change can cause further damage to coral reefs by smothering corals with increased sedimentation. Increases in coral mortality are linked to loss of marine biodiversity and could potentially lead to decreases in fish stock. This further decreases food security and livelihoods of the local community.

It is known that mangroves and coastal vegetation tend to prevent coastal erosion from SLR and storm surges and safeguard the health of corals. However, in some places mangroves and coastal vegetation were removed to pave way for the economic development on the coast. Some 25% of the total mangroves were removed between 2003 and 2013, making coastal communities more vulnerable to future climate change. Mangroves, coastal vegetation and beaches may provide a buffering system against long-term changes in SLR to some extent, but more hard technologies, such as sea walls and dikes, need to be incorporated with these soft measures to increase the resilience of the coastal communities to flooding due to SLR, storm surges and increased wave action.

4.2 DECISION CONTEXT

Adaptation measures for coastal communities to reduce the impact off coastal inundation and coastal erosion, primarily from SLR, are considered a high priority area and form an essential component in national plans and policies already discussed in section 1.2. The CVA report views the coastal protection as important and requiring significant investment in order to aid in climate-proofing coastal communities. The NAP lists the following adaptation measures for coastal protection from climate hazards:

1. Integrate ecosystem-based adaptation measures into considerations regarding the construction of sea walls and riverbanks, including mangrove planting.
2. Implement coastal protection measures in highly vulnerable communities (e.g. foreshore protection, artificial wave breaks, etc.).
3. Implement river-bank protection activities that integrate ecosystem-based approaches with hard infrastructure, in particular the use of riparian buffers.
4. Create flood-risk and management action plans for all human settlements that operate at the catchment scale and involve either hybrid or nature-based solutions and payments for ecosystems services.
5. Develop flood management activities for priority river systems, such as Nadi River, Sigatoka River, Rewa River, Labasa River.
6. Conduct regular river-flow monitoring and flood forecasting.

There have been a number of projects implementing adaptation measures in the coastal communities. The two most common adaptation projects to protect our coast from the impacts of climate change are planting of mangroves and other coastal vegetation and construction of sea walls. Table 4.1 shows the current and proposed sea wall construction to protect communities from coastal flooding and inundation.

The Mangrove Ecosystems for Climate Change Adaptation & Livelihoods (MESCAL) Project was established to address the key challenges of mangroves management to increase the resilience to climate change and improve livelihoods. A major outcome of the MESCAL project was the Mangrove Management Plan 2013, a document that provides a comprehensive analysis of policies and legislation pertaining to the management of mangrove ecosystems in Fiji.

Table 4.1: List of sea wall construction projects completed or in progress in different locations in Fiji.

No	Division	Amount	Remarks
COASTAL PROTECTION WORKS			
1	Namoli Village, Lautoka	$642,684	95% completed
2	Lamini Village, Taveuni	$995,690	Works Completed, now under defects liability period

3	Nadaro Village, Tailevu	$395,718	completed under maintenance period
4	Rukurukulevu Village, Nadroga	$437,619	75% completed
5	Namuana Village & Tavuki district school , Kadavu	$1,198,480	In progress with 15% works completed
6	Dravuni village , Tailevu	$490,974	In progress. 30% of works completed
7	Naisausau village, Tailevu	$401,133	New sites proposed and Expression of Interest to be advertised.
8	Matanivere village, Tailevu	$398,449	
9	Nawaisomo village, Beqa	$298,033	

The Restoration of Ecosystem Services and Adaptation to Climate Change (RESCCUE) project funded by the French Development Agency and French Global Environment Facility and was implemented by SPC. The project focused on increasing resilience by 1.) planting mangroves and coastal trees in Ra province and documenting existing knowledge in coastal community based protected areas, and 2.) mangrove and fisheries protection initiative in Ra. A total of 1,800 seedlings were planted in 6 villages, with a total planting area of 0.45 acres. An additional 1,362 seedlings were distributed to 10 other villages. In 2015 as part of the Coral Triangle Initiative (CTI) funded by the Asian Development Bank, five coastal villages in Ra undertook mangrove replanting: Navolau, Togovere, Vitawa, Narewa, and Naivuvuni. Approximately 19,000 mangrove seedlings were planted across an estimated 17 ha of coastal shoreline. The objective of the mangrove replanting exercise was to educate and encourage mangrove replanting by communities to safeguard and stabilise the coastline. The Mangroves for Fiji initiative also resulted in mangrove restoration at 15 sites in Viti Levu, 1 site in Lau Island and 2 sites in Vanua Levu.

There have been a few other projects for coastal zones such as the Ridge to Reef (R2R) project, that focused on watershed and coastal management, flood-hazard mapping and coral reef restoration projects, which are discussed further under the existing technologies.

4.3 OVERVIEW OF EXISTING TECHNOLOGIES IN COASTAL ZONE

In Fiji there have been a number of technologies available to stabilise and protect the coastline from increasing SLR and storm surges. It was noted that when Ra province was hit by category 5 Cyclone Winston in 2016, the local community realised the importance of mangroves and coastal vegetation in dissipating the wave energy and thereby decreasing the risk. An important lesson was learnt and through the European Union's RESCCUE project (RESilience to cope with Climate Change in Urban arEas) local communities in Ra were empowered in terms of planting and managing the mangroves and building their resilience to impacts of powerful cyclones.

Given below is an overview of technologies that have been used in Fiji to protect the coast and coastal infrastructure:

- Sea wall stone: A traditional hard-engineering technology whereby stones are piled along the coast lining the road to prevent infrastructure damage from wave action. Over the years this technology is compromised by wave action displacing the stones, and therefore is no longer favoured.
- Stone/Boulder masonry vertical sea-wall: Is the prefered hard technology to protect the coastline from erosion. Such technology has been widely accepted by communities and have been implemented in many villages, more construction is proposed. These vertical sea-walls arestronger than sea-wall stone but are not impervious to wave action and will collapse over time.
- Coastal vegetation and seagrasses: Increasing precipitation leads to an increase in sedimentation rates that could be detrimental to reef ecology. The native plants such as pandanus and beach creepers like "beach morning glory" are soft technology options that can prevent erosion. Seagrasses are also very beneficial in removing sediments from the water column and preventing its resuspension. The extended rhizome and root systems of seagrasses stabilise ocean-floor sediments and prevent them from being re-suspended.
- Mangrove restoration: Much work is being done on mangrove restoration in the country, as discussed in section 4.2. This technology is now very widely accepted by the local community after facing the wrath of a category 5 cyclone in 2016. Mangrove nurseries have been established in the country.
- Coral reef restoration: Coral restoration activities are conducted by the private company Reef Explorer, which aims to enhance community-based marine management efforts on the Coral Coast. With the assistance of village youth groups, coral nurseries containing over 1,200 corals each have already been established in four Korolevu-i-wai Marine Protected Areas (MPAs) and one fished location, with a total of 7,500 new coral colonies currently propagated in the nurseries.
- Flood-hazard Mapping: Flood-hazard mapping is an exercise to define those coastal areas that are at risk of flooding under extreme conditions. Flood-hazard mapping has been done for the Nadi River basin (See Figure 4.1), which can now be used in decision-making by property developers and insurance companies and emergency response by relevant authorities in case of natural disasters.

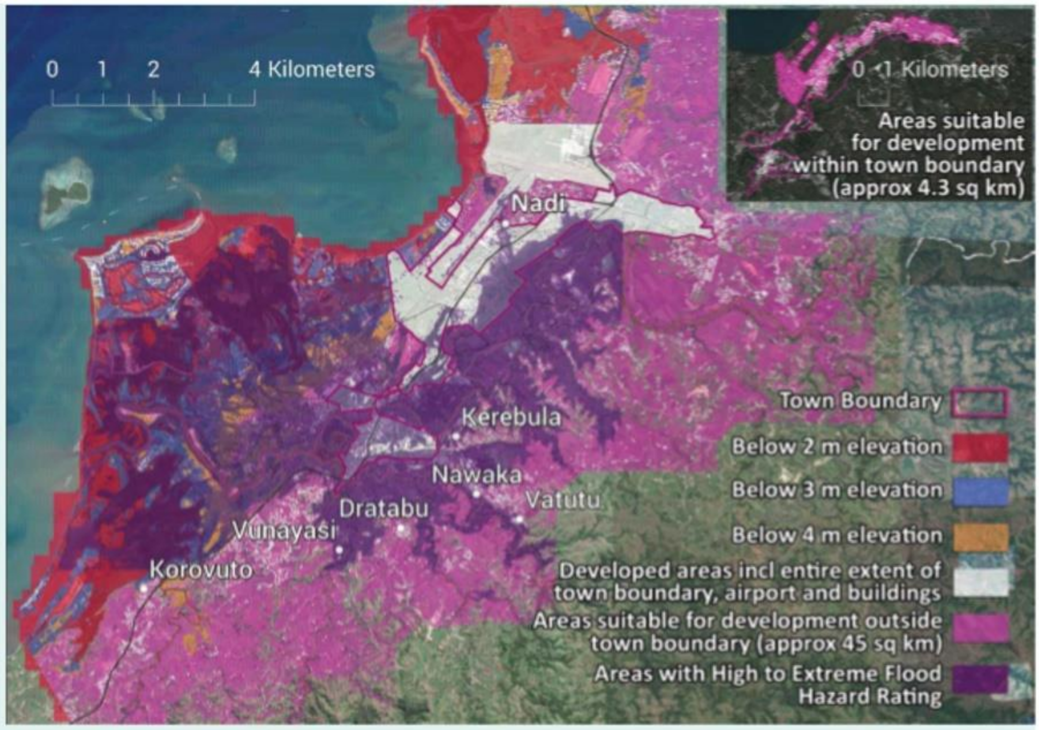

Figure 4.1: Flood-hazard mapping for the Nadi river basin (Source: GoF, 2017)

4.4 ADAPTATION TECHNOLOGY OPTIONS FOR THE COASTAL ZONE SECTOR AND THEIR MAIN ADAPTATION BENEFITS

The long list of technology options for the coastal zone sector was discussed and agreed by the stakeholders on 29th July 2019. The entries in Table 4.2 are not prioritised, and some have been implemented in Fiji to some extent. The table also highlights the linkages of the technologies to national policy and planning documents such National Adaptation Plan, National Climate Change Policy and is useful to demonstrate the political acceptability of the technology. The technology factsheet for each of these technologies is attached in Annex I, which contains a brief description of technology, application potential in the country, costs, technical aspects, and the environmen.

Table 4.2: Adaptation technology options in coastal zone sector and its adaptation benefits and linkages to national policies and planning documents.

Technology	Linkages to Policy and Planning Documents	Climate Change Adaptation Benefits
Rehabilitation of Mangroves	Adaptation measure #15.D.1 of NAP; NDP	In terms of climate change adaptation in the coastal zone, the main benefit of wetland restoration is the reduction of the incoming wave and tidal energy by enhancing energy dissipation in the intertidal zone. This is achieved by increasing the roughness of the surface over which incoming waves and tides travel. This

Technology	Linkages to Policy and Planning Documents	Climate Change Adaptation Benefits
		reduces the erosive power of waves and helps to reduce coastal flood risk by diminishing the height of storm surges.
Replanting of Corals		Replanting corals improvse a coral reef that is impaired due to coral bleaching or sedimentation. Increasing coral colonies will reduce wave energy reaching the shore, thus protecting the coastline from erosion. The establishment of artificial reefs will improve the status of coastal biodiversity and hence the fish populations depending on reefs for food and shelter will grow. This will enhance coastal fisheries and support the local livelihood.
Construction of Groynes and Sea Walls	#15.D.1 of NAP; NDP; DRRP	This is a hard defence mechanism against coastal flooding and damage to coastal infrastructure. The construction of sea wall prevents land loss and saltwater intrusion into groundwater and favours the agricultural sector. Appropriate sea wall design should be durable and able to withstand intense wave action and storm surges. Groynes are built perpendicular to sea walls and are designed to catch and trap sediments moving in a surf zone and reduce sediment transported seawards.
Sand Dune Rehabilitation	#15.D.1 of NAP; DRRP	Dune restoration refers to the rehabilitation of natural or artificial dunes to a better state of overall function in order to gain the greatest coastal protection benefits. This is a technology aimed at reducing both coastal erosion and flooding in adjacent coastal lowlands. Planting vegetation is perhaps the most preferred method to stabilise natural or artificial dunes.
Flood-hazard Mapping	#15.D.1 of NAP; CVA; GGF	This technology includes a number of hydrological methods like bathymetry, as well as the use of LIDAR (airborne laser scanning) to create flood-hazard mapping. The flood-hazard maps can steer development away from flood-prone areas and thereby reduce vulnerability.
Restoration of Coastal vegetation	#15.D.1 and 15.D.3	This is a soft defence mechanism of planting trees along the coast to prevent coastal erosion due to SLR.

4.5 CRITERIA AND PROCESS OF TECHNOLOGY PRIORITISATION

In the first national capacity workshop organised on 29th July, 2019, the TFS of a long list of technologies were discussed with the relevant stakeholders forming the Coastal TNA working group. Feedback was sought on the details of the factsheets, and some new technologies were suggested, such as flood-hazard mapping. During this workshop, stakeholders expressed their consensus on the applicability and the relevance of the technologies. The Multi-Criteria Analysis framework developed by the MCA4Climate project (UNEP, 2011) was used as a basis to develop the objective and subjective criteria for prioritising technologies. The objective criteria were the cost (including both capital and operational cost), and the subjective criteria were based on expert opinions and the knowledge and experience of working group members. Table 4.3 shows the criteria, indicators, and scoring scale used in the prioritising exercise by the stakeholders.

Table 4.3: Lists the criteria, indicators and scoring scale used for the prioritisation exercise.

Criteria		Indicators	Scoring Scale
Cost	1	Cost to set up and operate the technology (resources, skills, infrastructure, maintenance costs)	USD/yr Lowest value preferred
Implementation Considerations	2	Ease of implementation (timeframe, part of strategic plan of implementing agent, local availability and maturity of technology and existing expertise in Fiji)	1 – Very Difficult 2 – Difficult 3- Moderately difficult 4 – Easy 5 – Very Easy (preferred value)
Climate-Related	3	The indicator used was reduced vulnerability, and the factors considered for scoring included: the proven ability of the technology to control erosion/flooding, its potential to demonstrate tangible coastal protection results in a short time frame.	1 – Very low 2 – low 3- Medium 4 – High 5 – Very High (preferred value)
Economic Benefits	5	The indicators used for scoring were the creation of jobs, avoided damage due to implementation of technology, the local livelihood of people from eco-tourism activities on the beach.	1- very low 2 – low 3 – medium 4 – high 5 – very high (preferred value)
Social Benefits	7	Contribution to social and sustainable development (gender-sensitive and inclusive such as the enhanced role of	1- very low 2 – low

Criteria		Indicators	Scoring Scale
		women and women leadership in decision making, education or dissemination of knowledge, improvment in health due to enhanced livelihood and access to better health facilities and community engagement.	3 – medium 4 – high 5 – very high (preferred value)
Environment Benefits	8	Protects and safeguards the environment from pollution of air, water and soil. It improves the habitat for wildlife.	1- very low 2 – low 3 – medium 4 – high 5 – very high (preferred value)
Stakeholder Acceptability	9	Coherence with national development policies and priority.	1- very low 2 – low 3 – medium 4 – high 5 – very high (preferred value)

The stakeholders determined the weightings for each indicator. Table 4.4 shows the weightings used in the MCA analysis. Weighting 1 represents the primary weighting agreed by stakeholders and the other two weightings were used for the sensitivity analysis to evaluate the robustness of the MCA analysis. If the same three technologies are prioritised as first, second and third in all three weighting scenarios, the MCA can be considered valid.

Table 4.4: weightings used for different criteria for the prioritisation and sensitivity analysis

Criteria	Weighting 1	Weighting 2	Weighting 3
Cost	15 %	20%	25%
Implementation Consideration	2%	5%	3%
Climate Related	19%	25%	15%
Economic	19%	15%	20%
Environmental	21%	15%	15%
Social	19%	15%	15%
Political Acceptability	5%	5%	7%

4.6 RESULTS OF TECHNOLOGY PRIORITISATION

The results of the MCA exercise to prioritise technologies for coastal zone adaptation is shown in Table 4.5. The TFS of technologies identified as relevant for Fiji were finalised through bilateral meetings with the stakeholders before the prioritisation workshop organised on 13th September 2019. The following stakeholders participated in the prioritisation exercise:

1. Mr Alfred Ralifo — WWF
2. Mr Amit Singh — Ministry of Waterways
3. Ms Kelera Rayawa — Ministry of Education
4. Mr Samuela Tokakele — Ministry of Fisheries
5. Ms Evelyn Sami — Consumer Council
6. Mr Maika Tuicakau — Ministry of Infrastructure, Transport, Disaster Management and Meteorological Services
7. Mr Shaneel Prakash — Ministry of Lands
8. Ms Ana Vesikula — Soqosoqo Vakamarama Taukei
9. Ms Shirley Tagi — Diva (women's group)
10. Mr Ifereimi Dau — IUCN

These TFS were used by stakeholders to assess the criteria and come to a consensus on scores. The scores were normalised using the formulas, and the final scores given reflect the normalised scores and weights.

Table 4.5: Results of the technology prioritisation in the coastal zone sector. The performance matrix and scoring matrix are given in Annex III.

Criteria	Cost	Implementation Considerations	Climate Related	Economic Benefits	Social Benefits	Environment Benefits	Stakeholder Acceptability	Total Scores	Rank
Weightings (100%)	15	2	19	19	19	21	5		
Technology									
Option 1: Rehabilitation of Mangroves	15	1	13	13	10	11	3	64	2nd
Option 2: Replanting Corals	15	0	6	6	0	0	0	27	6th
Option 3: Construction of Groynes and Sea Walls	0	1	13	19	19	21	5	78	1st
Option 4: Sand Dune Rehabilitation	15	2	6	13	10	11	3	59	4th
Option 5: Flood-hazard Mapping	13	1	6	19	19	0	5	63	3rd
Option 6: Coastal Vegetation	15	1	0	0	19	21	3	59	4th

According Table 4.5 above, the following technologies were prioritised:

1. Construction of Groynes and Sea Walls
2. Rehabilitation of Mangroves
3. Flood-hazard Mapping

A sensitivity analysis using the weightings described in Table 4.4 was used to determine the robustness of the MCA results for the coastal zone sector. The sensitivity analysis showed that the ranking of first three technologies did not change. However, in the third weighting scenario, where the cost criterion weighting was increased to 25%, there was a marginal difference between the first three technologies. This is not surprising because the construction of Groynes and Sea Walls is both expensive and high beneficial (see Figure 4.2 below).

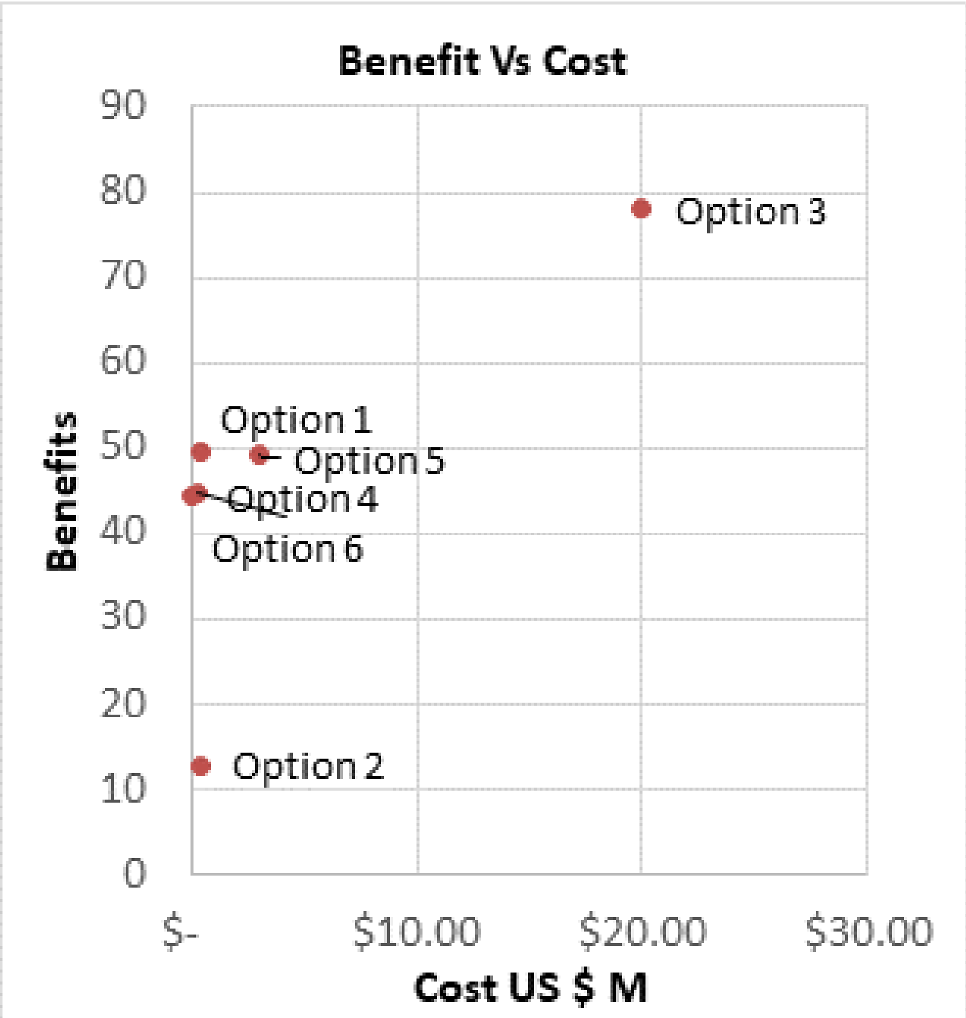

Figure 4.2: Cost-Benefit Analysis for technology options with Weighting 1 in the Coastal Zone sector. The overall score for prioritisation is based on criteria in addition to costs and benefits, such as implementation considerations and political acceptability. However, this figure illustrates that the technologies prioritised also have a ratio of benefits to costs.

The detailed information on the prioritised technology is given in the technology factsheet attached in Annex I. A brief summary of the prioritised technologies is given below:

1. **Construction of Sea Wall with Groynes**: There was immense acceptance by the stakeholders of this technology, which is considered to be hard engineering technology to protect coastal erosion. Sea walls of various forms have been around Fiji since the 1960s; however, concerns regarding the durability of the technology were raised in the discussion, and therefore appropriate and sustainable designs needs to be implemented. Nonetheless, there was great consensus that despite high cost, the technology is proven to provide more environmental, social and economic benefits from SLR and storm surges. The construction of sea walls with gyrates will be relatively new technology and will help in withstanding the strong backwash in waves that undercuts the sea wall and causes it to collapse. The groynes could be wooden structures perpendicular to the coastline extending out into the sea. The groynes prevents the movement of sand and help build a larger section of beach in front of sea walls. The new beach will increase the distance that waves have to travel to reach the coast and, in the process, lose most of their energy, reducing their impact on the sea wall.

2. **Mangrove Rehabilitation:** The technology already exists in Fiji, and the barriers to implementation are well known, such as survival rates of mangrove seedlings, species selection and lack of commitment from the local communities to sustain the mangrove. Nonetheless, it is a soft mechanism that will protect coastal erosion from storm surges and provide a buffer between the coast and the reef system by trapping nutrients, chemicals and sediments that could potentially damage the reef system. Mangroves will increase biodiversity and could improve the livelihoods of local women in terms of harvesting clams ("kaikoso"), mud crabs and fish, and also contributes to carbon sequestration.

3. **Flood-hazard Mapping:** An important tool to map out regions that are more prone to flooding in future due to climate change. Flooding causes huge economic losses in Fiji in terms of structural damage to infrastructure and damage to agriculture sector. The use of LIDAR measurements in conjunction with changes in bathymetry and topographic data could provide useful flood-hazard mapping to steer infrastructure development away from areas prone to future climate hazards and in planning national disaster-risk reduction programs.

CHAPTER 5: SUMMARY AND CONCLUSIONS

The technology needs assessment was a nationally driven, gender-inclusive process involving relevant stakeholders. The initial consultation with stakeholders and reviews of National Development Plans, the national Climate Vulnerability Assessment report and National Adaptation Plan resulted in the prioritisation of two sectors for the TNA process for adaptation. The two sectors prioritised were agriculture and coastal zones.

A long list of technologies was identified for each sector and was later shortlisted according to the maturity, applicability, local availability, and stakeholder acceptability of each technology. During the workshop conducted on 29th July 2019, a total of 8 technologies were identified in the agriculture sector, and a total of 6 technologies were identified in the coastal zone sector. The technology factsheets were developed further for these shortlisted technologies in consultation with stakeholder experts in the field through many bilateral meetings. The short-listed technologies underwent further analysis and prioritisation using the MCA tools. The decisions were based on cost; implementation considerations; climate-related goals such as reducing vulnerability; economic, social and environmental benefits and political or stakeholder acceptability.

The following technologies were identified as the most preferred technology options for the respective sectors;

1. **Agriculture Sector**
    i. Agro-forestry
    ii. Integrated Nutrient Management
    iii. Improved Crop varieties

2. **Coastal Zone Sector**
    i. Construction of Sea Wall with Groynes
    ii. Mangrove Rehabilitation
    iii. Flood-hazard Mapping

The technologies prioritised do not exist in the country to a significant extent, and stakeholders pointed out the need to upscale these matured technologies to develop a climate-resilient economy. Barrier analysis will be carried out and development of technology action plans developed for these prioritised technologies to reflect the need for such technology actions in the respective sectors and subsectors. The results of the TNA project will support the national development priorities.

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ANNEXES

ANNEX I: TECHNOLOGY FACTSHEETS FOR SELECTED TECHNOLOGIES

Agriculture Sector

Agro-Forestry Factsheet for subsector Sustainable farming systems

Technology: Agro-forestry	
Sector: Agriculture	
Subsector: Sustainable farming systems	
Technology Characteristics	
Introduction	Agro-forestry is a land-use system that aims towards optimal utilization of available land resources by multiple as well as beneficial practices of agriculture and forestry. The main purpose of agro-forestry activities is to sustain the fertility of the soil by substituting the nutrition required by intensive agriculture. The World Agro Forestry Centre defines the technology as an integrated approach to the production of tress and non-tree crops or animals on the same piece of land. The crops can be grown together at the same time, in rotation, or in separate plots, with materials from one are used to benefit another.
Technology Characteristics / Highlights	Agro forestry systems take advantage of trees for many uses: to hold the soil; to increase fertility through nitrogen fixation, or through bringing minerals from deep in the soil and depositing them by leaf fall; to provide shade, construction materials, foods and fuel. Agro forestry incorporates the benefits of both intensive scientific agricultural practices and forestry activities that yield the desired timber, fuel wood and non-wood forest produce. The agro-forestry models concentrate both on the short-term returns from agriculture and the long-term returns from forestry activities. Agro-forestry activities also ensure diversity in crops raised and enhance species diversity by encouraging plantation of multiple-tree species for various uses or plantation of multiple-purpose tree species.
Institutional and Organisational Requirements	The institutional context is essential to natural resource management and agro-forestry. The government agencies in Fiji such as the forestry department and the community extension based services in the Agriculture department needs to work at various levels: national, regional and local (including provincial, municipal, district and village levels). The development of Agro-forestry needs close collaboration with local, national and international NGO's such as Fiji REDD+ programme which is involved in relevant areas such as rural development and environmental conservation. The policy and legal framework are of great importance for the sustainable management of natural resources. Local government and forestry authorities should be lobbied to simplify the legal processes for commercialisation of native wood and non-timber products grown in agro-forestry systems. Increased adoption of agro-forestry should be supported by the government through finance. Research and training is required to match high-value agro-forestry species with the right agro-ecological zones and agricultural practices

Technology: Agro-forestry	
Sector: Agriculture	
Subsector: Sustainable farming systems	
Technology Characteristics	
Operation	It requires specialised skills in seedling production. Plantation and maintenance can be made easy by training farmers' representatives. Harvesting can be done using local knowledge.
Country specific Applicability and Potential	
Capacity	The capacity to develop the technology in Fiji seems favourable as the country is committed to GHG reduction by enhancing the forestry sector through the REDD + programme.
Scale of Application	Particularly to lands that are more susceptible to land degradation or soil erosion due to future climate-change impacts.
Time horizon- Short /Medium/Long-Term	Short-term
Status of technology in the country	
Availability of Technology	The technology already exists in the country, but the full potential is not realised. Several training has been conducted in Fiji to increase the knowledge of the local farmers about agro-forestry. A model farm has been established in Northern Fiji with different combinations of crops and trees being trialled on flat and sloping land. Indigenous tree species such as Dakua (*Agathis macrophylla*) and Vesi (*Intsia bijuga*) have been planted on the top of the slope, with trees of economic value, such as sandalwood, planted alongside citrus and other fruit trees in the middle of the slope. Crops such as taro, pigeon pea, okra, cowpea, watermelon, eggplant and capsicum have been planted at the base of the slope. (https://www.worldagro-forestry.org/news/agro-forestry-sustainable-farming-fiji)
Climate change mitigation/adaptation benefits	
Reduction to Vulnerability to Climate Change and Indirect.	Agro-forestry can improve the resilience of agricultural production to current climate variability as well as long-term climate change through the use of trees for intensification, diversification and buffering of farming systems. Trees are less susceptible than annual crops to inter-annual variability or short-lived extreme events like droughts or floods. Trees reduce water stress during low rainfall years or during droughts or increase infiltration rates during torrential rains.
Benefits to economic/social and environmental development	
Economic Benefits	• Creates employment due to year-round production. Creation of jobs in seedling preparation, land preparation, plantation, maintenance and harvesting. • Can create investment in forestry production inputs, equipment and production transformation industry. • Can reduce public expenditure on subsidised fertilisers and irrigation systems.
Social Benefit	• It increases the income earned through livelihood diversification and improves the quality of life of farmers.

Technology: Agro-forestry	
Sector: Agriculture	
Subsector: Sustainable farming systems	
Technology Characteristics	
	• Encourages greater participation of women in subsistence farming throughout the year and contribute to household income. • Through increased yields, it provides significant savings for households on firewood, forage and fertiliser purchase. • Trainings would be provided to improve local knowledge.
Environmental Benefits	• Enhances the carbon sink and reduce the country's carbon footprint. • The environment is preserved as agro-biodiversity is fostered, beneficiary insects are maintained, soil fertility is enhanced, and water stress is minimised from droughts. • Increasing water infiltration and slowing runoff flow during torrential rain, stabilising and protecting stream banks from erosion.
Financial Requirements and Costs	
Capital Costs	The cost of adaptation varies according to the scale of implementation and on the crop. Most of the cost will be for infrastructures such as community forest nurseries and equipment, training the extension service, capacity building for farmers and for the dissemination of the information through different means (seminars, pilot projects, booklets, media), seedling production and distribution. US$ 4 million
Operational & Maintenance Costs Over 10 years	Staff salaries, allowances, maintenance US$ 1 million
Other Costs Over 10 Years	
Acceptability to local stakeholders	Accepted by local stakeholders
Opportunities and Barriers	**Opportunities**: Promotes sustainable forest management while improving income-generating opportunities for local communities. More diverse farm economy. Barriers: Lack of demand for products, returns are slow, and land tenure issues.
Market Potential	There is a potential, but initially, the farmers need some incentives as the returns are slow.

Integrated Nutrient Management Factsheet for subsector Soil Management

<table>
<tr><th colspan="2">Technology: Integrated Nutrient Management</th></tr>
<tr><td colspan="2">Sector: Agriculture</td></tr>
<tr><td colspan="2">Subsector: Soil Management</td></tr>
<tr><td colspan="2">Technology Characteristics</td></tr>
<tr><td>Introduction</td><td>Future climate change will impact the soil organic matter content, particularly in the tropical region. The aim of Integrated Nutrient Management(INM) is to integrate the use of natural and man-made soil nutrients to increase crop productivity and preserve soil productivity for future generations. Rather focusing on nutrition management.

Fertilisers are typically classified as organic or mineral. Organic fertilisers are derived from substances of plant or animal origin, such as manure, compost, seaweed and vegetable peelings. Organic fertilisers generally contain lower levels of plant nutrients as they are combined with organic matter that improves the soil's physical and biological characteristics. The most widely-used mineral fertilisers are based on nitrogen, potassium and phosphate.

Efficient use of all nutrient sources, including organic sources, recyclable wastes, mineral fertilisers and bio-fertilisers should, therefore, be promoted through Integrated Nutrient Management.</td></tr>
<tr><td>Technology Characteristics / Highlights</td><td>• The aim of Integrated Nutrient Management (INM) is to integrate the use of natural and man-made soil nutrients to increase crop productivity. INM aims at optimal use of nutrient sources on a cropping-system or crop-rotation basis. This encourages farmers to focus on long-term planning and give greater consideration to environmental impacts.

• INM relies on a number of factors, including appropriate nutrient application and conservation and the transfer of knowledge about INM practices to farmers and researchers. In addition to the standard selection and application of fertilisers, INM practices include new techniques such as deep placement of fertilisers and the use of inhibitors or urea coatings (use of area coating agent helps to retard the activity and growth of the bacteria responsible for denitrification) that have been developed to improve nutrient uptake.

• Key components of the INM approach include:
i. Testing procedures to determine nutrient availability and deficiencies in plants and soils. Systematic appraisal of constraints and opportunities in the current soil fertility management practices and how these relate to the nutrient diagnosis, for example, insufficient or excessive use of fertilisers.

ii. Assessment of productivity and sustainability of farming systems. Different climates, soil types, crops, farming practices such trash as conservation, contour planting and vetiver along edges, and technologies dictate the correct balance of nutrients necessary. Once these factors are understood, appropriate INM technologies can be selected.

iii. Participatory farmer-led INM technology experimentation and development such as biochar incorporation and composting. The need for locally appropriate technologies means that farmer involvement in the testing and analysis is required.</td></tr>
</table>

Technology: Integrated Nutrient Management	
Sector: Agriculture	
Subsector: Soil Management	
Technology Characteristics	
	• Harsh climatic conditions are a major cause of soil erosion and depletion of nutrient stocks. By increasing soil fertility and improving plant health, INM can have positive effects on crops in the following ways: i. A good supply of phosphorous, nitrogen and potassium has been shown to exert a considerable influence on the susceptibility or resistance of plants towards many types of pests and diseases. ii. A crop receiving balanced nutrition is able to explore a larger volume of soil in order to access water and nutrients. In addition, improved root development enables the plant to access water from deeper soil layers. With a well-developed root system, crops are less susceptible to drought. iii. Build-up of soil organic matter.
Institutional and Organisational Requirements	• Ministry of Agriculture and in particular, the Koronivia Research Station will be able to do soil analysis. SRIF is also doing soil analysis for the sugar industry. • The technology requires a well-resourced research and extension organisation for its effective promotion and use. In addition, there is a need for appropriate extension approaches and methodologies that provides an opportunity for farmer experimentation and adoption of technology.
Operation	The technology can be promoted using existing research, extension and farmer linkages for technology dissemination. This, however, needs to be supported by effective capacity building at various levels to support operations at the farmer level. SRIF train farmers to sample soil and plant.
Country-specific Applicability and Potential	
Capacity	Agriculture has developed intensively in Fiji in the last 50 years, but proper nutrient management technologies, to maintain and improve soil fertility that is, which has been absorbed by crops during their growth period are missing. Especially in the last 20 years, organic fertiliser application has been ignored, which causes ecological degradation and negative effects on crop production. According to a soil fertility survey done in Fiji, 70.7% of cropland has soil with humus content of less than 2%.
Scale of Application	The technology is applicable to all farming scales (small farms and plantations) having access to irrigation water and can also work in conjunction with rainwater harvesting.
Time Horizon- Short /Medium/Long-Term	Long-term
Status of Technology in the Country	
Availability of Technology	Some composting, planting of legumes, application of mill mud and chicken manure have been the practice.
Climate Change Mitigation/Adaptation Benefits	
Reduction to Vulnerability to Climate Change and Indirect.	Contributes to the reduction of vulnerability to climate change through improvements in soil resources and increases in productivity

Technology: Integrated Nutrient Management	
Sector: Agriculture	
Subsector: Soil Management	
Technology Characteristics	
Benefits to economic/social and environmental development	
Economic Benefits	• The technology can contribute to the generation of employment at the community level through sales of transformed organic sources, e.g. compost, and increases in demand for lab technicians for soil testing. • Requires low investment in tools and equipment; and training of farmers for transforming organic sources into easily usable forms. • Reduces public and private expenditures in terms of expenditure on the use of inorganic soil nutrients.
Social Benefit	Could provide a source of extra income for individuals and groups from sales of transformed organic materials into organic soil nutrients, e.g. compost. Creates opportunity for increased group and individual learning at group and community level. It involves women in setting up and running a compost facility at the community level.
Environmental Benefits	Integrated Soil Nutrient Management will contribute to reduction in the use of inorganic fertilizers and reduce dangers of water pollution from poor handling and over use of chemical fertilizer.
Financial Requirements and Costs	
Capital Costs	Estimated costs for key components of the INM are listed below: 1) Testing of current soil conditions and appraisal of current labs in terms of instrumentation and staff – USD 500,000 2) Identify appropriate INM technologies for specific contexts (at least 10 contexts in 3 agriculture regions) USD 500,000 3) INM technology experimentation and development – USD 100,000 4) 4) Nationwide application of INM - USD 100,000
Operational & Maintenance Costs over 10 years	USD 100,000 /yr for consumables and providing ongoing training to farmers.
Other Costs over 10 years	Incentives to farmers to opt for new INM techniques
Opportunities and Barriers	**Opportunities**: Urban waste in an untapped source of potential fertiliser. Farmers associations and extension services to provide information on the most cost-effective and appropriate technologies. **Barriers:** unaffordable price, competition for organic resources may be high in areas where crop residues are used for fuel and animal feed.
Market Potential	Market potential is high, particularly when waste could be sold commercially as compost.
Status	Available locally
Acceptability to local stakeholders	High

Selection of Adapted Rootstocks and Varieties Factsheet for Subsector Improved Crop Varieties

Technology: Selection of Adapted Rootstocks and Varieties	
Sector: Agriculture	
Subsector: Improved Crop Varieties	
Technology Characteristics	
Introduction	The selection of adapted rootstocks and cultivars relies on several technologies, including biotechnology and plant breeding. - Biotechnology, which is a high-tech involving in many cases, the production of Genetically Modified Organisms (GMOs), is still prohibited in Fiji. For this purpose, this technology will not be addressed. - Plant breeding relies on natural selection; the cross-pollination of different varieties (hybridisation), natural mutation, and induced mutation through atomic manipulation, etc. No genes from other organisms are introduced.
Technology Characteristics / Highlights	Plant breeding requires scientific research and field studies before releasing the newly obtained breed to farmers for plantating on a commercial scale. • Plant breeding is conducted in research institutes and big nurseries and requires lab and field experimentations as well as genetic resources conservation facilities (seed bank, mother plants orchard, etc.). • Varieties are tested for their characteristics for several years in trial plots. • Amongst the criteria of selection we mention: - Fruit/ characteristics (flavour, colour, calibre, maturity date, etc.) - Plant characteristics (shape, vigour, type and date of blossom, etc.) - Agriculture characteristics (yield, bearing year for trees, resistance/tolerance to pests and diseases, training and pruning type for trees, winter/summer crop for field crops, etc.) - Environmental characteristics (tolerance/resistance to different soil conditions, high/ low temperatures, chilling requirement, drought, etc.) • Vegetative propagation methods (cutting, grafting and tissue culture) enable technicians to sustain varieties of mother plants characteristics and transmit them to other generations. However, propagation from descendants could diminish these characteristics.
Institutional and Organisational Requirements	Plant breeding involves significant investment, hence most of the varieties are patented, and breeders expect royalties for a defined period of time. For this purpose, new varieties are copyrighted and protected by the international Union for the Protection of New Plant Varieties (UPOV). Countries who joined UPOV acknowledge the breeders' achievement by granting them intellectual property right.
Operation	Plant breeding requires substantial investments in skills, labour, equipment, money and time. Maintaining the varieties requires the conservation of parents and varieties in seed banks or orchards. Only research institutions such as SPC CePCT and SRIF have the capacity to ensure operation and maintenance in Fiji.

Technology: Selection of Adapted Rootstocks and Varieties	
Sector: Agriculture	
Subsector: Improved Crop Varieties	
Technology Characteristics	
	The introduction of imported varieties should be through their testing in experimental orchards belonging to the mentioned institutions, then at farmers' level with the collaboration of the importing agents.
Country Specific Applicability and Potential	
Capacity	Some plant-breeding work has been carried out by SRIF and SPC CePaCt. In fact, the CePaCT gene bank is one of the most important in world supporting food and nutrition security in the Pacific.
Scale of Application	All farmers of Fiji are concerned, namely those growing vulnerable crops (fruit trees, chillies, root crops and legumes, etc.). However, the selection of the suitable cultivar or variety depends on the type of impact on the concerned crop for a specific bioclimatic zone.
Time Horizon- Short /Medium/ Long Term	Medium - Long term
Status of Technology in the Country	
Availability of Technology	A plant breeding programme is available in Fiji that can lead to promising lines of new varieties such as taro that is resistant to taro leaf blight (undergoing selection breeding programme), anthracnose-resistant chilies, dwarf varieties of breadfruit, sweet potatoes (golden brown variety) and salt-tolerant yams.
Climate Change Mitigation/Adaptation Benefits	
Reduction of Vulnerability to Climate Change and Indirect.	- Selecting specific rootstocks would increase drought tolerance, thus reducing water consumption by plants. - Certain rootstocks such as yams and taro and varieties are tolerant to dry and wet conditions and are also salt tolerant. - Some varieties have low chilling requirements, are resistant to cracking due to rain or excessive drought or, resistant to sunburn. - Some varieties have a longer or shorter vegetative periods which enables the farmers to adjust their planting/harvesting period according to climate. - Some rootstocks and varieties are resistant or tolerant to pests and diseases that might emerge under future climate conditions. They can be means to reduce these outbreaks without relying on pesticides for concerned crops. - The availability of a broader range of a varieties and rootstocks would increase the farmer's choice and consequently resilience to climate change.
Benefits to Economic/Social and Environmental Development	
Economic Benefits	• Job opportunities would increase especially at the technical level within the service providers' enterprises, nurseries, labour force, as well as within the research institutes if the introduced varieties were to be tested before releasing them to the market.

Technology: Selection of Adapted Rootstocks and Varieties	
Sector: Agriculture	
Subsector: Improved Crop Varieties	
Technology Characteristics	
	• Capital requirements are essential at research institutes, nurseries, and farmer's level. Increased production of selected plant material is reflected in increased economic growth.
Social benefit	• The income of farmers increases. • Farmers' capacity to manage their production and adapt to climate change (resilience) through training is higher. • The use of varieties resistant/tolerant to pests and diseases is reflected in lower pesticide residues in plants, which has a positive impact on health.
Environmental benefits	Reduction in chemical pollutants (pesticides), reduction of water consumption when varieties tolerant to drought are used.
Financial Requirements and Costs	
Capital Costs	Each variety or rootstock has a different price according to the species and the propagation technique, whether it is patented or not, or produced locally or imported. The price for fruit tree seedlings, their price may range from 3.5$ (local certified seedlings) to 20$ (imported patented seedling). The cost per surface unit depends on plantation density, which also varies with rootstock and species' varieties. Costing per crop Field experiment – USD 30,000 Research Personnel USD 34, 000 Capital Cost USD 20,000 Contracted expenditure – USD 20,000
Operational & Maintenance Costs	USD 120, 0000
Other Costs Over 10 years	None
Local Context	
Opportunities and Barriers	**Opportunities**: innovative partnerships between producers, research institutes and the private sector. **Barriers:** Market demand could be low for new varieties, and farmer experimentation is the misconception that local species have low productivity. More trained breeders needed.
Market Potential	Market potential is high, particularly when native species are developed for better traits that can be on sale on national and international markets.
Status	Available locally
Acceptability to Local Stakeholders	High

Coastal Zone Sector

Construction of Groynes & Sea Walls Factsheet for Subsector Sea walls Dikes and Barriers

<table>
<tr><th colspan="2">Technology: Construction of Groynes & Sea Walls</th></tr>
<tr><th colspan="2">Sector: Coastal</th></tr>
<tr><th colspan="2">Subsector: Sea walls Dikes and Barriers</th></tr>
<tr><th colspan="2">Technology Characteristics</th></tr>
<tr><td>Introduction</td><td>Sea walls are hard defence structures that are built parallel to the shoreline in coastal area that are subjected to erosion due to sliding of soil as a result of high wave action and coastal flooding. The physical form of these structures is highly variable; sea walls can be vertical or sloping and constructed from a wide variety of materials. They may also be referred to as revetments. Sea walls are frequently used in locations where further shore erosion will result in excessive damage, e.g. when roads and buildings are about to fall into the sea, and they are often built as a last resort, and most are continually under severe wave stress. Sea walls usually have a deep foundation for stability. Also, to overcome the earth pressure on the landward side of the structure, ‘deadmen’ or earth anchors can be buried upland and connected to the wall by rods. However, while they prevent further shoreline erosion, they do not deal with the causes of erosion

Sea walls will provide protection against water levels up to the sea wall design height. In the past, the design height of many sea walls was based on the highest known flood level (van der Meer, 1998). Global climate change has already begun to have serious impacts on socio-ecological systems around the world. Increased average temperatures have set in motion a variety of forces that are producing rises in sea levels globally and, in a number of specific locales, they promise to have serious impacts in both proximate (decades) and distant (centuries) futures. Most recent scientific assessments of global climate change indicate that sea- level rise will have significant impacts on coastal environments and their biotic communities, including human settlements.</td></tr>
<tr><td>Technology Characteristics / Highlights</td><td>Sea walls range in type and may include steel sheet pile walls, monolithic concrete barriers, rubble mound structures, brick or block walls or gabions (wire baskets filled with rocks). Some typical sea wall designs are shown in Figure 1. Sea walls are typically heavily engineered, rigid structures and are generally expensive to construct and require proper design and construction supervision.

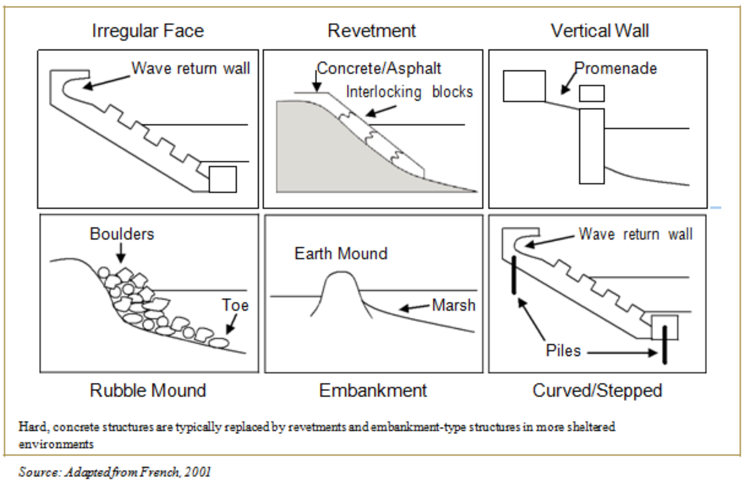


Figure 1: Variation in design type of sea walls. Source: Adapted by Linham and Nicholls (2010) from French (2001).</td></tr>
</table>

Technology: Construction of Groynes & Sea Walls	
Sector: Coastal	
Subsector: Sea walls Dikes and Barriers	
Technology Characteristics	
	Rubble mounds constructed using granite boulders are the most common in Fiji. However, during extreme events they have not protected the infrastructure within Fiji's coastal belt, which has been altered due to anthropogenic activities over the years such as coral mining for the lime industry. Therefore, revetments, vertical walls and sea walls with irregular faces and wave-return walls would be the most suitable hard defence structures to consider for coastal belts needing protection from high wave action and storm surge. Furthermore, as indicated in the bottom-cnter penel in the above illustrations, they could be coupled with soft barriers. If such soft barriers were artificially transplanted within the irregular depressions on the hard defence structures or designed to give a terraced appearance, they would enhance the effect of hard structures against wave action. Sea walls are typically heavily engineered, inflexible structures and are generally expensive to construct and require proper design and construction supervision.
Institutional and organisational requirements	Sea walls are typically, heavily engineered, inflexible structures and are generally expensive to construct and require proper design and construction supervision (UNFCCC, 1999). Sea wall construction is possible on a community scale. There are many examples of ad-hoc construction to protect individual properties and communities. However, ad-hoc sea walls are unlikely to adequately consider the water levels, wave heights and wave loadings during an extreme event. This is largely because these events are hard to foresee without a well-developed science and technology base. For example, traditional sea wall construction methods in Fiji involved poking sticks into the ground to create a fence, behind which logs, sand and refuse would be piled to pose a barrier to the sea. This type of traditional construction has shown to have low effectiveness against significant events, however, and in many cases, these defences are washed away during extreme events (Mimura & Nunn, 1998). A degree of technical guidance would be of benefit in the design and construction of effective sea walls. This would improve their effectiveness during extreme events and would also help to reduce adverse impacts on adjacent coastlines. Although it is clearly possible to construct ad-hoc, or traditional, low-technology sea walls at a community level, these structures have been shown to afford lower levels of protection against extreme events than designs with a solid science and technology base. They have also been known to exacerbate existing problems. At present, the advice given in developing countries for modern sea wall construction appears to be informal, if given at all. If effective design and construction are to occur, local communities must be given at least basic design guidance. This may come from government or voluntary organisations. Sea wall maintenance could well be possible at a community level with appropriate training. This may include educating maintenance engineers on likely failure mechanisms, how often to survey the structure, what to look for

Technology: Construction of Groynes & Sea Walls	
Sector: Coastal	
Subsector: Sea walls Dikes and Barriers	
Technology Characteristics	
	and how to identify weaknesses in the design. If major weaknesses are found, it may be necessary to employ a professional organisation to repair the structure in the most effective manner.
Operation	The raw material to build sea walls and revetments is plentiful, as are the field workers. However, the structure and strength of existing sea walls are not strong enough to hold the waves and contain the movement of land, so that the lifetime of the construction is not as initially expected.
Country-specific Applicability and Potential	
Capacity	Local data is required or any policies that support building sea walls along the coastal areas. Projects completed.
Scale of Application	Applicable to all coastal zones that have been affected by coastal flooding and land loss due to erosion.
Time Horizon- Short /Medium/Long-Term	Medium- term – long term
Status of Technology in the Country	
Availability of Technology	The technology is available, and the government is committed to building sea walls to protect the coastal communities.
Climate Change Mitigation/Adaptation Benefits	
Reduction of Vulnerability to Climate Change and Indirect.	Sea wall and revetment technology is potentially used as a technological adaptation for coastal communities. It does not directly reduce the presence of carbon dioxide (CO_2), but the immediate benefit is felt by the surrounding community, such as reducing damage to fish.
Benefits to Economic/Social and Environmental Development	
Economic Benefits	• This project will provide employment opportunities to persons involved in the coastal construction sector. • Small & medium scale entrepreneurs will be able to establish new industries within the coastal belt due to the reduced risk to infrastructure from coastal erosion & inundation, which will provide self-employment opportunities and employment for others. • Expansion of tourist hotels will also provide more employment opportunities. **Investment**: • Investment in new enterprises by coastal communities. • Although there is no direct investment involved, protection of coastal structures and properties is an indirect investment that reduces or eliminates costs for rehabilitation and maintenance of coastal structures that otherwise would be damaged by wave action and coastal inundation.
Social Benefit	• Improvement of socioeconomic status of coastal communities due to reduction in loss of land, properties and infrastructure and availability of more land for new business enterprises and tourist hotels. This would lead to greater numbers of women participation in subsistence farming and setting up eco-tourism business.

Technology: Construction of Groynes & Sea Walls	
Sector: Coastal	
Subsector: Sea walls Dikes and Barriers	
Technology Characteristics	
	• Increased income of persons involved in construction and maintenance of sea walls. • Improvement of knowledge on effect of hard defence structures against strong wave action and erosion. • Opportunities for undergraduate and postgraduate students to carry out research projects to improve the quality of and reduce the cost of hard defence structures and on incorporating soft defence mechanisms to enhance the effects of hard constructions
Environmental Benefits	• Sea walls provide a high degree of protection against flooding in low-lying coastal areas. They often form the cheapest hard defence when the value of coastal land is low (Brampton, 2002). • The sloped seaward edge of a dyke leads to greater wave energy dissipation and reduced wave loadings on the structure compared to vertical structures. This is achieved because the seaward slope forces waves to break as the water becomes shallower. • Wave breaking causes energy dissipation and is beneficial because the process causes waves to lose a significant portion of their energy. Because the waves have lost energy, they are less capable of causing negative effects such as erosion of the shoreline. • By reducing wave loadings, the probability of catastrophic failure or damage during extreme events is also reduced. • With the sea level rise, the surface area available for settlement of benthic marine organisms will be increased, which will improve the coastal biodiversity.
Financial Requirements and Costs	
Capital Costs	A study by Linham et al. (2010) indicates that the unit cost of constructing 1 km of a vertical sea wall is in the range of US$0.4 to 27.5 million, depending on the height of sea wall required. Variation in costs among projects is a result of numerous factors: • Design height is a major factor affecting costs per unit length of the sea wall. Height affects the volume of materials required for construction and the build time. • Anticipated wave loadings will affect how resilient the structure needs to be; deeper waters and exposed coasts cause higher wave loadings, which require structure that are more robust, and more costly. • Single or multi-stage construction; costs are lower for single stage. • Selected sea wall design and the standard of protection desired. Certain design features will increase costs and more robust sea walls will be more costly.

Technology: Construction of Groynes & Sea Walls	
Sector: Coastal	
Subsector: Sea walls Dikes and Barriers	
Technology Characteristics	
	• Construction materials (e.g. rubble blocks, pre-cast concrete elements, metal, soil, etc.). • Proximity to and availability of construction materials. • Availability and cost of human resources, including expertise. Maintenance costs, are another significant and ongoing expense when a hard defence is selected. These costs are ongoing for the life of the structure and are, therefore, likely to result in significant levels of investment through a project's lifetime. Continued investment in maintenance is highly recommended to ensure defences continue to provide design levels of protection (Linham et al., 2010) Cost Range of Projects in Fiji (Kiuva Sea Wall Project and Namoli in Lautoka): USD 1000/m - USD6500/m
Operational & Maintenance Costs over 10 years	If the sea walls and revetments are modified with applications of coral transplants and establishment of seagrass plots consideration of expected sea-level rise, then additional costs will apply.
Other Costs Over 10 Years	
Opportunities and Barriers	Opportunities: Reduction in coastal flooding and safeguarding saltwater intrusion into groundwater. Barriers: Transportation and availability of local materials.
Market Potential	Market potential is high as this is a mature technology.
Status	Quite extensive in Fiji
Timeframe	2020 - 2022
Acceptability to local stakeholders	Highly acceptable.

Rehabilitation of Mangroves Factsheet for Subsector Restoration of Coastal Vegetation

Technology: Rehabilitation of Mangroves	
Sector: Coastal	
Subsector: Restoration of Coastal Vegetation	
Technology Characteristics	
Introduction	One of the most commonly restored wetland ecosystems for coastal protection are mangroves. Wetland habitats are important because they perform essential functions in terms of coastal flood and erosion management. They help dissipate wave and tidal energy and act as a sediment trap for materials, thus helping to build land seawards. The dense root mats of wetland plants also help to stabilise shore sediments, thus reducing erosion. Wetland restoration re-establishes these advantageous functions for the benefit of coastal flood and erosion protection. Restoration is required because many of the world's wetlands have become increasingly degraded through both natural and human activities. Techniques have been developed to reintroduce coastal wetlands to areas where they previously existed and to areas where they did not, if conditions will allow. Mangrove ecosystems have played a vital role in buffering the force of tsunami waves and in protecting human inhabitants. For mangrove restoration, it is necessary to collect plant propagules from a sustainable source, prepare the restoration site for planting and directly plant propagules at regular intervals at an appropriate time of year. In re-establishing mangroves, it may also be desirable to establish nurseries to stockpile seedlings for future planting. Mangroves can also be re-established by planting dune grasses. These grasses provide a stable, protective substrate in which mangroves can establish their root systems. However, as the mangroves grow, they will eventually overshadow the dune grasses and cause them to die. Thereafter, the mangrove becomes the dominant species.
Technology Characteristics / Highlights	• Collect plant propagules from a sustainable source. • Prepare of the restoration site for planting and directly plant propagules at regular intervals at an appropriate time of year. • Establish nurseries to stockpile seedlings for future planting. Mangrove re-establishment can also be achieved by planting dune grasses, which are known to provide a stable, protective substrate for mangroves to establish their root systems. After mangroves are established, they over-grow the seagrasses and become dominant

Technology: Rehabilitation of Mangroves	
Sector: Coastal	
Subsector: Restoration of Coastal Vegetation	
Technology Characteristics	
Institutional and Organisational Requirements	At a local level, proactive measures can be implemented to ensure wetland habitats are maintained and used in a sustainable manner. This will preserve habitats into the future and reduce or even avoid the cost of restoration and planting schemes. By preventing wetland loss or degradation, it is also possible to avoid the many potential problems encountered in the course of wetland restoration efforts. It is important that the multiple agencies involved in shoreline management avoid providing conflicting guidance. In the Pacific islands, many communities were advised to clear mangroves on medical advice in the 1930s and 1940s because these areas were seen as a breeding ground for malaria-transmitting mosquitoes. Today, however, the ecosystem services provided by mangroves, including their coastal protection function, is valued. As such, many communities have been encouraged to replant mangroves to prevent shoreline erosion. Past wetland restoration projects have been conducted on an experimental basis through 'learning by doing' with limited technological experience. Using this approach, it is foreseeable that communities could implement wetland restoration on a local scale, although with improved understanding, failures could be minimised and cost reduced. At a larger scale, it is useful for governments to adopt proactive coastal management plans to protect, enhance, restore and create marine habitats. Without such a framework, action to restore wetlands is likely to be fragmented and uncoordinated. This is compounded by the involvement of multiple federal agencies with overlapping responsibilities and different policies.
Country Specific Applicability and Potential	
Capacity	Local data is required or any policies that support mangrove rehabilitation along with the coastal areas. Projects completed.
Scale of Application	Coastal communities depending on mangroves for socioeconomic activities reef communities: • Fisher communities • Those that use mangroves for their fruits, firewood etc. • Tourist industry involved in Ecotourism • Research & educational institutes
Time Horizon- Short /Medium/Long Term	Medium term – long term
Status of Technology in the Country	
Availability of Technology	Highly locally available and implemented successfully.

Technology: Rehabilitation of Mangroves	
Sector: Coastal	
Subsector: Restoration of Coastal Vegetation	
Technology Characteristics	
Climate Change Mitigation/Adaptation Benefits	
Reduction to Vulnerability to Climate Change and Indirect.	The main benefit of wetland restoration for climate-change adaptation in the coastal zone is the reduction of incoming wave and tidal energy by enhancing energy dissipation in the intertidal zone. This is achieved by increasing the roughness of the surface over which incoming waves and tides travel (Nicholls et al., 2007b). This reduces the erosive power of waves and helps to reduce coastal flood risk by diminishing the height of storm surges. It also addresses food security due to impacts of future climate change.
Benefits to Economic/Social and Environmental Development	
Economic Benefits	**<u>Employment</u>** • This project will provide direct employment opportunities to a persons involved in managing nurseries and eco-tourism centres. • Persons who collect propagules, use fruits for making drinks, tour guides, krall owners and other fishers in the lagoon will earn a living due to mangrove replanting and successful establishment of mangroves. • Supports grassroots women fishers in mud crabs, kaikoso, mangrove fish. **<u>Investment</u>** • Improved foreign exchange earnings through eco-tourism. • Income to fisher communities due to the improvement of recruitment of fish stocks into lagoons and estuaries with thick mangrove vegetation. • If ecotourism & research centres are established they will attract foreign and local tourists and conservationists, which would, in turn, attract foreign exchange for mangrove rehabilitation programmes. • Blue carbon sequestration leading to carbon market commodity. • Reduce costs for construction of hard defence structures for reducing coastal erosion such as dykes, coastal revetments, etc., as the mangroves and their root systems have a mechanism to stabilise the soil in the coastal habitats. • Reduce costs for controlling coastal pollution as mangrove roots act as pollutant traps.
Social Benefit	**<u>Income</u>** • Improvement of the economy of mangrove-dependant communities. • Socioeconomic status of coastal communities improves due to reduced risk of coastal inundation and erosion. • Increased income to persons involved in mangrove rehabilitation programmes, tourism (especially in eco-tourism) coastal resource management and hotel sectors.

Technology: Rehabilitation of Mangroves	
Sector: Coastal	
Subsector: Restoration of Coastal Vegetation	
Technology Characteristics	
	• Supports grassroots women fishers in villages and their livelihoods in terms of catching bivalves, crabs and fish from the mangrove area. **Education** • Improved of awareness of the importance of conservation, management and restoration of mangroves. • Improved of scientific knowledge of the sensitivity and complexity of mangrove plant communities and associated biotic communities. • Improved knowledge on adaptation to natural phenomena by scientifically manoeuvring the natural coastal ecosystems. • Demonstrated value of using natural barriers against coastal erosion and inundation **Health** • Improved security of coastal dwellings will naturally improve the health conditions of coastal communities. • Proper management of coastal ecosystems by controlling harmful anthropogenic activities such as destruction of mangroves and the establishment of illegal prawn farms, will improve the ecological conditions of mangrove habitats and play an important role in human health. • Improvement of the area covered with mangrove vegetation will also indirectly help in increasing the mangrove forest cover and hence the controlling the release of CO_2 the environment
Environmental Benefits	• In addition to providing protection against coastal erosion, mangrove planting also helps create large areas of land through accretion, provide large quantities of wood and other forest products and provide employment for local villagers throughout the duration of the scheme. • Although mangrove plantations could become damaged during significant storms, full recovery occurs within a short period because the system is self-repairing. • The main benefit of wetland restoration to climate change adaptation in the coastal zone is the reduction of the incoming wave and tidal energy by enhancing energy dissipation in the intertidal zone. This is achieved by increasing the roughness of the surface over which incoming waves and tides travel (Nicholls et al., 2007b). • This reduces the erosive power of waves and helps to reduce coastal flood risk by diminishing the height of storm surges.
Financial Requirements and Costs	
Capital Costs	Factors affecting costs for wetland restoration:

Technology: Rehabilitation of Mangroves	
Sector: Coastal	
Subsector: Restoration of Coastal Vegetation	
Technology Characteristics	
	• Type of wetland to be restored, expertise availability, and consequent chances of success. • Degree of wetland degradation and consequent restoration requirements. • Intended degree of restoration (for example, it may not be possible to restore all the ecosystem functions of a wetland if it is located in a highly industrialised/urbanised environment, and the planned restoration measures may be less ambitious). • Land costs if the land purchase is required to convert to wetlands. • Labour costs • Transportation distance between seedling source and planting site. • Seedling mortality rate between collection and planting. • Cost of raising specific species in nurseries before transplantation because they cannot be directly planted on mudflats due to strong wind and wave forces. • Scale of post-implementation monitoring operations USD 8, 245 per haare, GIS mapping USD 300,000.
Operational & Maintenance Costs over 10 years	To receive maximum benefits from this technology, sensitivity to the importance of mangroves should be improved among all stakeholders for whom mangroves are a source of livelihood and stakeholders who visit the area for different economic, research and educational purposes. Awareness among coastal communities, school children, hoteliers and industrialists, should be improved, and awareness programmes should be conducted from time to time. Ecotourism and research centres should be established in mangrove areas with high biodiversity in order to ensure conservation of endangered mangrove species and sustainable utilization of mangrove resources, which will reduce the costs for monitoring, security and maintenance cost of replanting sites.
Other Costs over 10 years	
Opportunities and Barriers	Barriers: Policy gaps, no National Mangrove Management Plan, detailed and updated maps are needed. Opportunities: prevents coastal erosion and enhances the blue carbon economy of Fiji.
Market Potential	Very high potential
Status	Available and an ongoing technology in the country
Timeframe	2020- 2022
Acceptability to Local Stakeholders	Highly Acceptable

Flood-hazard Mapping Factsheet for Subsector Accommodation Approaches

<table>
<tr><th colspan="2">Technology: Flood-hazard Mapping</th></tr>
<tr><td colspan="2">Sector: Coastal</td></tr>
<tr><td colspan="2">Subsector: Accommodation Approaches</td></tr>
<tr><td colspan="2">Technology Characteristics</td></tr>
<tr><td>Introduction</td><td>Flood-hazard mapping is an exercise to define those coastal areas that are at risk of flooding under extreme conditions. As such, its primary objective is to reduce the impact of coastal flooding. However, mapping of erosion-risk areas may serve to achieve erosion-risk reduction. It acts as an information system to enhance our understanding and awareness of coastal risk.

Flood-hazard maps are designed to increase awareness of the likelihood of flooding among the public, local authorities and other organisations. They also encourage people living and working in flood-prone areas to find out more about the local flood risk and to take appropriate action. It is important to note here that climate change must be carefully considered when implementing flood-hazard mapping. Flood-hazard mapping typically provides a ‘snapshot’ of flood risk at a given point in time. When considering the effects of climate change, however, it is important to consider the dynamic nature of flood risks. For example, SLR and changes in storm intensity, occurring as a result of climate change, will causes changes in the areas susceptible to flooding.

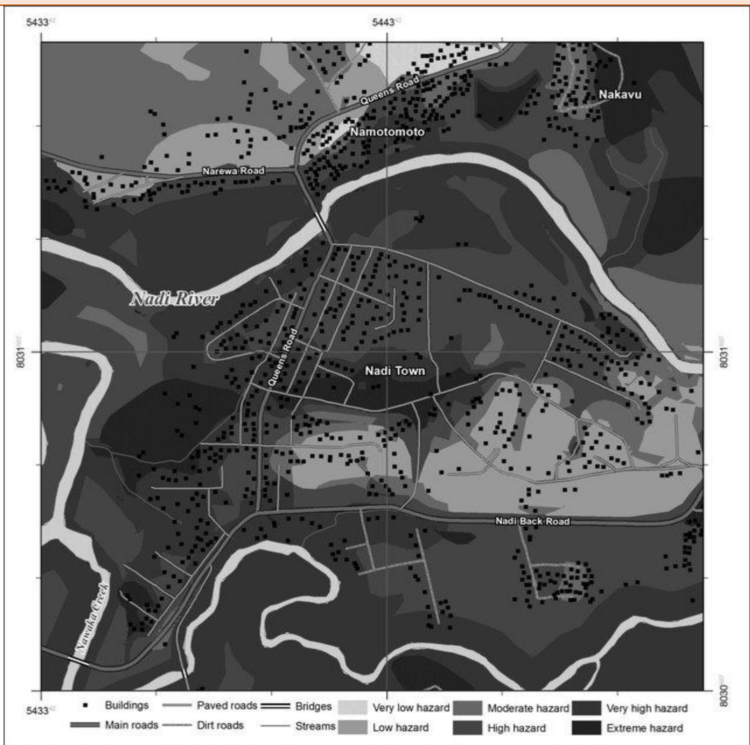
Due to climate change and changes in relative sea level, it is important to note that flood-hazard maps will require periodic updates in order to reflect the changing risk of flooding. These updates should account for SLR, erosion, changes in storm frequency and intensity, etc.

Flood-hazard maps can be used by developers to determine if an area is at risk of flooding, and by insurers to determine flood insurance premiums in areas where flood insurance exists.

Due to sparse empirical records and the statistical rarity of extreme coastal events, coastal flood prediction often relies on complex numerical models that approximate the processes and phenomena that lead to coastal floods. Coastal flood-hazards are determined by the interaction of storm surges and waves with seabed bathymetry and coastal land cover. These factors determine the inland extent of flooding. Coastal flood models must, therefore, account for these features, as well as the processes associated with storm surges and waves.

The creation of flood maps usually combines topographic data with historic or modelled information on extreme sea levels and wave heights. This allows determination of the water level at the coast under extreme conditions and shows how this water could flood inland. This is likely to involve the deployment of storm surge and wave models.</td></tr>
</table>

Technology: Flood-hazard Mapping	
Sector: Coastal	
Subsector: Accommodation Approaches	
Technology Characteristics	
Technology Characteristics / Highlights	• Identification of flood-risk areas is likely to help in the planning of a more effective emergency response. The flooding-hazard map may protect essential infrastructure such as electricity supplies and sewage treatment, and ensure that essential services, such as emergency services, continue to function during a flooding event. • Quantification of what is at risk of being flooded, such as the number of houses or businesses. This will help identify the scale of emergency and clean-up operations. • Once buildings at flood risk are identified, raising community awareness of flood procedures will promote the implementation of flood-proofing measures. • In the longer term, the flood-hazard maps can support planning and development by identifying high-risk locations and steering development away from these areas. This will help to keep future flood risk down and encourage sustainable development. In order for this to occur, the consideration of flood-hazard maps must be integrated into planning procedures.
Institutional and organisational requirements	Flood-hazard mapping may be difficult to undertake at the community level due to the need for complex numerical modelling for the forecast of extreme water levels, storm surges and wave heights. The required expertise and modelling capacity is unlikely to be locally available, especially in developing countries. As such, it may be necessary to enlist the help of external organisations. Following developed-country examples, this type of mapping has been accomplished via national programmes.
Operation	Using a multi-criteria decision analysis (MCDA) approach coupled with GIS layers for elevation, a model to assess flood hazard of a region employing catchments, land-use, slope, distance from channel, and soil types could be developed.
Country Specific Applicability and Potential	
Capacity	The SPC in collaboration with researchers at USP and international organisation have developed flood-hazard modelling for Nadi town
Scale of application	This technology can be applied for planning future developments and current developments in flood-prone areas such as Nadi, Ba, Rewa, Sigatoka and Labasa.
Time Horizon- Short /Medium/Long Term	Short term- medium term
Status of Technology in the Country	
Availability of Technology	Flood-hazard modelling and risk assessment in the Nadi River Basin, Fiji, has been conducted using GIS and MCDA. Results obtained are shown below.

Technology: Flood-hazard Mapping	
Sector: Coastal	
Subsector: Accommodation Approaches	
Technology Characteristics	
	

Census data	
Enumeration areas in the zone	15
Total population (2007)	6,441
Total number of house holds	1,394
Education level	
No formal education / primary diploma	1,343
Secondary / specialist diploma	4,353
Tertiary diploma	745
House condition	
Good condition	812
Average condition	503
Poor condition	79
House wall building materials	
Concrete	816
Tin / iron	418
Wood	153
Bure materials	3
Makeshift materials	3

Satellite data	
Buildings in the zone	1,307
Difference census / satellite	87
Building types	
Dense commercial (dark blue)	247
Commercial (light blue)	93
Dense residential (dark orange)	247
Residential (light orange)	680
Industrial (yellow).	94
# of buildings in each hazard zones	
Extreme vulnerability	92
Very high vulnerability	226
High vulnerability	472
Moderate vulnerability	298
Low vulnerability	161
Very low vulnerability	58

Climate Change Mitigation/Adaptation Benefits	
Reduction to Vulnerability to Climate Change and Indirect.	In itself, flood-hazard mapping does not cause a reduction in flood risk. It must be integrated into other procedures, such as emergency response planning and town planning before the full benefits can be realised and make the community more resilient to flooding in future.
Benefits to Economic/Social and Environmental Development	
Economic Benefits	• Reduces the damage costs associated with flooding through flood proofing mechanisms to buildings and infrastructure. • Improves indemnity estimation for insurance companies.
Social Benefit	• Allows the local communities, particularly women, children and disabled persons to be ready for risk associated with flooding in high-risk areas. Improves access to essential services and minimises any health issues such as water-borne diseases. • Allows the areas to be prioritised for evacuation by the National Disaster Management Office.

Technology: Flood-hazard Mapping	
Sector: Coastal	
Subsector: Accommodation Approaches	
Technology Characteristics	
	• Allows the town planning office to identify high-risk areas in future and steer developments away from these areas.
Environmental	The mapping process itself has minimal impact on the environment. Mapping can be done by aerial photography via drone to minimise carbon footprint.
Financial Requirements and Costs	
Capital Costs	The costs of flood-hazard mapping are not widely known. Therefore, it is not possible to provide likely cost estimates here. A number of factors that are likely to contribute toward the cost of flood-hazard mapping are: • External expertise on numerical modelling of flood risk brought in from academic institutions or commercial organisations. • Topographic surveys (LiDAR or remote sensing) to provide information on land elevation which will feedback into the flood risk model. • Historic costs of collecting extreme event data such as water levels, wave heights, etc. • Cost of employing a Geographic Information System (GIS). • Total cost of USD 3 million.
Opportunities and Barriers	**Opportunities**: Complements and strengthens other adaptation measures such as flood proofing and evacuation. **Barriers:** Expertise may not be readily available
Market Potential	High potential
Status	Available locally as SPC Oceanography section has been involved in some past studies doing flood-hazard mapping.
Acceptability to local stakeholders	High

ANNEX II: LIST OF STAKEHOLDERS AND THEIR CONTACTS

Stakeholder for Agriculture Sector

Name	Organisation	Position	Email Contact
Ms Deborah Sue	Ministry of Forestry	Director - Forest Resource Assessment and Conservation	Deborahlsue@gmail.com
Mr Saimone Johnson	Sugar Research Institute	Research Officer	saimonej@srif.org.fj
Mr Viliame Waqa	Ministry of Lands	Principal Geospatial Officer	viliame.waqa@govnet.gov.fj
Ms Nazeea Bano	Sugar Research Institute	Technical Officer	nazeeab@srif.org.fj
Ms Reshmi Kumari	Ministry of Sugar Industry	Director Policy & Research	reshmi.kumari@govenet.gov.fj
Ms Tavaita Tamani	Ministry of Agriculture	External Policy Officer	tavaita.tamani@agriculture.gov.fj
Ms Olivia Tawaqa	Ministry of Youth and Sports	Coordinator - Insights and Grants	olivia.tawaqa@youthandsports.gov.fj
Mr Adriano Tabualevu	Ministry of Agriculture	Senior Agriculture Officer	adriano.tabualevu@yahoo.com
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Mr Romuluse Rajale	Ministry of Forestry	Forester	romu.rajale@yahoo.com
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Stakeholder for Coastal Zone Sector

Name	Organisation	Position	Email Contact
Mr Alfred Ralifo	WWF	Policy Coordinator	aralifo@wwfpacific.org
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Ms Evelyn Sami	Consumer Council	Manager Research	manager_rpa@consumersfiji.org
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Mr Shaneel Prakash	Ministry of Lands	Principal Geospatial Officer	shaneel.prakash@govnet.gov.fj
Ms Ana Vesikula	Soqosoqo Vakamarama Taukei	Project Volunteer	ssvitaukeivt@gmail.com
Ms Shirley Tagi	Diva (women's group)	Coordinator	shirleytagi@gmail.com
Mr Ifereimi Dau	IUCN	Climate Change Officer	ifereimi.dau@iucn.org

ANNEX III: SCORING MATRIX AND NORMALISED SCORING MATRIX FOR THE TECHNOLOGY PRIORITISATION.

Sector: Agriculture

Scoring Matrix

Criteria	**Cost**	**Implementation Considerations**	**Climate Related**		**Economic Benefits**		**Social Benefits**	**Environment Benefits**	**Political Acceptability**
Level 1 weighting	**20%**	**5%**	**25%**		**15%**		**10%**	**20%**	**5%**
	USD Million		Enhancing Resilience	Potential to Reduce GHG emissions	Creation of Jobs	Increasing Revenue			
Level 2 weighting			70%	30%	40%	60%			
Technology									
1. Drip Irrigation	10	1	4	3	4	4	4	5	2
2. Integrated Nutrient Management	1.5	3	4	4	4	4	3	5	4
3. Selective Breeding via Controlled Breeding	3	2	3	3	4	4	4	3	5
4. Agro-forestry	4	4	5	5	4	5	4	5	4
5. Improve Crop Variety	1.5	3	4	2	4	4	4	4	2
6. Integrated Pest Management	2	3	4	3	4	3	4	3	4
7. Sustainable Livestock Management	2	3	3	4	4	4	3	3	5
8. Index Insurance	1.5	5	2	1	3	1	4	3	3

Normalised scoring matrix

Criteria	Cost	Implementation Considerations	Climate Related		Economic Benefits		Social Benefits	Environment Benefits	Political Acceptability
Level 1 Weighting	**20 %**	**5%**	**25%**		**15%**		**10 %**	**20%**	**5%**
	USD Million		Enhancing Resilience	Potential to Reduce GHG emissions	Creation of Jobs	Increasing Revenue			
1.Drip Irrigation	0	0	67	50	100	75	100	100	0
2. Integrated Nutrient Management	100	50	67	75	100	75	0	100	67
3. Selective Breeding via Controlled Breeding	82	25	33	50	100	75	100	0	100
4. Agro-forestry	71	75	100	100	100	100	100	100	67
5. Improve Crop Variety	100	50	67	25	100	75	100	50	0
6. Integrated Pest Management	94	50	67	50	100	50	100	0	67
7. Sustainable Livestock Management	94	50	33	75	100	75	0	0	100
8. Index Insurance	100	100	0	0	0	0	100	0	33

Sector: Coastal Zones

Scoring Matrix

Criteria	Cost (USD/m or ha	USD/hat	Implementation Considerations	Climate Related	Economic Benefits	Social Benefits	Environment Benefits	Stakeholder Acceptability
Weightings (100%)		**15**	**2**	**19**	**19**	**19**	**21**	**5**
Technology								
1. Rehabilitation of Mangroves	8845USD/ha	476900	2	4	4	4	4	4
2. Replanting Corals	377,104USD/ha	377104	1	3	3	3	3	2
3. Construction of Groynes and Sea Walls	1000-6000USD/m	20000000	3	4	5	5	5	5
4. Sand Dune Rehabilitation	USD30000/100 m	60000	4	3	4	4	4	4
5. Flood-hazard Mapping	1 million USD	3000000	3	3	5	5	3	4
6. Coastal Vegetation	30,000 for 100m	300000	3	2	2	5	5	4

Normalised Scoring Matrix

Criteria	Cost (USD/m or ha	USD/hat	Implementation Considerations	Climate Related	Economic Benefits	Social Benefits	Environment Benefits	Stakeholder Acceptability
Weightings (100%)		15	2	19	19	19	21	5
Technology								
Rehabilitation of Mangroves	8845USD/ha	98	33	67	67	50	50	67
Replanting Corals	377,104USD/ha	98	0	33	33	0	0	0
Construction of Groynes and Sea Walls	1000-6000USD/m	0	67	67	100	100	100	100
Sand Dune Rehabilitation	USD10000/ha	100	100	33	67	50	50	67
Flood-hazard Mapping	1 million USD	85	67	33	100	100	0	67
Coastal Vegetation	30,000 for 100m	99	67	0	0	100	100	67

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