Griffith UNIVERSITY

Pacific EcoAdapt

Phase 1 Final Report

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We are grateful for the assistance and wise guidance provided by Alan Dan in community and cultural liaison, and the Tanna community leaders and in particular the communities of Port Resolution, the Middle Bush villages of Enkatalie and surrounds for their support, collaboration and sharing of local knowledge, as well as those of Erakor lagoon and Port Vila.

Disclaimer

In providing this report we expect that any use of this report will be based on an informed assessment of the limitations of the data, information and methodologies described in the context in which they are applied

Images

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1. DIRECTOR'S REVIEW

As the EcoAdapt project comes to a close, I am pleased to report that our research team has developed a wide range of outputs, including stakeholder engagement approaches and tools, for Ecosystem-based Adaptation (EbA) in the context of small island developing states. The project has been geographically focussed in Vanuatu and we have undertaken analyses at national, provincial and local scales, with the finer scaled studies conducted at Port Vila and on Tanna Island.

We are grateful for the support of the national agencies, provincial government, Council of Chiefs and local communities. This research was undertaken with the approval of a research agreement from the Vanuatu National Cultural Centre representing the Government of the Republic of Vanuatu and the local community, and under a Memorandum of Understanding between the Tafea Provincial Government Council and the Griffith Climate Change Response Program. In addition, I would like to acknowledge the following people and organisations without whose collaboration, guidance and knowledge, this project would not have been possible:

- Alan Dan, our Tanna Kastom advisor and community liaison project officer.
- The Tanna Island communities, especially those of Port Resolution and Enkatalie, and the Efate Island communities of Erakor lagoon and Port Vila Bay. We thank these communities for their permission to undertake this research and for their cooperation, generosity, humour, and hospitality. And, we thank our research assistants in Port Resolution, Esther Karrahi and Alfred Iouma.
- Dr Krishna Kumar Kotra, Science Programme Coordinator, The University of the South Pacific, Emalus Campus, Port Vila, Vanuatu.
- The Secretariat of the Pacific Regional Environment Programme (SPREP)
- The Climate Change Department of Vanuatu
- The Department of Water Resources of Vanuatu
- The Office of the Maritime Regulator of Vanuatu

A key output of this project is the Pacific EcoAdapt website (www.pacificecoadapt.org). This website is designed as an enduring portal to support data and knowledge sharing, resources and tools for EbA in Vanuatu and beyond, well into the future. Building and strengthening relationships with key stakeholders has been a major focus of the final year of the project, along with working to share the knowledge and resources generated by the project and co-develop and co-design tools and capacity building activities to support embedding the new knowledge on the ground decision making processes.

In keeping with the original vision of the EcoAdapt project, over the life of the project, significant contributions to new knowledge across a range of aspects of climate change adaptation have been made, including the social, cultural, economic, ecological aspects of the communities in focus. The interdisciplinary, action-oriented approach was designed to support practical outcomes on the ground and for the sometime technical knowledge to be more accessible for those affected by, or making decisions about climate change adaptation in Vanuatu and beyond. Incorporation of local community perspectives has been a theme throughout the project and many opportunities have been identified to continue to support local communities in dealing with the risks of climate change in their local areas and to support those who support communities including provincial and national governments. We have endeavoured to give full consideration to traditional indigenous knowledge in conjunction with the use of advanced environmental modelling and decision-support systems. A significant contribution of the project has been how adaptation planning and decision making can be supported in the absence of the availability of "ideal" scientific data sets. Another critical lesson has been the need for a "bottom-up" approach that is based on the perspectives and aspirations of the local communities.

Brendan Mackey

ECOADAPT PROJECT DIRECTOR

Figure 1.1: Traditional cyclone "safehouse" in the Middle Bush area of Tanna.

2. OVERVIEW AND AIMS OF THE ECOADAPT PROJECT

The EcoAdapt project broadly aimed to develop the new knowledge and methods needed to help ensure that the benefits of ecosystem-based adaptation are understood and the datmethods and tools needed to inform planning and decision making are available. A key objective of the project was to provide guidance on how ecosystem-based adaptation can be integrated into policy and decision making by governments and local communities particularly in the coastal zone of Least Developed Countries.

Three primary research questions guided the research:

1. What constitutes an ecosystem-based approach to climate change adaptation?
2. How do the differing social and economic contexts in the Pacific impact the outcomes for ecosystem-based adaptation responses in the coastal zone?
3. What information and decision-making processes are required by stakeholders to adopt ecosystems when selecting climate change adaptation

Focusing on Vanuatu as the project location (Figure 1), an interdisciplinary and integrated approach to the research was applied to provide in depth findings to inform ecosystem-based adaptation (EbA) in the Pacific Small Island Developing States (SIDS) more broadly. Given Vanuatu, as with other Pacific SIDS are facing a rapidly changing climate and ongoing capital-intensive developments, the Pacific EcoAdapt Project also aimed to identify appropriate adaptation interventions in the coastal zone.

Figure 2.1: Port Resolution Yacht Club.

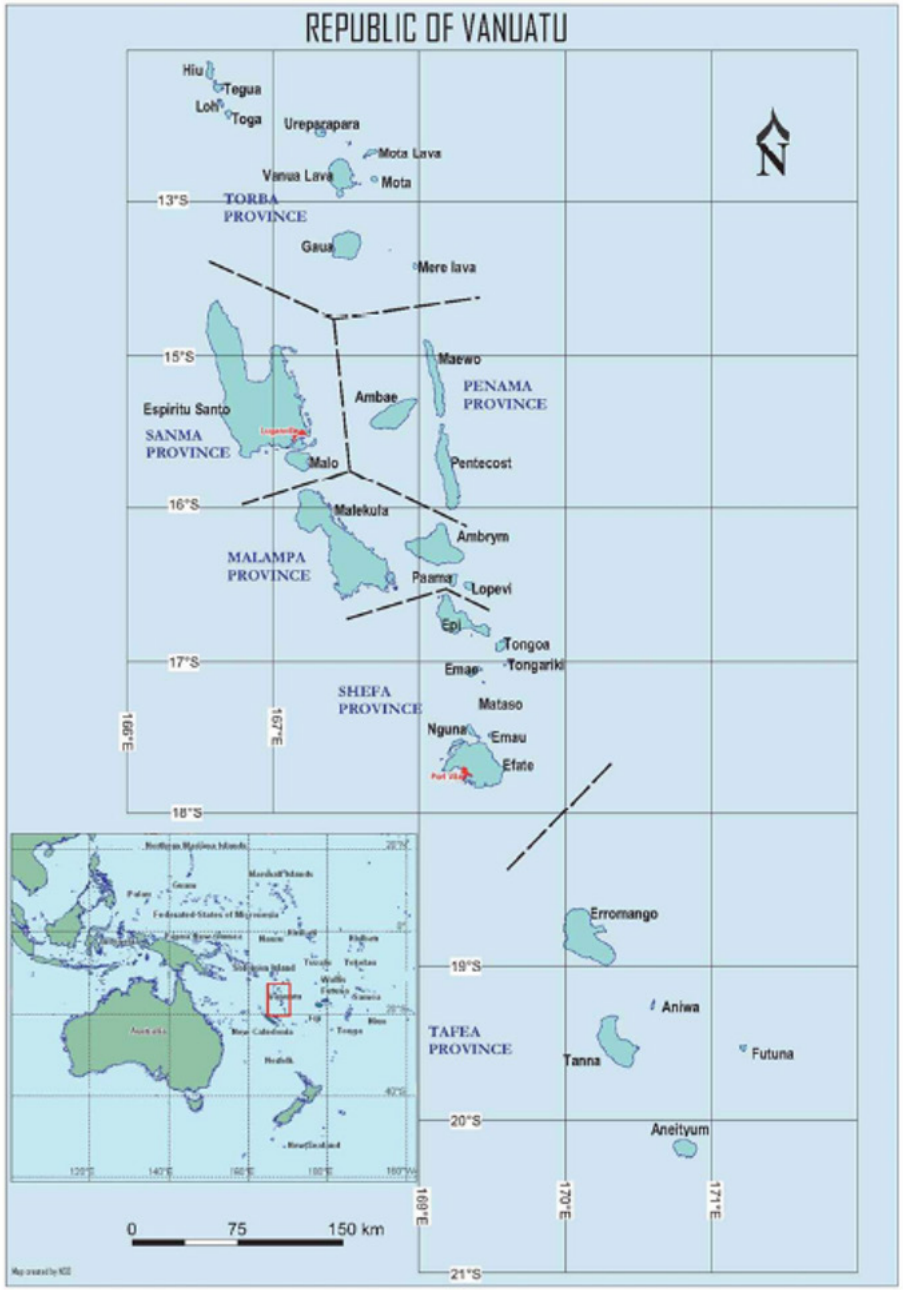


Figure 2.2: Map of Vanuatu (source VNSO Mini-Census Report 2016)

3. APPROACH TO THE RESEARCH

Assessing the risks to people and nature from climate change must be considered in light of development pressures and the needs, rights and aspirations of the local communities. In Vanuatu, the majority of people still live in and have close ties to their traditional communities, with the majority of food being grown in subsistence gardens and from harvesting the coastal and marine environments. In these circumstances, the integrity of ecosystems and the health and wellbeing of local communities are closely connected.

For ni-Vanuatu people, these connections are understood through the concept of "kastom" with all the traditional knowledge, customs and responsibilities that entails. From an academic perspective, these connections are represented by the concept of a "social-ecological system". This concept is used to identify the key components, interactions, and feedbacks that are most important for understanding climate risks to human and nature, and the kinds of adaptation intervention that can help mitigate them.

Using the concept of socio-ecological systems has the advantage of enabling simulation of future scenarios in order to identify options that are robust under different settings and that avoid negative, unintended side-effects. This complex methodology is needed because "climate change" is an example of what has been referred to as "wicked problems that share the following characteristics:

- *The level of uncertainty is often high* – while we know that the global climate is changing rapidly, there is less certainty as to precisely what impacts will occur where and when at the scale of small islands;
- *Subjective values are central to the problem and in dispute* – Vanuatu, like many small island developing states in a phase of development with an emerging hybrid subsistence-cash economy and an influx of foreign investment in capital works especially for tourism.
- *Social stakes are high* – for the ni-Vanuatu people, the customary lands are held in trust for future generations in perpetuity.
- *Impacts are potentially irreversible* – ecosystems are quickly lost and degraded, but ecological restoration is slow and once destroyed many ecosystems cannot recover.
- *There is more than one plausible answer or multiple possible resolutions* – there are many potentially feasible, effective and cultural appropriate ways to mitigate climate risks and support sustainable development.
- *The system comprises complex webs of cause/effect, feedbacks and emergent properties* – a good island example is that what people do in the forest on the ridge affects the water quality flowing into the fringing coral reef, which can impact on coastal community's food security.

The types of research that address these complex problems has been called "post-normal" science (PNS); as distinct from "normal" science, which can be conducted in a laboratory and addresses straightforward problems. (Funtowicz and Ravetz, 1993). PNS is characterised by: addressing real world practical problems; taking an interdisciplinary approach that draws upon the expertise in many disciplines; and is also transdisciplinary by integrating the various and complementary ways by which people acquire and apply knowledge, including the experience of practitioners and communities. These inter- and trans-disciplinary approaches are needed because solutions will inevitably fall across a range of academic and professional disciplines and require local knowledge to evaluate their efficacy and appropriateness.

Implementing a PSN approach to climate change adaptation problems in practice is challenging as it requires reconciling and working through different world views, theoretical framings and 'languages', as well as overcoming professional and institutional barriers to integration.

Special methodological challenges also arise from taking a systems-based, approach including the need to integrate qualitative and quantitative data and achieve a genuine synthesis of results from multiple sources that generate new insights above and beyond what can be achieved from conventional disciplinary-based investigations alone. However, without a social-ecological system framing, 'solutions' will be limited in scope and likely to have unforeseen or unwanted impacts across other parts of the system.

With this theoretical background in mind, the Pacific EcoAdapt program of research sought to address the research questions through an inter- and trans-disciplinary approach that applies and integrates theory, methods, data and knowledge from multiple knowledge types and sources, as well as drawing upon local knowledge from practitioners and communities. Mixed methods were developed applied drawing upon expertise at Griffith University in the fields of coastal management, oceanography,

climate change risk assessment, marine and terrestrial ecology, engineering, social sciences, systems modelling, micro-economics and sustainable development.

A range of research methods were used within each of these themes to address the key research questions and sub-questions including:

- Coral reef and forest ecosystem assessment
- Remote sensing, GIS and environmental modelling
- Systems modelling including oceanographic and coastal process modelling
- Social science surveys of communities and stakeholders
- Tourism impact assessment
- Benefit-cost analysis
- Climate risks assessment.

In addition, several training and capacity building initiatives for government stakeholders and community members were delivered by the research teams to support embedding the knowledge generated into practice. The approaches taken within each theme are briefly outlined in the following sections.

Figure 3.1: (right): Yasur volcano on Tanna is in a state of almost constant eruption and is an important tourist attractor on the island.

4. KEY OUTPUTS

The project has generated a number of novel and useful outputs including the following highlights:

- ***Coastal process models*** – understanding and predicting the impacts of climate change in the coastal zone requires the ability to model the impacts of sea level rise on coastal erosion and inundation. We have calibrated a set of nested, multi-scaled models (global, regional, local) for simulating coastal processes at Port Resolution and Port Vila. Furthermore, we did this in a "data poor" region of the world. We additional support, these models could be calibrated for all major coastal settlements in Vanuatu as well as other Pacific Islands, or better still, we could train colleagues at the University of South Pacific and government agencies in how to calibrate and run these them.
- ***Monitoring the integrity of coral reef ecosystems*** – we applied a recently developed method for surveying the ecological conditions of coral reefs. This method is straightforward yet generates useful data and local community members, including youth can be readily trained in how to undertake these surveys.
- ***Whole-of-island land cover mapping*** – a "ridge to reef" approach is critical on islands. A major data gap for this region is the lack of up-to-date land cover maps. Obtaining these data has been expensive and technically complicated, resulting in available coverages being rarely updated and quickly out of date. We have developed a new approach which uses expert local knowledge and cloud-based data and processing. This is an exciting new tool that can be quickly rolled out across Vanuatu and the Pacific.
- ***Q-method for community consultations*** – we applied for the first time a method for eliciting in a culturally appropriate way the values, preferences and priorities of local communities. This approach is also generic in that it can be readily applied throughout Vanuatu and the Pacific.
- ***Integrated climate risk assessment*** – we developed novel approaches to climate risk assessment that simulates the relevant "socio-ecological system", utilised qualitative and quantitative data and information, and that enables alternative solutions to be explored against future scenarios.
- ***Other decision support*** – we produced materials that translate our research findings into information and guidance for decisions makers, practitioners and stakeholders.

The remaining sections of this report provide an overview of selected research studies and relevant findings conducted across the life of the EcoAdapt project. For the purposes of this final report, a selection of relevant knowledge generated throughout the life of the project is provided with the aim of providing a high-level synthesis and insights generated from integration of the different research streams in the final year of the project. A more detailed account is located in each of the key publications located on the EcoAdapt project website www.pacificecoadapt.org.

Figure 4.1: A lively food market on Tanna. The island produces almost all its own food.

5. UNDERSTANDING COASTAL PROCESSES

Understanding the coastal environment, interactions between marine, land and hydrological cycles and social systems was the core focus of the EcoAdapt's coastal process research. This research involved two related foci:

(a) Understanding coastal processes involved use of a nested set of models that account for key biophysical processes at a range of spatial and temporal scales: global, regional and local. The use of multi-scale modelling was used to generate understanding and predictions for three key coastal risks: inundation; erosion; and water quality. The regional ocean circulation model is to the best of our knowledge, the first of its kind for the south Pacific; and

(b) Integrated Risk Assessment was undertaken that drew upon the outputs from the process models using a combination of Bayesian network models and system dynamics modelling to provide an in-depth understanding of climate risks to the fringing coral reefs systems.

5.1. Coastal processes team

Calibrating a regional ocean circulation model for the entire region, this enabled simulation of all key aspects of ocean currents including; the direction and velocity of currents, along with water temperature, chemistry and sediment transport. The regional ocean circulation model provides the 'boundary conditions' for the calibration of a coastal dynamics model. Both models can be driven by current and future climate change projections.

The coastal dynamics model takes into account local physical conditions near and at the shoreline including bathymetry and enables simulation of waves and storm surges, among other things. The high-resolution coastal dynamics model is also able to make use of fine resolution drone imagery on the location and height of the fringing coral reefs and the effect these have on attenuating wave energy.

Development of a localised coastal dynamics model inclusive of waves and water flows was developed for the case study area of Port Resolution on Tanna and also Port Vila on Efate. These models in turn provide the tools needed to examine fine scale conditions including water quality and coastal accretion and erosion. From these models, we were able to simulate the impacts on coastal ecosystems of different climate change and development scenarios and assess how inundation and erosion might impact ecosystem health or various adaptation interventions.

Field trips were undertaken, to provide valuable site-specific data to verify modelling efforts, in addition to providing baseline information describing water quality and marine ecosystem health, at our study sites. Assessing coastal hazards in the South Pacific was made particularly challenging with limited accessible data. Hence many of the outputs of the research provided valuable new knowledge about the baseline systems and processes in the coastal zone of the Vanuatu study areas. In the final year of the project, the models were applied in adaptation scenario analyses.

5.1.1. Regional ocean model

One of the challenges Pacific small island developing states (SIDS) face when trying to develop adaptation strategies to limit the impact of sea level rise and climate change on coastal communities, is a lack of understanding regarding the variability of sea level and sea temperature. While data are available from satellite observations and global ocean models, their coarse spatial and temporal resolution are unable to predict how the ocean processes influence water levels, currents, and water temperatures within coastal waterways and at island shorelines. Consequently, there is a gap in our understanding of how climate change will impact SIDS at the scales necessary to generate useful information about impacts on ecosystems as well as settlements and infrastructure. As part of the EcoAdapt project the coastal team addressed this gap in understanding by developing a regional ocean model capable of replicating the behaviour of complex jets and currents in the deep ocean, to allow modelling of high-resolution near-coast circulation including sea level variability around individual islands. The Vanuatu regional ocean model domain, shown in Figure 5.1 (over the page), covers both the Vanuatu and New Caledonia archipelago. The model is based upon the Finite Volume Community Ocean Model (FVCOM) (Chen et al., 2006).

Temporal and spatial variations were analysed to gain a more thorough understanding of the exposure of each location to ocean processes. On the whole, model runs demonstrated that ocean processes driven by the complex regional circulation significantly affect coastal water levels in this oceanographically dynamic region. That is, the position of high water, which affects a location's exposure to coastal hazards such as high wave events and storm surge, shifts in response to the presence of jets and currents flowing in deep water. The presence of these currents lowered the position of high tide during the timeframe studied. Luganville (in the northern island of Espiritu Santo) was identified as the least sensitive to ocean processes during this timeframe, while Tanna Island showed a strong response to ocean processes, which was relatively

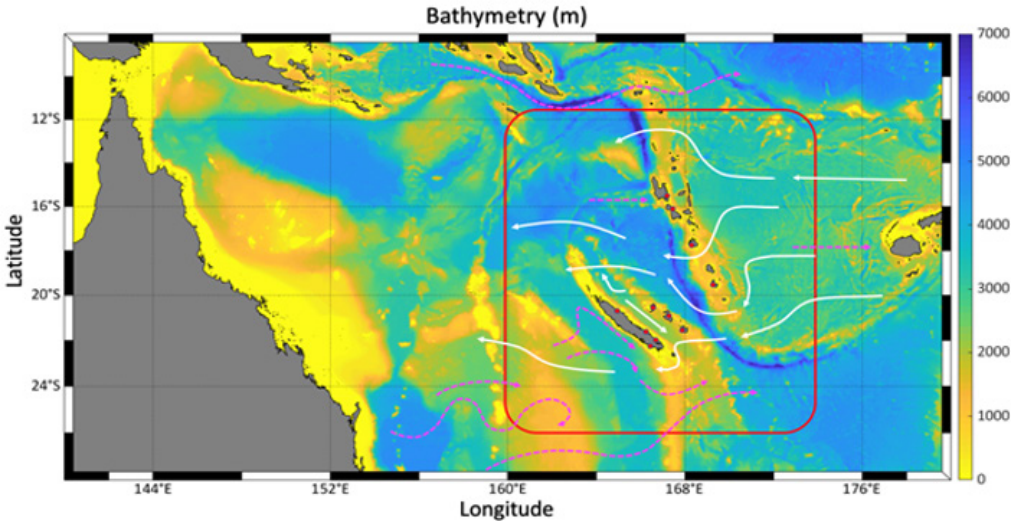


Figure 5.1: Vanuatu Regional Ocean Model Domain

The model domain covered by the Vanuatu regional model (within red square) lies in the south-west Pacific Ocean. The colourmap shows bathymetry across the region, highlighting the sharp increase in water depth on the western side of the Vanuatu archipelago due to the New Hebrides Trench. Location of the permanent tide gauges across Vanuatu and New Caledonia are represented by red dots. Currents and jets due to splitting of the westward flowing Southern Equatorial Current (SEC) are displayed as white arrows. Eastward flowing counter currents are displayed as magenta dashed arrows. Current abbreviations: North Fiji Jet (NFJ), South Fiji Jet (SFJ), North Vanuatu Jet (NVJ), South Vanuatu Jet (SVJ), East Caledonia Current (ECC), Vauban Current (VC), North Caledonia Jet (NCJ), South Caledonia Jet (SCJ), Southern Equatorial Counter Current (SECC), Coral Sea Counter Current (CSCC), Fiji Basin Counter Current (FBCC), Alis Current of New Caledonia(ACNC), Subtropical Counter Current (STCC).

consistent over the time frame. While the capital, Port Vila, showed a mixed response which changed during the timeframe. This information is needed to in understand how changes in ocean processes will increase or decrease the vulnerability of a site to both coastal hazards and future sea levels. The sensitivity of the results, particularly with respect to sea levels, demonstrate the value that can be added by attempting to better replicate the full spectrum of processes influencing circulation in island settings.

5.1.2. Coastal process models

As noted, the approach to understanding coastal processes involved use of a nested set of models. While regional modelling efforts address the whole archipelago, three study sites were locations for higher resolution investigations of coastal hazards: Port Resolution on Tanna Island, and Vila Bay and Erakor Lagoon, both on Efate Island. These sites all face increased exposure to coastal hazards under future climate conditions, but the principal hazards affecting each site differ. By studying all three, a more representative understanding of the different threats faced by coastal communities across the region could be developed.

A mixed method approach was used. First, a review of coastal hazards at the three locations under both present-day and future climatic conditions was conducted. Understanding the wave climate (using WaveWatch III (WW3) at both locations, Tanna and Efate Islands allowed a first pass assessment to identify a coarse risk zone based on high wave energy from offshore. Following this, a review of coastal adaptations to mitigate coastal flooding and erosion was conducted. These two steps fed into development of a coupled wave-flow numerical model (using a mix of existing and primary data collected from fieldwork) to identify zones exposed to erosion and accretion. The outputs of the numerical modelling, together with assessment of historical coastal changes observed by satellite images (Google Earth Pro, 2020) were completed with engineering formulae to estimate coastal erosion and flooding zones.

Based on the local scale outputs from the model (together with the cost-benefit study conducted by the microeconomics team – see following section), potential impacts on the coastal ecosystems relevant to different climate change and development scenarios were able to be identified and adaptation options prioritised based on systemic

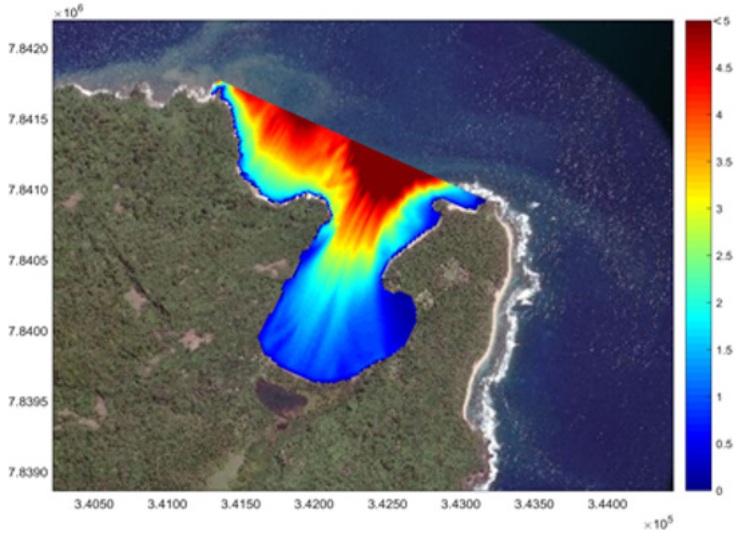


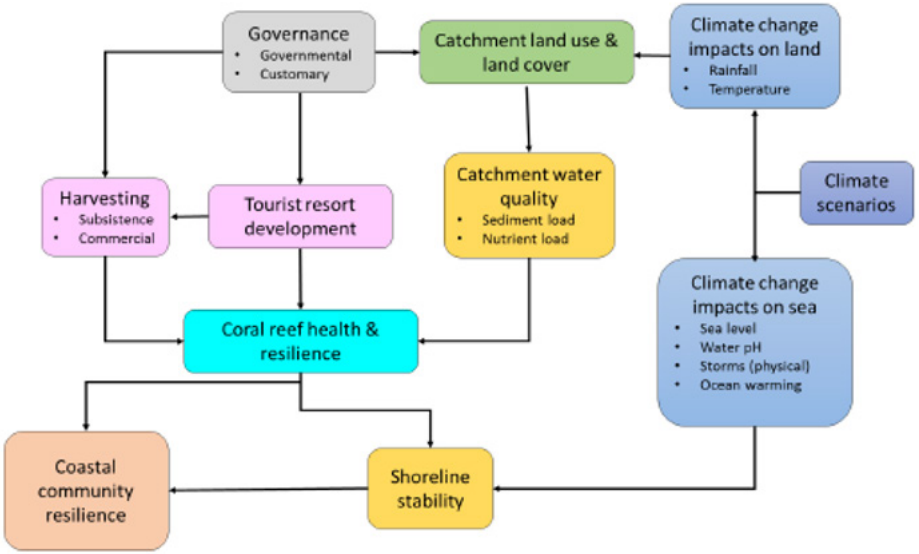
Figure 5.2 Significant wave heights modelled for Port Resolution Bay during a 100 year event.

criteria to mitigate current and future risks. These criteria include impacts to the local ecosystems, community, and costs associated with reducing exposure to the risk.

At Port Resolution, the analysis found the most feasible strategy for reducing exposure to coastal hazards was relocation of coastal infrastructure beyond what we identified as the 100-year risk zone, alongside the protection of existing natural resources ("holding line" option). Furthermore, enhancing and protection of the natural resources through EbA was found to be the most sustainable way in Vanuatu to adapt to the impacts of climate change. Identified options include coastal habitat restoration, reducing land-based sources of pollution from sewage, fertilisers and soil from agriculture, and establishing protected areas to reduce human impact on coral reefs, mangroves and seagrasses.

Beyond Port Resolution, collection of wave and current data for Port Vila's Erakor Lagoon on Efate was conducted as a case study to explore the health of coral reefs. Coral reefs are a significant drawcard for tourism activities, a major contributor to Vanuatu's economy. The focus here was to enhance the understanding of the connections between waste-water treatment and coral reef health. In addition to the data collection work, a significant collaboration was built with the Vanuatu Water Department to develop a detailed coastal process model for the coastal lagoon systems of Port Vila. A critical challenge for the health of coral reef ecosystems is water quality issues inside lagoons particularly those adjacent to major settlements such as Port Vila. Water quality has become such a concern in Port Vila that swimming has now been banned in the main harbour which in addition to the immediate environmental health concerns is also an important issue for the national economy, given Vanuatu's dependence on tourism. The establishment of coastal process models can support water resources management activities of government, in particular planning for waste-water treatment. Over time this collaboration will enable the government to reduce the stress on coral reefs and increase their resilience to climate change pressures. Together these models facilitate building a picture of how climate change will interact with coastal processes in the region and facilitate more effective management of ongoing development pressures around Port Vila.

Figure 5.3: Factors, influences and pressures on the coral reef socio-ecological system for Tanna.



In Vila Bay, it was found that coastal flooding was the main issue and erosion was mainly coming from local sand mining. Poor water circulation was found in Vila Bay particularly during the low wind season (Wet season). This is a major concern regarding the fate of pollutants in the bay particularly during the wet season which also brings higher rainfall.

5.2. Risk assessment team - Spatial Bayesian network and system dynamics models of coastal processes

Understanding the risks arising from the impacts of coastal processes was addressed by the Risk Assessment team through development of a set of models to assess impacts to coral reefs.

5.2.1. Spatial Bayesian network model for prediction of sea level rise induced coastal erosion

The prediction of future shoreline change is a challenging issue due to a range of complex factors contributing to inherent uncertainties and the absence of high-resolution data required for accurate physical modelling. To address these complexities, an integrated approach combining Bayesian Network with GIS was developed for making a probabilistic prediction of sea-level rise induced coastal erosion, the risks to ecosystems and human assets, and assessing potential adaptation measures. The Bayesian Network integrates qualitative and quantitative information into a single

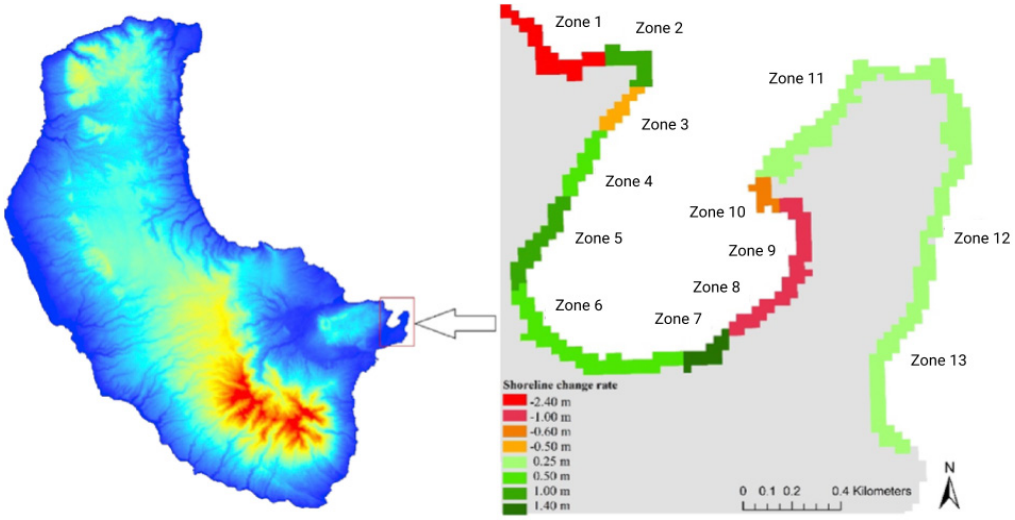


Figure 5.4: Case study area and modelling zones for Port Resolution, Tanna Island.

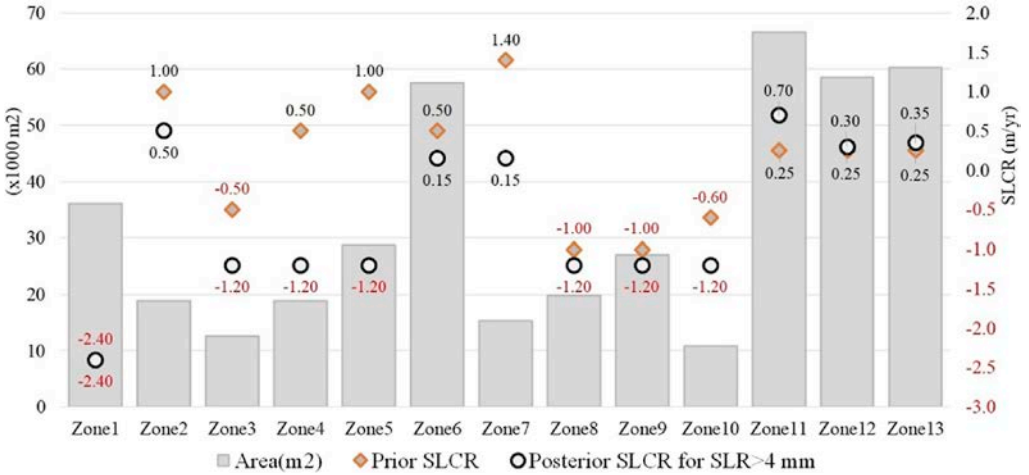


Figure 5.5: Shoreline change rates for each geographic location. The primary ordinate (LHS) represents the surface area (×1000 m2) and the secondary ordinate (SLCR) shows the shoreline change rate (m/yr).

probabilistic model, while GIS is a tool for mapping the key input data and model predictions.

The spatial Bayesian Network model was used to predict coastal erosion scenarios at Port Resolution, Tanna Island. A rate of the island shoreline change was predicted probabilistically for each shoreline segment and was visualised using GIS (Figure 5.4). The spatial distribution of shoreline change prediction results for various sea-level rise scenarios was mapped. As shown in Figure 5.5, the shoreline change rate (SLCR) for each zone comparing the prior SLCR and the posterior SLCR for a Relative sea-level rise (RSLR) scenario of above 4 mm/yr. The erosion rate is represented by negative values in red. Situations in Zone 4 and Zone 5 change significantly from a stable condition (no significant erosion or accretion) to an erosion rate of 1.20 m/yr, respectively. Zone1 maintains the most erosion-prone status. The erosion rates increase considerably in the other areas previously prone to erosion (Zone 3, Zone 8, Zone 9, and Zone 10). The findings of this research paper support risk-based adaptation planning and can be further developed to enable the incorporation of high-resolution coastal process models, thereby supporting localised land-use planning decisions.

5.2.2. Bayesian network model for adaptation strategies for coral reef ecosystems

A participatory probabilistic modelling framework was developed to integrate local and long-term climate change pressures on coral reefs by coupling "structural analysis" and Bayesian Network (BN) techniques. The BN model was quantified through using data from a range of sources to incorporate:

1. projections of future climate conditions and changing human activities;
2. the influences of multiple stressors including physical environmental and sociological factors; and
3. spatial variability in the key processes and variables.

The BN component of this framework was used to integrate the opinions/inputs of a team of multidisciplinary experts. Data for the BN model was extracted from literature which reported the results of regional and downscaled climate models, GIS-based analysis, the regional sources as well as local stakeholders and experts' knowledge.

The developed model was used to analyse the coral reef ecosystem and predict the risks to the health and resilience of the Port Resolution coral reef system from the adverse impacts of climate change and harmful human activities and the possible success of adaptations strategies. Figure 5.6 shows a Driver-Pressure-State-Impact (DPSI) framework depicting the threats responsible for the decline of coral reefs

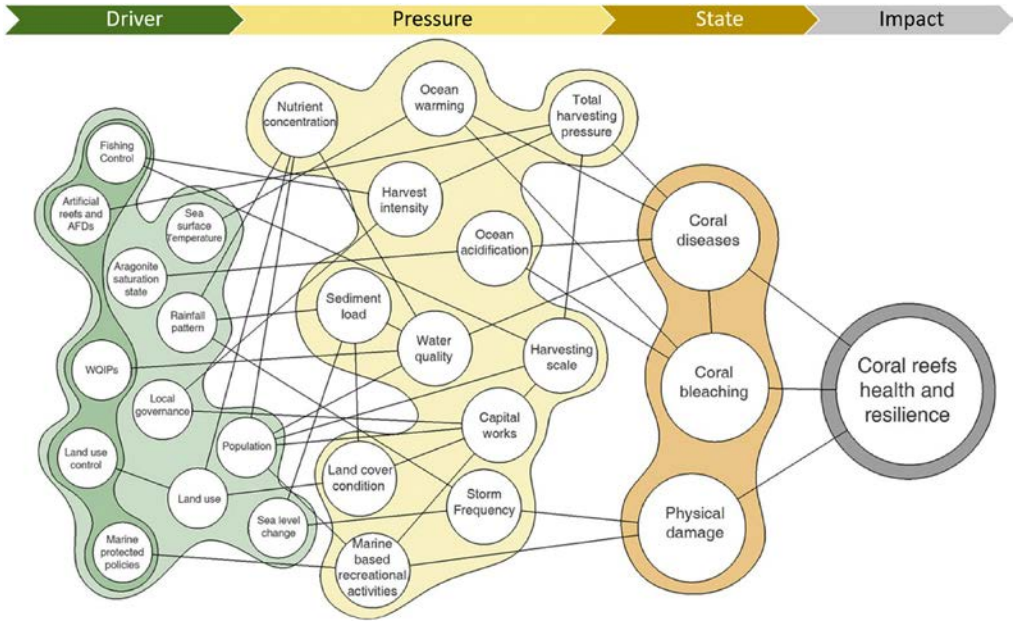


Figure 5.6: Causal relationships of nodes within the Driver-Pressure-State-Impact (DPSI) framework (management nodes: within dark green; other driver nodes: within light green; the pressure nodes: within yellow; state nodes: orange; the impact (target) node: grey).

health, the predictions on the future conditions of coral bleaching, diseases, and physical damages.

The results showed that despite the current fair ecological condition of coral reefs in the area, their health and resilience would be severely threatened by 2070 in the absence of implementing adaptation strategies and associated sustainable management interventions.

5.2.3 Assessment of long-term coral reef ecosystems regime shifts

The risk team assessed dynamic casualties and temporal changes of coral reef ecosystem regime change over a long-time perspective in Port Resolution, Tanna Island. We identified twenty-seven principal influential factors and their corresponding causal relationships. We then analysed the coral reef regime shift under four main plausible scenarios representing major climatic and non-climatic trajectories. As shown in Figure 5.7, the scope of influencing stressors on coral reef cover in Port Resolution,

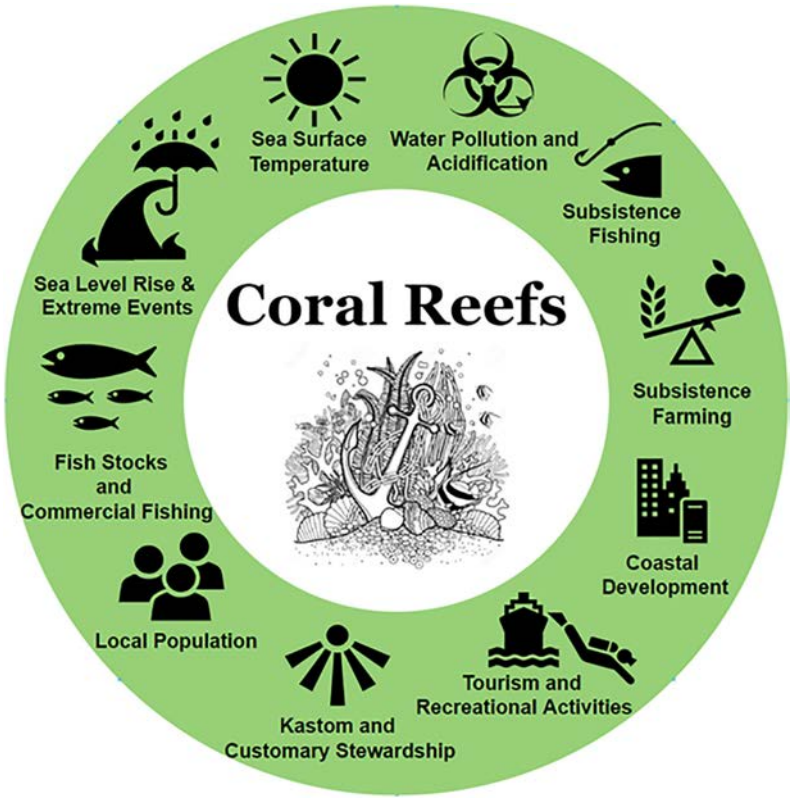


Figure 5.7: Scope of influencing stressors on coral reef cover in Port Resolution, Tanna Island.

Tanna Island was identified through a set of 10 interrelated factors: climatic, socio-economic and human factors including sea surface temperature, ocean dynamics (e.g. sea-level rise and extreme events), fisheries, fish stocks and species diversity, population, cultural values, recreational activities, coastal development, food demand and marine water quality.

The assessment found that climatic factors play pivotal roles in the regime shift of the coral reef ecosystem globally, and that the tourism industry and coral fisheries are the ecosystems services provided by coral reefs most vulnerable to these projected impacts. Therefore, coupled local management interventions and global efforts in

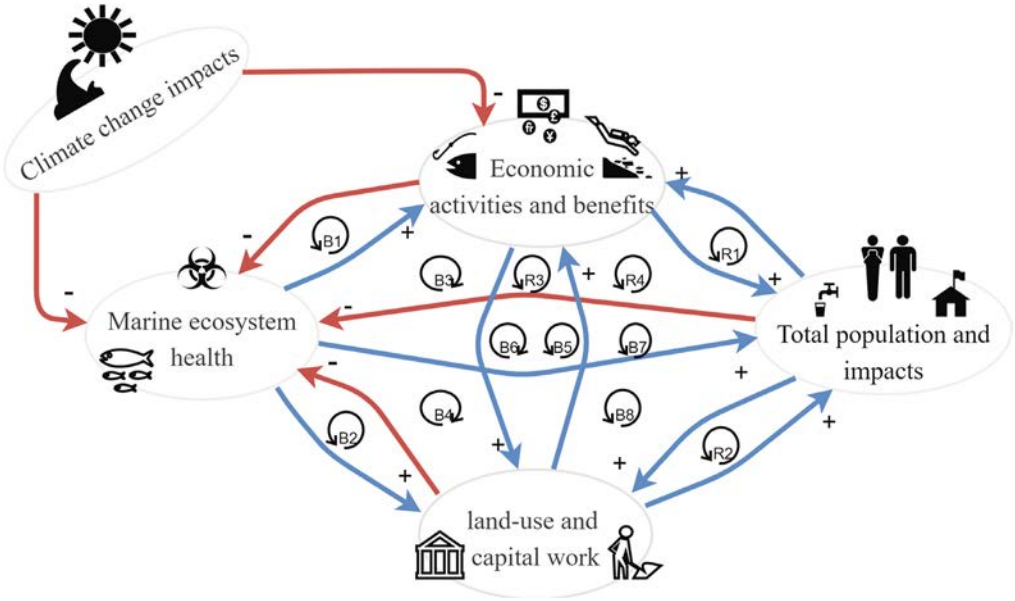
mitigating the adverse impacts of climate change is likely to yield better coral reef ecosystem services at a local community level.

5.2.4. System dynamics model for climate change adaptation strategies for coral reef ecosystem services

A system dynamics (SD) model was developed to assess the condition and resilience of coral reefs under different climate change scenarios, and their consequential impacts on human well-being in Port Resolution, Tanna Island. The outputs of the previously developed BN model for the assessments of coral reef health and resilience were used to quantify the SD model variables of the model, where the existing data and information were insufficient.

Applying the SD, we assessed coral reef ecosystem conditions under different management and climate change scenarios, and their consequential economic impacts in Port Resolution, Tanna Island. Figure 5.8 shows a high-level integrated view of the coral reef health and resilience system components grouped under five main subsystems. Simulation results under different climate change and adaptation scenarios indicate a dramatic rise in extinction threat to the coral reef site of Port

Figure 5.8: A conceptual diagram for the coral reef's health system.



Resolution in the absence of effective local-based adaptation strategies, regulatory enforcement, supervision and stewardship and lack of sufficient global mitigation.

Our findings also show that the adoption of integrated and community-based sustainable management strategies could help to preserve coral reef ecosystems and maintain local communities' well-being over the long-term. Further, the implementation of an integrated portfolio of management strategies better protected the flow of ecosystem services provided by coral reefs under low, medium and high emission climate scenarios, as well as maximised the total economic benefits despite high initial capital investments and some reductions in income due to fishing and tourism restrictions.

5.2.5. Key findings in relation to coastal adaptation

The study in Port Resolution highlighted an issue slowly coming to the attention of policymakers: coastal and terrestrial ecosystems are increasingly exposed to climate hazards that are stretching adaptive capacities and that may breach them in the near- to long-term. With increasing climate change, historical data are becoming less reliable for predicting future risks patterns (Burby et al., 2020). Both natural hazard and coastal development planning need to be more responsive and dynamic to this uncertainty and flexible to allow for adaptive and when necessary transformative adaptations. In many contexts, ecosystem-based adaptations are cost effective compared to hard engineering solutions where structures need to be maintained, upgraded and rebuilt (Hinkel et al., 2014).

Adaptation strategies to mitigate coastal hazards are wide ranging but vary according to local characteristics and context. In the South Pacific islands, the "defence" of coastal assets with engineering structures such as concrete sea walls, remain the 'go to' option for many governments and businesses. However, what needs to be considered are the full life cycle costs including valuation of the existing assets exposed to the hazards, the hazard impacts on hydrodynamic to the exposed assets and risk and their viability in the long-term, as well as potential impacts up or downstream on the integrity of ecosystems.

In Port Resolution, based on results from the fine scaled modelling, the identification of the key factors causing erosion of the cliff edge at the bay suggest a strategy of conservation of the "natural" defences through stabilisation of the cliff top with a re-vegetation programme, rather than installing a seawall and wave breaker. Our research identified the importance of efforts to preserve the integrity of the coral reef, particularly as potential future development plans – such as to grow tourism

opportunities through dredging the Bay to accommodate larger ships – could have devastating impacts to the fringing coral reefs as well as increasing erosion of the Port Resolution coastline. These impacts would have cascading and cumulative impacts on the local community as well. A detailed assessment also showed that drainage plays also an important role in the stability of the cliff at Port Resolution as the cliff can slide due to high water pressure (Clark and Fort, 2009. Limiting the intensive irrigation above the cliff therefore should be further investigated as part of the set of the set of cost-effective EbA adaptation solutions implemented to address the actively eroding cliff face.

In considering appropriate adaptation options, in some cases, "managed retreat" could be the most cost-effective path forward, when exposed built assets such as buildings can be moved at far less cost than engineered work for coastal. This is the case in Port Resolution where the costs to shift and rebuild the school building, and realigning the unsealed road, are substantially lower than any hard or even "soft" engineering options. The loss of the school is not inevitable, nor it is necessarily urgent depending on the effectiveness of re-vegetation and irrigation management in stabilizing the cliff face. Ongoing monitoring is needed on the any interventions and the risk to the school buildings and serviceability of the road. Other pressures also need to be taken into account including new developments and geotechnical issues related to volcanic eruption and seismic activity. "Managed retreat" can be a socially contentious strategy invoking many social and land management implications in the long-term.

For the other two study sites on Efate – Erakor lagoon and Vila Bay – being located in a more developed area, the context for addressing coastal risks is different. In addition to the coral and other marine ecosystems present, major high value built assets and infrastructure exist along the lagoon and in Vila Bay which need to be considered in adaptation planning. The coral reefs in addition to the intrinsic value of their biodiversity are a valuable asset to the community of Erakor and significantly reduces hazards thorough absorbing wave energy. Hence their protection is crucial for the local community and ecosystem health.

Their integrity is also threatened by water pollution from urban run-off. The other important ecosystem here are the mangroves along Erakor lagoon which as well as being critical habitat for many marine species play a key role in mitigating erosion and flooding. Avoiding the loss and degradation of mangrove and discontinuation of sand mining would therefore help prevent coastal risks in the area. Water quality is a key concern around Port Vila as indicated by the government having to ban swimming in the main harbour. In addition to the immediate environmental health concerns, this is also an important issue for the national economy, given Vanuatu's dependence on tourism. The high level of E.coli can be sourced back to effluent from the surrounding urban developments which include a hospital, villages and tourist resorts.

In the context of Port Vila, understanding the role of EbA required working with key stakeholders in undertaking research on the role of fringing coral reefs in attenuating wave energy and related water quality issues. With development pressures increasing for Port Resolution and many other communities across Vanuatu and the Pacific, lessons from more populated areas such as around Port Vila can be transferred to avoid negative impacts. Local planning for tourism developments would be wise to carefully consider the potential for how increased human waste including waste water will be treated to ensure the ongoing integrity of coral ecosystems and to protect human health.

We identified a gap in policy related to water quality. Currently land use planning legislation and policies consider natural hazards in a changing climate but not how

Figure 5.9: Fringing coral reef, Tanna Island. The photograph was taken during a field survey of the reef's ecological condition. Observations are taken along a 50m-tape measure of the presence and type of coral, algae and fish.

these affect water quality in the coastal zone. Integration of these planning policies and schemes is needed to ensure comprehensive protection.

The data collection work on waves, currents and water quality for Port Vila's Erakor Lagoon on Efate is continuing. This work is collaborative and is being continued through engagement with local and national partners and stakeholders whose involvement and in-kind support have been critical to the project's success.

5.3. Recommendations

In terms of EbA, our research reinforces the importance of and the benefits arising from protecting and restoring ecosystems. In all contexts, ecosystems provide services that can mitigate against many climate-related risks to people, settlements and built assets.

A key area for action is in capacity building and knowledge sharing with local communities about the hazards and risks from a rapidly changing climate and their interactions with development pressures. All levels of governance – national, provincial, local – will benefit from increasing their capacity to understand the risks and make informed adaptation planning decisions, considering multiple sources of knowledge and information.

In particular, educational activities can help integrate scientific understanding of ecosystems with traditional knowledge and these can be applied to help with their protection and restoration. There is now the opportunity and need to raise awareness of how ecosystems provide a range of services that can help mitigate climate-related risks. This is especially the case in the coastal zone where they provide (1) natural defences - coral reefs (reducing wave energy); mangroves (reducing wave energy, stabilising the shoreline, maintaining water quality); and vegetation (stabilising the shoreline and cliff tops). Encouraging communities to "work with nature" is consistent with "kastom" approaches.

EbA also requires careful planning to avoid activities that could damage these ecosystems and the "natural defences" they provide. Activities such as dredging, removing vegetation and mining sand all come with negative ecological consequences for the impacted ecosystems. In Port Resolution for example, knowledge of the risks associated with heavy rainfall events that may trigger cliff collapse can be considered in community planning and decision making around where buildings should be placed to reduce exposure to high hazard areas. For national and provincial government planners and decision makers, capacity building is also available to assist them in understanding a social-ecological systems view of climate risks, the role of EBA versus other adaptations, their benefits and costs within local contexts, and how such assessments can better support community-based decision making.

In this study, we found that one of the biggest barriers to climate risk and EbA assessment is the lack of scientific data, including (i) spatial data on the distribution of marine and terrestrial ecosystems, land use and built assets and (ii), time series data from regular systematic surveys of physical, ecological and social-economic factors. A considerable effort was expended in obtaining critical data sets needed to support the various linked modelling and assessment analyses. Key data gaps included: wave buoy data which are needed to validate the wave hindcast model and to then be used for wave climate projections; lack of historical data in shoreline changes, particularly after extreme wave events, and time series of changes to bathymetry before and after extreme events, which constrained calibration of dynamic process models. I

We addressed the limited data for numerical modelling by combining with other methods which allowed estimation of the risk and understand local coastal processes. We have been able to use modelling outputs; including wave setup, storm surge, wavelength, and depth of closure; to be fed into theoretical formulas and obtain a better estimation of the coastal hazard zones with sea level rise. These outputs were complemented with short-term and long-term shoreline movement rates calculated from satellite images.

Citizen science programs provided one approach for filling data gaps by providing training and resources to enable local community members, especially youth to undertake monitoring and data collection. These programmes also serve to support the integration of local knowledge into climate risk and EbA assessments.

6 SOCIO-ECONOMIC ANALYSES

The socio-economic analyses presented in this chapter combines the work of two research teams - social and policy team and the micro-economics team.

The major findings from the Social and Policy Theme in EcoAdapt are below mapped against the four key research questions that have been posed, along with the three main questions to be addressed at the whole-of-project level. Beyond this, contributions from members of the Social and Policy Theme to other activities in EcoAdapt have ensured that the human and policy dimensions have also been incorporated into other outputs.

6.1. Social and policy

The social and policy analysis stream of research sought to explore a wide range of human dimensions that can support, or limit, the success of ecosystem based adaptation (EbA) interventions. The social context is critically important, so the component has engaged with a range of stakeholder groups to examine stakeholder-specific knowledge and attitudes regarding adaptation options and the decision-making processes that are in use when choosing adaptation options. In addition, the team has worked across scales to identify constraints in multi-level governance of adaptation in the context of small island developing states, ranging from community to provincial to national to regional levels.

The four guiding research questions for the social and policy analysis stream area were:

1. What knowledge and attitudes do different stakeholder groups hold about various types of adaptation options and how might these change under future climate?
2. How are decisions made about adaptation options at present and how might they change under future climate?
3. What are the commercial and livelihood opportunities arising from ecosystem-based approaches?
4. How could current policy regimes be changed to enable appropriate use of ecosystem-based adaptation and prevent maladaptation?

The early years of EcoAdapt research focused on broadly understanding the policy landscape at the National and regional scale and then a focusing on the impacts of climate change on the tourism industry and exploring options for supporting adaptation and building resilience in the sector. As knowledge has grown through the life of the project (in addition to some team member changes), there has been a switch to a focus on community and regional government as the key stakeholders engaged in discussions around climate change risks and adaptation options.

A wide range of methodological approaches have been used in the Social and Policy theme. Early work focused on document analysis and policy at the National and Pacific regional scales, local analyses of tourism and community level activities and decision making. Much of the approach throughout EcoAdapt has been to apply systems theory to identify the systemic change that is required to collectively and holistically address and adapt to climate change. In some ways this is a household or community level consideration, in other ways this can be a sector (ie tourism) or regional (Area Council or Province) level approach to understanding and mitigating risks.

Most recent activities have focused on integrative approaches, working closely across the research streams and teams to bring diverse disciplinary-based knowledge together to understand and explore climate change adaptation in a range of contexts and scales.

This has largely revolved around building a shared systems thinking evaluation of the Vanuatu context, through the development of Bayesian Networks that can be used to model not just development pathways or climate change impacts, but also can be used to evaluate the merits of various adaptation options under a variety of scenarios. This work highlights the critical need for multidisciplinary teams to address climate change risk assessment and adaptation option evaluation. This is discussed further under Chapter 8 of this document.

6.1.1. Understanding community stakeholders

EbA is increasingly being advocated as a climate adaptation approach that can deliver multiple benefits to communities. EbA scholarship argues that community-based projects can strengthen those ecosystems that deliver critical services to communities and in doing so enhance community resilience. In particular, the inclusion of Indigenous and Traditional Knowledge (ITK) into community based EbA projects is positioned as critical to successful climate adaptation. Yet, there is surprisingly little investigation into how ITK is being defined and incorporated into EbA initiatives. A foundational activity of the social and policy team was to review EbA literature to identify empirical examples from Vanuatu and Samoa to demonstrate the different ways ITK relates to EbA projects. The review identified widespread recognition that ITK is important for indigenous and local communities and can be employed successfully in

EbA. However, this recognition is more aspirational than practical and is not being necessarily translated into ITK-informed or ITK-driven EbA projects. ITK should not be conceptualized simply as a collection of local environmental information that is integrated with Western scientific knowledge. Instead, ITK is part of nested knowledge systems (information–practices–worldviews) of indigenous peoples. This knowledge includes local natural resource management, sociocultural governance structures, social norms, spiritual beliefs, and historical and contemporary experiences of colonial dispossession and marginalization. At present, most EbA projects focus on the provision of information to main decision-makers only; however, since ITK is held collectively, it is essential that entire communities are included in ITK EbA projects. There is a huge potential for researchers and ITK holders to coproduce knowledge that would be best placed to drive climate adaptation in a changing world.

These findings informed the research design to maximise meaningful engagement with communities within the case study areas across Tanna and Efate. Discussions were held at the 'Nakamal' - the village meeting space, centred around a large banyan tree - where community members were free to assemble and ask questions of us. We also walked the land (and paddled the sea) with community members to discuss and witness first-hand their environmental and development concerns. More structured interviews were also held with groups of women in the communities with the aid of a multilingual community member. We also conducted formal meetings with provincial government planners and other officials and stakeholders. Taking such a '360 degree' approach meant we were able to gain insights into the local realities - including the growing pressures on their natural resources and economies - that the communities are experiencing and having to manage and respond to.

Stakeholder interviews and focus groups have been conducted within local communities to better understand perceptions around climate change threats and explore traditional knowledge. Critically, return trips to communities offered an important opportunity to present research findings to key stakeholders and open up dialogue to support relationship building and trust between the research team and communities, but it also enabled deeper learning and understanding of values and concerns of community stakeholders.

The early study to conduct a Social Benefit-Cost Analysis (SBCA) of different EbA interventions involved stakeholder engagement on Tanna (over several visits) to inform options to be considered for analysis. The community engagement activities aimed to ensure the research team had a grounded understanding of the everyday vulnerabilities that underlie the social and environmental context. The engagement activities included workshops, community focus group discussions in selected communities, guided forest and reef transects, and formal interviews with the provincial government policy makers, planners and field officers, particularly to learn more about opportunities to improve subsistence garden productivity. Community-level engagement was centred on the villages around Port Resolution, which are both subsistence farming and fishing communities. In most cases, the women and men were involved separately, due to the strong gender division prevalent in the traditional culture that is strong on Tanna. This approach secured a more equitable research process and allowed the voices of women, which can often be marginalised, to be heard.

6.1.2 Understanding government stakeholders

The Social and Policy team has also actively engaged in global, regional and national policy and science discussions and research activities. For example, team members participated in the Pacific Coastal Climate Change Symposium in Apia where Dr Nalau gave a keynote presentation based on the EcoAdapt research on defining ecosystem-based adaptation, and the kinds of challenges that are currently constraining EbA approaches in the Pacific.

More recently, engagement with Area Council Managers, Provincial Government staff and Council of Chiefs have sought to build a shared understanding of climate risks and adaptation opportunities. In addition, a critical capacity building activity, in the form of a GIS training course, was delivered in 2019, which not only built trust with key government stakeholders, but also enabled a stronger understanding of the development pathways and opportunities being explored for Tanna Island. It was also the first time the planners from across the island had engaged in GIS and mapping tools at this level and much discussion focused on how such skills could continue to be built and support decision-making within Tafea Provincial Government.

The research teams also visited Tanna Island on numerous occasions to conduct community discussions and meet with government and tourism stakeholders in order to develop a better understanding of current issues and the kinds of climate adaptation strategies that can support both climate and development needs.

6.1.3. Understanding tourism sector stakeholders

Tourism is the second largest economy in Vanuatu after agriculture and is of interest in Pacific SIDS broadly due to its economic contribution to countries and as a pathway to increasing incomes. The Pacific EcoAdapt project conducted a number of studies focusing on this sector and how climate change might impact it, what we need to know

about the local tourism sector and its vulnerability to climate change and how tourism development can be guided towards EbA principles.

A number of studies explored the drivers of change impacting Vanuatu's tourism destinations and the contexts within which they operate. Context has a significant influence on resilience, how a destination responds to change, and sustainability, thus, making context specific approaches to tourism policy development and planning paramount.

Vanuatu, as with many Pacific governments, has a goal to expand the tourism sector and spread benefits to outer islands and rural areas. This needs to be managed to ensure growth is sustainable and equitable and cost are not passed on to the most vulnerable. although policies that recognise and work with sustainability principles are in place, there are gaps in the understanding of tourism as a system.

Better understanding is needed of the formal and informal institutions, cultural values and the traditional and cash economy and how these influence the system, including its resilience. As well as how the change types influence resilience and how long-term system wide sustainability and resilience can be achieved.

What role tourism can play to enhance the resilience of the wider system.

Key studies explored the Vanuatu tourism system and identified two important trade-offs that exist:

- Foreign investment accelerates tourism development and improves standards but also reduces tourism's ability to address poverty due to high leakages and thus impacts the sector's ability to reduce vulnerability.
- Increased visitor numbers which increase benefits to tourism but also increase pressure on the natural environment, including through emissions, thus increasing climate risk and affecting ecosystem health which in turn negatively impacts communities relying on ecosystem services.

Recommendations for EbA in the Tourism Sector

- Integrating tourism and climate change policies and plans, particularly through aiming to strengthen climate risk reduction through reducing reliance on external support and resources.
- Investing in education and capacity building in the tourism sector to strengthen operators' adaptive capacity and enhance decision making on the selection of interventions.
- Engage with diverse stakeholders on adaptation strategies.
- Increasing Ni-Vanuatu participation in tourism to enable greater influence on tourism development at local level.
- Build capacity of policy and decision makers for systems thinking and how climate risk impacts at tourism destinations are connected in feedback on each other.
- Use innovative financing tools to support climate risk reduction activities in the tourism sector and generate e.g. a tourist tax or levy could be reinvested back into local EbA activities and risk reduction activities.
- Invest in destination specific climate change research and education to support locally relevant outcomes.
- Redefining the tourism industry objectives to create wider benefits beyond small-scale economic gain.
- Thus tourism can contribute to or initiate EbA by providing resources, access to information and support in capacity building for EbA.

Figure 6.1: Beach tourism accommodation, typical of Vanuatu. This example is from Espiritu Santo.

A summary of findings in relation to the specific Social and Policy Theme questions are outlined below.

6.1.4. What knowledge and attitudes do different stakeholder groups hold about various types of adaptation options and how might these change under future climate?

Throughout the EcoAdapt project, views and perceptions of community members, governmental personnel and other stakeholders have been sought informally, to better understand the level of perceived risk that climate change poses and the willingness of stakeholders to adopt approaches, like EbA, that harness ecosystem services and support resilience and development.

A key contribution was a collective generation of the Community Wellbeing Bayesian Network Model designed to identify anticipated impacts of climate change and the benefits of the ecosystem-based adaptation (EbA) approaches on community wellbeing in Vanuatu. The model was constructed through participatory and expert elicitation methods to develop the model which enabled evaluation of likely community wellbeing outcomes at four explicit spatial scales – Port Resolution (the community), Port Vila (urban centre), Tanna (whole of island) and Vanuatu (national).

The model includes both acute and chronic impacts of climate change, the impact of coral bleaching, and the potential loss of Vanuatu's fringing coral reefs. The model predicts that all proposed EbA interventions will have a positive impact on wellbeing in all four locations to some degree, by either directly improving the integrity of Vanuatu's ecosystems or by protecting these ecosystems as a positive spill-over of related actions. Significantly, it also predicts that if climate change exceeds 1.5°C of warming, the costs of achieving the same level of wellbeing are increased.

Tourism stakeholders have been consulted widely in the work of Dr Johanna Loehr, with a view to better understanding climate risk and supporting decision making to improve the resilience of tourism operations and destinations that support many local people. The Vanuatu context includes a government goal to grow the tourism sector and spread benefits to outer islands and rural areas. This needs to be managed to ensure growth is sustainable and equitable and cost are not passed on to the most vulnerable. The recently released Vanuatu Sustainable Tourism Policy and Tourism Standards program take a more holistic, context specific approach aiming to lift standards and frame sustainable tourism as something for the whole industry to work towards.

The research has revealed that the drivers of change impacting on Vanuatu destinations can be classified as internal or external, fast or slow, and include for example: demographic change, shift from subsistence to cash economy (slow internal), climate change (slow external) and upgrading of facilities and infrastructure (fast internal). A major challenge in Vanuatu lies with the dualistic governance system, whereby Government on the one hand is expected to follow a neoliberal course by external influences, while on the other hand recognising the importance of Ni-Vanuatu custom and culture.

Knowledge gaps remain which limit discourse and hamper decision making. Some of these gaps represent significant philosophical challenges, like appropriate levels of understanding of the formal and informal institutions, cultural values and the traditional and cash economy and how these interact and influence the system, including its resilience. By extension, the remains uncertainty around how changes can influence resilience and how long-term system wide sustainability and resilience can be achieved.

A key contribution to this question was addressed through the micro-economics team study of community perceptions (in Port Resolution) to natural resource management options. This is discussed under the Micro-economics summary following in Section 7.2.

6.1.5. How are decisions made about adaptation options at present and how might they change under future climate?

Understanding decision making is critical to the success of any adaptation program. In Vanuatu, where governance is a mix of cultural Kastom and western law, the nature and type of decisions made, across a range of scales is worthy of further consideration. Exploration of decision making across the complex governance domains (Table 1) has revealed that tensions may emerge where top-down and bottom-up decision making processes collide.

While tensions may exist across the governance domain, there is also an effort in some sectors (like tourism) to support a shift away from the neo-liberal mindset to a more holistic sustainability perspective. Such a shift would strongly strengthen and enable the application of EbA (as an approach) to support decision making around climate change risks throughout Vanuatu. To incorporate these scale-related dimensions, SES modelling work to understand community wellbeing has been undertaken at a range

of scales to tease out where the social and economic context drives different (stronger or weaker) outcomes under climate change scenarios.

Table 6.1: Scales of decision-making in Vanuatu

Scale	Decision making /Governance domain	Examples
Coastal processes		
Port Resolution	Household, community, Nakamal	Household gardens, community managed MPAs
Tanna	Provincial Government, National Government	Land use and land cover
Port Vila	Provincial Government, National Government	National legislation
Melanesia	National Government, Regional communities (MSG)	Regional agreements
Pacific	National Government, Regional communities (SPREP, SPC)	Pacific-wide agreements

6.1.6. What are the commercial and livelihood opportunities arising from ecosystem based approaches?

Most of the commercial opportunities arising from EbA approaches have been couched within the context of sustainable tourism development in Vanuatu. However, exploring the potential impacts of climate change, development and adaptation interventions on either commercial or livelihoods has required the adoption of a socio-ecological system (SES) framework, to test the flow on effects of adaptation interventions along with other development and policy scenarios. Research has revealed that EbA has potential as an adaptation intervention for tourism as it can produce wider benefits to the destination in form of contributing to environmental, human, social and financial/physical capital. Tourism can contribute to or initiate EbA by providing resources, access to information and support in capacity building. Critically, EbA needs to go beyond conservation goals by taking an active approach to enhancing ecosystem health and resilience. This can be achieved by forward planning, considering future climatic conditions and implementing appropriate design and management (e.g. through zoning and scaling human interaction), and ongoing monitoring.

6.1.7. How could current policy regimes be changed to enable appropriate use of ecosystem based adaptation and prevent maladaptation?

In the tourism sector there are a range of disconnected components and processes that limit the application of adaptation in general, and EbA in particular. Dr Loehr constructed the Vanuatu TAS (Tourism Adaptation System), which is made up of 51 interlinked variables that can be grouped into eight categories: Risk Framework, Tourism & Development, Community & Culture, Natural Environment, Governance, Finance, Information & Educations and Human Psychology. The feedback loops in the TAS highlight the importance of integrating tourism into national climate policy, the differences between internal and external funding streams and the importance of socio-cultural elements such as networks and access to land.

Challenges in adaptation within the tourism sector reflect the growing levels of foreign investment which accelerates tourism development and improves standards but also reduces tourism's ability to address poverty due to high leakages and thus impacts the sector's ability to reduce vulnerability. In addition, growing visitor numbers which increase benefits tourism delivers but also increase pressure on the natural environment, including through emissions, thus increasing climate risk to destination and effecting ecosystem health which in turn negatively impacts communities relying on ecosystem services. In the context of the Vanuatu Sustainable Tourism Policy and Tourism Standards program, these challenges run counter to the holistic and sustainable ambition of the policy.

Tourism-specific policy changes require stronger integration of tourism and climate change policy, including tourism to feature more dominantly in national climate change policy and sector specific policies to support priority climate actions. Policy objectives and funding should be aimed at strengthening feedback loops that enable climate risk reduction though internal processes and reduce reliance on external support, e.g. through tourism if leakages are reduced. Dr Loehr's work also highlighted the benefits of the tourism sector working with nature rather than against it, by supporting and implementing EbA which will sustain the environments that enhance destination appeal.

At a broader scale, consideration of development pathways for Vanuatu, as a Nation, is required to explore how and when EbA interventions can support sustainable development in the country and how development pathways will shape Vanuatu

communities and disrupt or enhance the ecosystem service flows that underpin EbA approaches.

6.2. Micro-economic analyses

The microeconomics stream aimed to answer and inform the following research questions.

1. Which factors have historically influenced the kinds of climate change adaptation projects and the efficacy of their outcomes in the region?
2. Which factors affect local preferences for adaptation options and local valuations of adaptation outcomes from ecosystem based and engineered approaches?
3. What is the extent and distribution of the benefits and costs of an adaptation project?

The approach was grounded in five key studies:

1. Aspects of climate change adaptation projects (from the Global Environment Facility's Small Grants Program) were analysed to understand what factors made it more likely to be successfully completed, and, perhaps more importantly, which aspects of a potential project generate a risk that needs mitigating.
2. Another major study conducted an ecosystem assessment and economic valuation of ecosystem services at the Pacific scale as well as a more detailed assessment of the ecosystems of Tanna Island, using new spatial data from the research.
3. Combining the economic valuation study (above) with community and stakeholder consultation, a social cost benefit analysis (CBA) was conducted on a series of proposed EbA options for the island of Tanna. A social CBA takes a whole-of-society view of the costs and benefits (often monetised social and environmental costs and benefits) of proposed projects.
4. The small village of Port Resolution in the south-east of Tanna Island was also the focus of an intensive participatory process to identify collective community and stakeholder views towards natural resource management in times of social, economic and environmental change. It found three main viewpoints around natural resource management - demonstrating the importance of kastom, but also the importance of the contribution of economic opportunities to improved well-being
5. Further analysis to consider gender differences, i.e. whether differing views were held between males and females in that community identified that significant differences exist. This work is undergoing review.

Figure 6.2: Survey of mangroves being undertaken as part of an Ecosystem-based Adaptation project in Port Resolution on Tanna. (Photo courtesy of Alfred Iouma.)

Table 6.2: Total median, mean, minimum and maximum final ecosystems service value for Vanuatu (US$'000 yr-1) based on habitat extent.

Habitat type	Extent (Ha)	Gross value (thousands US$ per year)				Variance from mean		
		Median	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Coastal coral	70,238	58,050	461,357	12,081	2,742,716	7.9	0.2	47.2
Coastal mangrove	1,665	12,529	12,545	9,634	15,473	1.0	0.8	1.2
Coastal seagrass	124,038	8,185	8,185	4,072	12,298	1.0	0.5	1.5
Tropical forests	934,831	857,523	1,758,854	560,825	6,173,858	2.1	0.7	7.2
Grassland	39,776	24,094	37,193	14,801	72,677	1.5	0.6	3.0
Freshwater water bodies	539	1,001	991	168	1,795	1.0	0.2	1.8
Freshwater wetlands	406	83	319	8	1,320	3.8	0.1	15.9
Subsistence gardens	154,186	1,935,300	1,935,300	1,357,5984	2,513,001	1.0	0.7	1.3
Plantation cropping	73,940	4,141	4,141	4,141	4,141	1.0	1.0	1.0
Total final ecosystem service value		**2,900,906**	**4,218,885**	**1,963,327**	**11,537,280**	**1.5**	**0.7**	**4.1**
Total intermediate		213,943	633,226	66,953	1,992,709			

6.2.1. Meta Analysis of success factors of EbA projects

Our meta-analysis findings show that, all else equal, small grants projects (specifically, GEF-SGP projects) that are shorter, with a higher level of cash co-financing and/or in-kind contribution from other donors and project partners, a single adaptation approach, and a clear consistent focus on adaptation as opposed to other outcomes, have a higher probability of completion. Based on these results, we also constructed a mathematical model to test whether we could make predictions on project success, based on the project attributes. Our model had 'excellent' predictive capacity, showing that, given a set of project attributes, we could predict the level of project success. Such a model should be able to assist potential donors and proponents in improving their project proposals to increase the chances of project completion. Successful project completion, should, however, only be seen as a precursor to successful adaptation projects; as yet, there is little agreement on how to do monitoring and evaluation on climate change adaptation projects.

Our results show that a singular focus on either hard-engineered, ecosystem-based, or human capital development likely assists project completion, particularly of smaller projects. However, the EcoAdapt project, more broadly, has well-demonstrated that many climate change adaptation challenges need integrated and complex approaches, often combining a combination of all of these elements in an ecosystem-based 'approach'.

Our findings should *not* be used as an excuse to not pursue these types of projects (which are likely to be more appropriate), but to highlight that such a project carries an increased risk of failure and other elements of project design should be in place to mitigate against failure. So, in situations where complex, multi-disciplinary projects are determined to be required by a project proponent, funders should pay attention

Table 6.3: Net present value (NPV) and benefit cost ratio for a programme to increase subsistence garden productivity, both with a supporting community radio station and without (r=10%).

Improvement in productivity over 25 years	Subsistence gardens with supporting radio station		Subsistence gardens without supporting radio station	
	NPV	Benefit cost ratio	NPV	Benefit cost ratio
100%	182,575,159	93	86,654,751	74
50%	112,755,934	58	51,188,706	45
25%	73,738,681	38	31,292,990	28

to factors that enhance completion, such as promoting co-financing cash from other donors and project partners.

Alternatively, where circumstances are warranted, funders should be prepared to tolerate higher levels of risk of failure surrounding their project funding decisions, which invariably goes against the grain of business case development, which generally promotes projects with the lowest risks of failure. As the GEF promotes itself as a risk taker and an innovator (GEF, 2015), understanding how to decrease known risks of non-completion, at the margins, is vital.

Whilst our study provides some useful initial directions, and provides excellent levels of predictive accuracy, improved understanding of factors influencing effective CCA could be obtained if more nuanced indicators of ultimate adaptation effectiveness were available for cross-project evaluation. Currently, monitoring and evaluation and then on-going reporting of the outcomes of climate change adaptation needs to be improved.

6.2.2. Challenges and sensitivities study

The total flow of value provided by the habitats of ecosystems of Vanuatu and Tanna to their people is substantial, far outweighing traditional measures of economic activity that are recorded in GDP. Therefore, measures of well-being need to be inclusive of

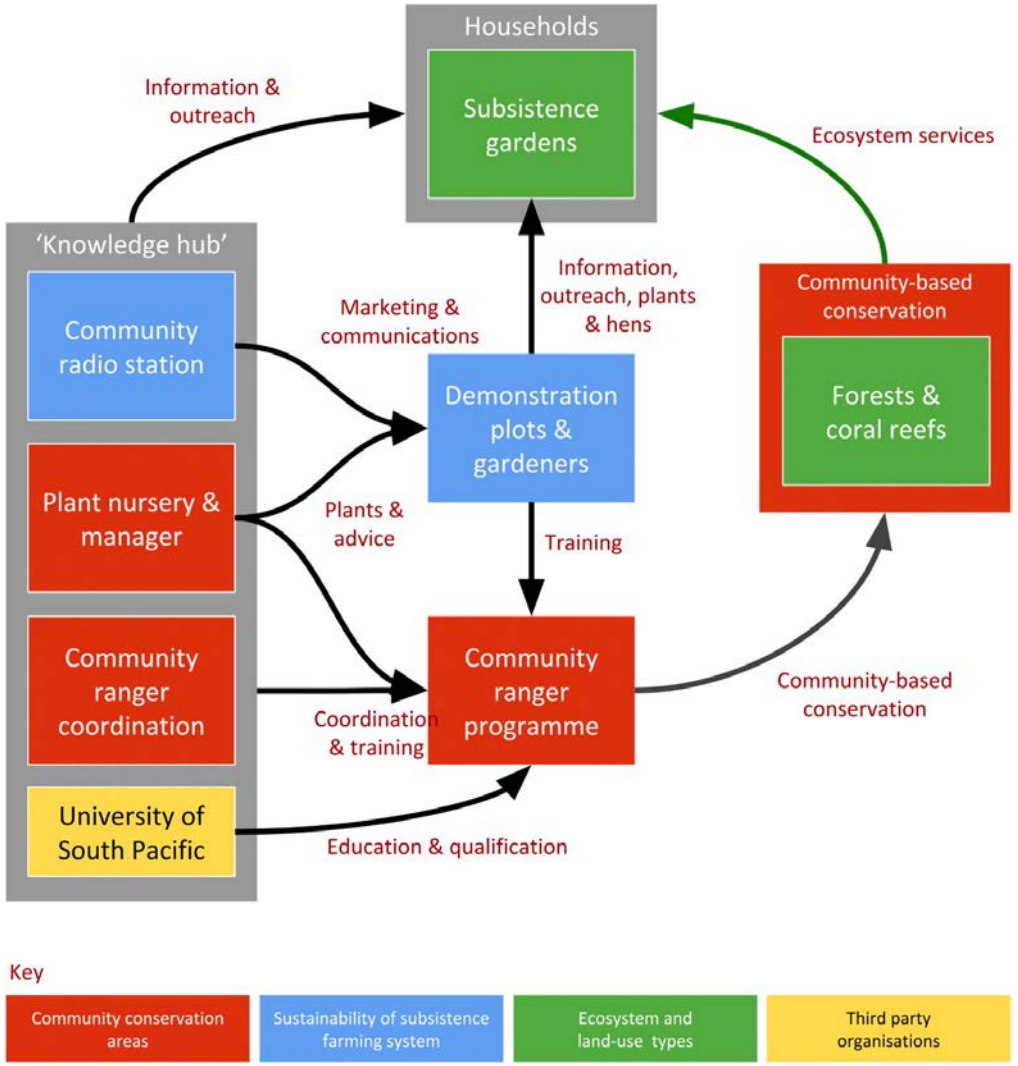


Figure 6.3: Conceptualisation of mutually supporting the selected four EbA interventions considered in the Social Benefit Cost Analysis conducted by the Micro-economics team.

the contributions of ecosystems, particularly in the role of providing a buffer against climate change, such as in taking an EbA approach to adaptation.

However, accounting for ecosystem services, particularly in Pacific SIDS contexts, where communities are largely subsistence and kastom ownership and management of natural resources is a strong organising force, faces a number of challenges. If these are not accounted for, or acknowledged, they can encourage misinterpretation or maladaptive responses to environmental pressures.

We have pointed to a number of ways of improving ecosystem services valuation in Pacific SIDS contexts, such as hastening new primary research, maintaining serviceable valuation databases, augmenting ecosystem accounting with stated preference valuations to incorporate complex, social values, such as Kastom value, incorporating data on ecosystem condition into benefit transfer approaches, and supplementing survey methods with more participatory methods of value elicitation.

6.2.3. Social benefit-cost analysis for EbA approaches to adaptation on Tanna

The foci of funded EbA projects in Pacific SIDS has been dominated by 'downstream' activities, such as ecosystem asset conservation or augmentation in the service of adaptation and by capacity building and community planning activities to improve adaptive capacity. Projects that tackle 'upstream' factors—factors that reduce anthropogenic stressors to existing habitats, such as the impact of unsustainable agricultural practices—have tended to be less successful in securing funding.

Our social benefit-cost analysis (SBCA) study of a targeted programme of EbA interventions aiming to improve community resilience to climate change on Tanna employed methods for economic valuation of ecosystem services in the assessment of positive environmental externalities. The SBCA revealed that very considerable social benefit is derived from interventions that aim to improve the productivity of subsistence gardens of Tanna by the implementation of programme of demonstration plots and agricultural extension workers, which also simultaneously take the pressure off deforestation and improve well-being, even under conditions of a growing population. Increasing the intensity of food production reduces pressure on a range of resource management threats and can potentially be adopted by all households on Tanna.

The initial project investment is, however, considerable, putting it into either the medium- or full-sized project envelope for major funding organizations. From a more modest investment, increasing the community capacity to balance formal forest and reef conservation with customary management can provide small, but nevertheless important complimentary social benefits. The individual projects were designed to operate separately or be integrated to operate with synergies. Figure 6.1 shows how the projects could effectively increase effectiveness through being more scaleable, generate spill-overs (also known as externalities) and synergies and assist knowledge management.

The SCBA did not specifically model this outcome as we felt we could not effectively quantify monetary benefits from the synergies. However, this integration was explored further through the Bayesian Network and Systems Dynamics modelling described in Chapter 7 of this report.

Given the lack of global progress towards reducing greenhouse gas emissions, the impacts of climate change are likely to accelerate. If the impacts of climate change on SIDS are to be mitigated and resilience to environmental change for rural communities is to be supported, then EbA approaches that improve food production (or reduce food

6.3. Collective viewpoints of natural resources and ecosystem based adaptation

The Q method study set out to identify discourses towards natural resource management and social and economic transition, in the context of environmental and climate change in rural communities on Tanna, to understand constraints and enabling factors for implementation of ecosystem based adaptations.

We identified three dominant discourses:

1. Strong Kastom;
2. Kastom + Health; and
3. Tentative Modernity.

In each of these discourses, there was a strong affinity to issues associated with provisioning and regulating ecosystem service that reflected the omnipresent function of Tanna kastom in arbitrating social relations and customary management of natural resources. However, Tentative Modernity had significantly greater openness to economic development opportunities associated with generating income from promoting cultural ecosystem services, such as the area's forests, reefs and natural beauty. This desire to pursue income generating opportunities, which were noticeably absent from the discourses, Strong Kastom and Kastom + Health. Whilst our research

did not reveal any strong concern over climate change impacts (despite the historical impacts of Cycle Pam in 2015), it did reveal that attitudes in the community will likely be receptive to EbA, as it supports community reliance on provisioning ES and kastom-related ecosystem functions.

A key step in climate change adaptation project design is to identify a candidate set of adaptation interventions to ameliorate the identified climate risk. At least at our case study site, for each of the identified discourses, interventions are more likely to resonate with the community if they enable local decision making for natural resource management and reflect traditional knowledge of ecosystems and related kastom practices, and, for the inclusion of women, provide opportunities for generating income, and promote equity in decision making. Our findings also suggest that external climate change practitioners do not necessarily prioritise the need for income generation, such as through eco-tourism, as being important to community livelihoods.

Subsistence provisioning from local ecosystems remains important and kastom and its cultural equivalents, retains a persuasive organising force across Melanesia and the Pacific, despite fast-urbanising populations. Due to their common vulnerability to climate change impacts, Pacific SIDS are and will increasingly be in receipt of climate change adaptation funds, commonly focussed on ecosystem-based adaptations. Our findings have broad applicability to rural areas of Pacific SIDS and have implications for project evaluation and distribution of funds.

6.3.1. Gender-based perspectives of natural resource management

We also re-analysed our data in terms of more intersectional issues, particularly along gender lines. Re-analysis of the original dataset for women and men identified subtle different womens' and mens' viewpoints. Three women's discourses were identified: traditional–kastom, natural resource orientated, and tentative economic and social transformation. Likewise, three men's discourses were identified: traditional–kastom, health–traditional, and social and economic change. There was reasonable overlap between the womens' and the mens' more traditional factors and transformative factors. And both the womens' and the mens' traditional discourses contained the largest number of respondents. However, more women associated with the transformative discourse than men. Also significant was that women who identified with the transformational discourse tended to not have an existing income, whilst the opposite was true of men.

Women remain inequitably impacted by the implications of climate change in Pacific SIDS. They also require very specific CCA and EBA programme design that explicitly includes opportunities to start to generate income as a precursor to broader engagement in localised, kastom decision making structures in rural communities, which remains a dominant organising force, and where the influence of formal government institutions in terms of infrastructure and health remain distance and most resources are still managed in common.

6.4. Key findings of the micro-economics studies

Putting all of our findings together, we can offer the following answers to the original microeconomics research questions.

6.4.1. Which factors have historically influenced the kinds of climate change adaptation projects and the efficacy of their outcomes in the region?

We determined that a number of project attributes tends towards CCA projects being successfully completed. However, though our model had 'excellent' skill in predicting CCA project success, we can only make this conclusion based on the project attributes that are consistently reported. It is possible other non-reported attributes may also play a role. In terms of efficacy, we can conclude that where there is more a focus on ecosystem-based approaches (not specifically 'pure' EbA projects), such as improving the productivity of subsistence gardens, or decreasing the impacts of existing activities, efficacy can be exceptionally high.

6.4.2. Which factors affect local preferences for adaptation options and local valuations of adaptation outcomes from ecosystem based and engineered approaches?

Local preferences for adaptation options are strongly influenced by the concept of kastom. Options that support local continuation of, or re-discovery of, customary natural resource management of habitats to sustainably produce and harvest food, water and materials. During our research we undertook significant local and expert consultation, which revealed strong preferences for EbA approaches. One engineered option was considered (see Coastal Processes chapter) to manage erosion hazard in

Port Resolution at the request of the community, however, this was not considered cost effective.

This subsistence production provides an important buffer against the impacts of climate change. However, we revealed that conceptions of kastom are most strongly supported when they are associated with natural resource management and that for those community members not already, at least partially, engaged in cash exchange, economic development opportunities are important, but only to an extent.

Cash can provide additional buffers against local shortages and provide access to schooling. The localised context of the natural resource base, and social factors, such as income, insider/outsider status; and gender also influence preferences for adaptation options. Our results show that Ni-Vanuatu rely significantly on ecosystem services for well-being and therefore ecosystem based approaches will inevitably be highly valued. However, we found very little local data is available for economic valuation of ecosystem services. This is a key gap in the literature.

6.4.3. What is the extent and distribution of the benefits and costs of an adaptation project?

Unless local contexts are considered, there are risks that the distribution of costs and benefits of EbA projects will not be optimally allocated. Our findings show that the rural Ni-Vanuatu rely significantly and acutely on ecosystem services for their well-being. At face value, pursuing EbA projects can support an equitable share of benefits, as commonly EbA supports habitat conservation, either directly (Community Conservation Areas), or indirectly through reducing pressures on habitats by improving the productivity of food systems. Such benefits generally flow as public goods or common pool resources, which are non-excludable - that is, the benefits are freely accessible. Furthermore, our *social* CBA study showed the benefits of EbA can be very, very substantial.

6.5. Summary

When considering hosting externally-funded complex, climate change adaptation projects in Vanuatu, if the government commits to co-financing, either in-kind or in cash, the project will more likely to be successfully completed. While a project successfully completing is not a measure of adaptation success, commitment from the Vanuatu government, most appropriately in terms of providing in-kind assistance from government officials, will greatly increase the chances of success. The Vanuatu government, the non-government sector and grant giving organisations should collaborate and assess project design to ensure that risk of implementation failure is reduced at all stages of the project.

Determining how effective climate change adaptation projects are at delivering actual adaptation (i.e. not simply monitoring whether a project has been successfully completed) is confronted with several challenges, including a lack of measurable outcomes against which adaptation effectiveness can be determined, an absence of a systematic and readily definable metric for measuring adaptation success, and a lengthy delay between adaptation implementation and delivery of beneficial outcomes.

Where the Vanuatu government is involved in providing host to adaptation projects, it must request resources to monitor the actual success of the project in assisting the adaptive capacity of the host community through adequately resourcing the monitoring and evaluation over a period of time sufficient to detect impact. This monitoring and evaluation needs to be both appropriate for the project but be consistent enough for building a consistent dataset for ongoing analysis.

Much of Vanuatu's income and well-being is generated through the non-cash economy. The government of the Republic of Vanuatu should continue to invest in and explore methods to ensure that subsistence-based incomes from gardening and fishing are better assessed and included in measures of well-being and 'income', such as in the reporting of national income in GDP reports.

Global frameworks, such as the United Nations' System of Environmental Economic Accounting (SEEA) and particularly SEEA's Experimental Ecosystem Accounts framework [1] and Natural Capital Accounting and Valuation of Ecosystem Services (NCAVES) (or what follows)projects are important and well-supported. The SEEA framework will eventually be included as an indicator for measuring national progress towards achieving the 17 Sustainable Development Goals [2]. The government of Vanuatu should invest in the skills, knowledge and experience of government land managers, planners and agronomists and investing in the technical tools and techniques to effectively map and classify habitat will be essential in valuing the trade-offs and measuring community well-being into the future.

Ecosystem based approaches to climate change adaptation can achieve greater leverage when targeted at 'up-stream' activities that reduce the pressures on natural resources, such as reefs and forests, rather than intervening directly in habitat restoration. Our

1 https://seea.un.org/home/Natural-Capital-Accounting-Project

2 https://sdgs.un.org/goals

consultation activities and economic modelling demonstrated that funding targeted at increasing productivity of subsistence gardens can achieve very significant social returns on investment (that is, non-cash, community returns). However, the initial investments required can be large. As 98% of households do some farming (Vanuatu National Statistics Office, 2009) and adoption of new farming techniques can spread from household to household, the cohort of people who can benefit is potentially island wide.

Such EbA approaches generate immediate benefits, regardless of the uncertainties in the amount of climate change impacts and social and economic changes. Community conservation projects, which are targeted more directly in EbA's provide more modest benefits, but from a smaller investment.Rural communities in Tanna (and likely across Vanuatu) are likely to be predisposed to EbA approaches to climate change adaptation. Such approaches tend to support sustainable harvest from kastom natural resources and EbAs provide indirect adaptation co-benefits. Whilst this should not be inherently controversial, there are nuances. Projects that also support economic development and the generation of cash – and potentially challenge some of the traditional social aspects of kastom – will resonate more strongly with women who are not currently engaged in cash generation.

Therefore, in project consultation and design, these womens' voices need to be heard. Similarly, expert outsiders may have a blind spot when it comes to the reforming nature of economic development in helping achieve womens' aspirations and instead perhaps more support the continuation of kastom to support sustainable development, without the necessary social reforms. The short to medium term impacts of the travel restrictions imposed by the 2019-onwards Covid-19 pandemic will likely have a very significant influence on the generation of cash incomes from tourism in Vanuatu, which will likely influence poverty rates and limits access to food. During a pandemic, food security is a precondition for successfully fighting the virus. This makes the continued productive capacity of the complex subsistence garden-forest-reef socio-ecological system imperative.

The pandemic may also exacerbate unregulated and unreported small-scale fishing and timber extraction in some areas, putting pressure on the acceptance of community-based restrictions on resource extraction, such as Community Conservation Areas. Any loss of productive natural capital assets to degradation, development and over-extraction should be eliminated. If rural Ni-Vanuatu become reliant on the

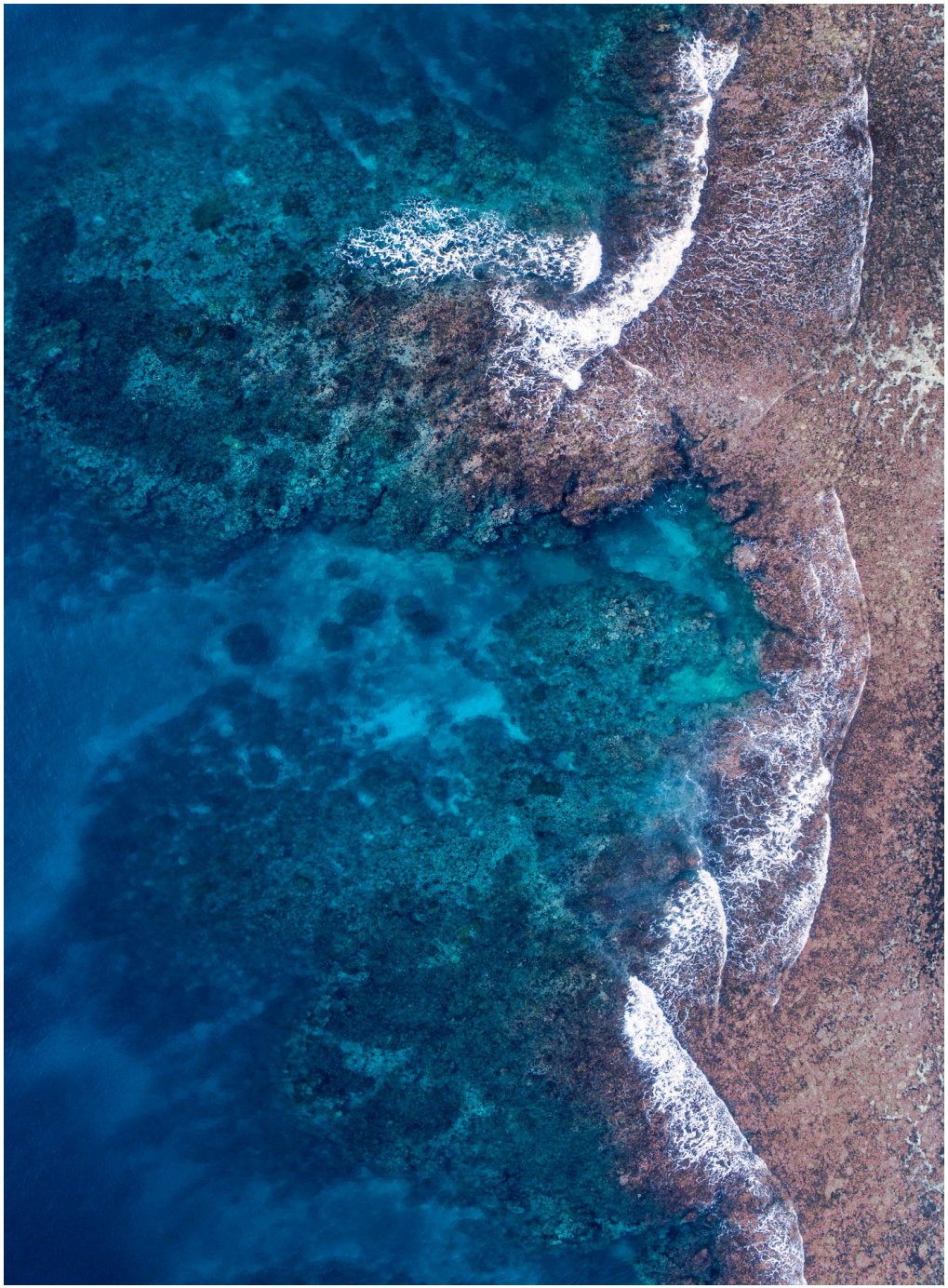


Figure 6.4: Coral reefs in Vanuatu are n important driver of tourism visitation.

cash-economy for food items, they are likely to experience hardship if global food prices rise (United Nations Environment Programme, 2020).

6.6. Specific recommendations related to the economics of adaptation in Vanuatu

The following recommendations are applicable to the government of Vanuatu and the non-government sector undertaking projects in Vanuatu and can inform practice across the Pacific islands more generally:

1. When considering hosting externally funded complex climate change adaptation projects in Vanuatu, the government should commit to co-financing, either in-kind or in cash. In-kind support can be provided by offering time and effort of government departments. The government, the non-government sector and grant giving organisations should collaborate and assess project design to ensure that risk of implementation failure is reduced at all stages of the project.
2. The Vanuatu government should commit resources to building staff skills and capacity in integrating natural capital accounting into national accounts and well-being measures, building on SEEA for a Melanesian context. Engagement with SEEA will offer opportunities for Vanuatu to be supported to in participate in funded SEEA implementation projects, such as NCAVES (or what follows).
3. Using the tools and frameworks of SEEA and natural capital accounting the Vanuatu government should develop a series of key ecosystem accounts, both for spatial scales (such as an island) and for important sectors, such as eco-tourism. Sustainable development and the achievement of the SDGs will require economic development to be consistent with conservation of natural capital and the flows of ecosystem services it provides. Such accounts can inform where, for example, the eco-tourism sector's impacts and dependencies are, so that it can be developed equitably and sustainably. The post-Covid-19 recovery will provide an opportunity for a reassessment of tourism development patterns, using natural capital accounting tools.

7. PROJECT INTEGRATION AND SYNTHESIS

A feature of the Pacific EcoAdapt project's research is the integrated methodology which involved bringing together multi-disciplinary teams to undertake an wholistic assessment of the focal social-ecological systems in terms how they will be impacted by climate change related risks and the benefits provided from an ecosystem-based approach to adaptation (EbA).

A good example of the positive outcomes that arose from the interdisciplinary approach of our research is the ways in which the ecosystem and climate change themes' analyses informed the micro-economic evaluations. We modelled the distribution and condition of the major ecosystem types of Tanna Island, including the fringing coral reefs, using high resolution satellite data, existing maps, and field observations.

Cross-disciplinary contributions have included:

- social and policy input to completion of Q method tasks with Area Council and Provincial Government representatives on Tanna Island (led by microeconomics team);
- all teams working on design and evaluation of the wellbeing BN model (led by integrated risk assessment theme);
- all teams contribution to the coastal modelling work, to embed adaptation options and decision making frameworks into the modelling effort;
- risk assessment team major contribution to coastal processes work; and
- all teams working on synthesis and stakeholder engagement.

7.1. Integrated risk assessment

A major focus of the integrated risk assessment analysis has been on understanding climate risks to coastal environments which has been captured in Chapter 5 of this report, in the context of the key research questions. The complex and integrated social, economic and environmental dimensions of climate change adaptation cannot be effectively managed using traditional approaches that focus only on one dimension and are unable to examine adaptation strategies in the face of alternative future scenarios, large uncertainties, and a range of stakeholder needs. Therefore, innovative approaches that are accessible (including for 'non-modellers'), robust given the best available data, integrate social, economic and environmental factors, and can account for the dynamic aspects of the system being studies are needed for making informed and meaningful decisions about climate change adaptation options.

The approach employed for risk assessments draws upon Structural Analysis, System Dynamics (SD) and Bayesian Network (BN) modelling methods to develop integrated assessment models. BN & SD models are used to integrate the influence of a range of key factors, spanning both socio-economic and bio-physical considerations through developing several models. For example, the participatory combined (BN-SD) modelling approach applied to assessing climate risks to coral reefs. The developed approach integrates the influence of a range of key factors, spanning both socio-economic and bio-physical considerations to conduct a comprehensive risk assessment.

The advantages of BN-SD include its ability to use data from a wide range of sources both qualitative and quantitative, it can be easily coupled to GIS when a factor needs to be mapped, and it can provide the basis for developing tools to aid decision-makers. This approach enables decision-makers to consider various alternative courses of action and select the most appropriate option. Thus, this approach is also ideal for multi-disciplinary projects such as EcoAdapt where the outputs from different themes must be brought together in a systematic way. This was a novel exercise for most of the researchers and has proven to be a valuable platform for assisting with the difficult task of getting researchers from different disciplines to communicate and share their expertise in ways that facilitate the project's goals.

As explained below, we have used a number of procedures to integrate data/knowledge/expertise generated by the other four themes to contribute the overall project activities in answering the overall research problems.

7.2. Assessing community wellbeing impacts from climate change in Vanuatu

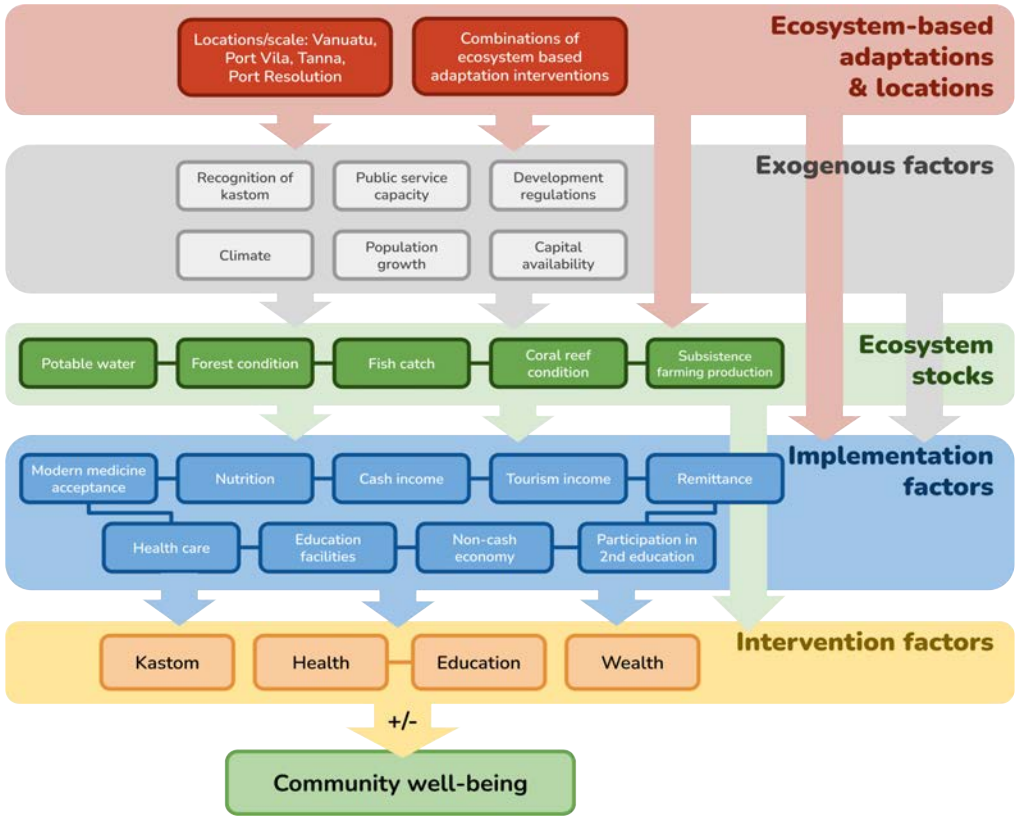
A key activity was development of an integrated, multidisciplinary BN Model to evaluate the anticipated impacts of climate change and the benefits of the EbA approaches on community wellbeing in Vanuatu. Community wellbeing is the combination of social, economic, environmental, cultural, and political conditions identified by individuals and their communities as essential for them to flourish and fulfil their potential. The model was used for evaluating community wellbeing responses at four explicit spatial scales in Vanuatu:

1. the village community of Port Resolution on Tanna Island;

2. the whole of Tanna Island;
3. Port Vila; and
4. the whole of Vanuatu.

The developed model is capable of exploring both acute and chronic impacts of climate change, in particular the impact of coral bleaching and the potential loss of Vanuatu's fringing coral reefs. The developed BN model and associated analyses demonstrated how each component of a series of coordinated and complementary EbA approaches can improve community wellbeing at multiple scales. Contributions from across all thematic areas of work towards the model has enabled a revision of ecosystem services being provided in Port Resolution, with inclusion of freshwater resources as an important component influencing human health and well-being within the community.

Figure 7.1: Influence diagram showing key factors affecting Community wellbeing.



By using this model, we assessed the anticipated impacts of climate change and the benefits of the EbA approaches on community wellbeing in Vanuatu. Figure 7.1 shows the conceptual model of the socio-ecological system, which contains 27 variables arranged into seven groups, representing: target node (light green); key interventions factors (orange); implementation factors (blue); ecosystem stocks (bright green); exogenous factors (grey); ecosystem-based intervention options (pink); and spatial locations (yellow).

The developed model was used to evaluate community wellbeing responses at four explicit spatial scales, Port Resolution, Tanna Island, Port Vila, and Vanuatu. The model predicted that all proposed EbA interventions will have a positive impact on the baseline wellbeing value in all four locations, to some degree, by either directly improving the integrity of Vanuatu's ecosystems, or by protecting these ecosystems as a positive spill-over of related actions. It also predicted that if climate change increases global temperatures by more than 1.5°C above pre-industrial levels, the cost of achieving the same level of wellbeing will be increased.

7.2.1. Summary of integrated assessment research

The lack of scientific knowledge, the uncertainty in the timing and local associated with projections of future climate and risks from climate-related natural hazards, should not be seen as barriers to effective adaptation assessment and planning. Our findings show that adaptation interventions could be more effective and successful when the full suite of potential and feasible strategies is evaluated and integrated into the planning process.

Model integration techniques such as SD, BN and GIS are useful for conducting long-term risk assessments where there is a high degree of uncertainty with the scenario input parameters. Use of a GIS allows decision-makers to instantly visualise the spatial impacts of various scenarios at a range of scales (i.e. local, regional, and country).

Identification and assessment of adaptation options for coastal communities require an integrated assessment of climate change impacts on coastal processes, risks to coastal ecosystem condition and services, impacts on human settlements and implications for activities such as coastal agriculture and fisheries. Deployment of an integrated

approach can support developing a holistic adaptation planning framework that increases the likelihood that the adaptation planning process will be successfully executed.

Another important finding is while human impacts – over fishing, coral mining, water pollution – are currently the main factors influencing the integrity of coral reef ecosystems, in the near-term that will shift to climate change impacts; the main impact being from marine heat waves which cause coral bleaching events. Preserving coral reef ecosystem services therefore needs an integration of global action – to reduce greenhouse gas emissions – and local efforts to reduce the current suite of pressures. These ecosystems are home to a rich biodiversity, provide a valuable source of food for local communities, and are one of the natural assets underpinning the tourist sector. Coral reef adaptation plans are therefore urgently needed that take into account these factors, inclusive of community-based and culturally appropriate solutions.

Our research also reveals that EbA offers multiple benefits and have the potential to integrate adaptation priorities with development processes, tackling many issues threatening the most vulnerable countries and communities. Holistic EbA interventions (from ridge to shoreline, forest to reef) have great potential to maximise community wellbeing and contribute to climate resilient sustainable development.

The integrated assessment and modelling approach employed here – combining systems dynamics, Bayesian network modelling and structural dynamics with participatory (stakeholder and expert informed) processes – provides researchers and decision-makers with a more wholistic understanding of the long-term impacts of climatic and non-climatic stressors, the effectiveness of management interventions in the region, and useful insights for evaluating project proposals to determine where and when resources can be focussed to provide the most significant improvements in ecosystem health and community wellbeing, given limited resources.

7.2.2. Recommendations for supporting an integrated approach to EbA planning

The probabilistic and dynamic features of our modelling approach make it useful for conducting long-term risk assessments where there is a high degree of uncertainty with the scenario input parameters. The use of GIS as part of the modelling framework allows decision-makers to instantly visualise the spatial impacts of various scenarios at various scales (i.e., local, regional, and national).

Using modelling as a decision support tool is limited by the availability of data and subject to the sensitivity of the assumptions. The absence of high-resolution data required for precise bio-physical and social-economic modelling is a gap that needs to be addressed. Future research should explore further improvements to incorporate higher resolution data outputs from other modelling techniques such as coastal process models into risk assessment simulations.

8. REFLECTIONS ON KEY RESEARCH QUESTIONS

8.1. What constitutes an ecosystem-based approach to climate change adaptation?

An important component of the EcoAdapt project focused on understanding EbA and deriving realistic examples of EbA interventions that can support sustainable and climate resilient communities on Tanna Island. This work included high level analysis of the successes and failures of EbA interventions throughout the Pacific and dovetailed into the work of the Microeconomics team via analysis of costs and benefits of adopting EbA. Building on this work, we then characterised how EbA interventions can support communities and livelihoods across a wide range of scales – community, island, capital city and Nation.

To do this we modelled focal social-ecological system (SES) using Bayesian Network techniques. These were designed to evaluate how EbA interventions can positively protect the integrity of the ecosystems as well as the local community well-being. This work synthesised knowledge across all EcoAdapt theme areas to explore how adaptation interventions and climate change impacts will ultimately shape the livelihoods of community members and the health of the ecosystems.

Over the course of the project, the research team's thinking about EbA has led to a refined understanding of what constitutes EbA. Traditional approaches have focused on considering EbA as one of multiple alternative adaptation option. Alternatives include engineering solutions such as building concrete sea walls or a "retreat" strategy where coastal communities are mover inland to remove them from being exposed to climate related hazards.

From this perspective, EbA options harnesses ecosystem services to provide protection for people and human systems and can be selected from a menu of alternative strategies and options. Our research suggests that considering EbA as one of a number of alternative options limits its potential and application.

Rather, we now recommend that EbA is better understood not just as an option but an integrated, wholistic approach to adaptation. This interpretation embodies a much broader range of actions and, importantly, highlights the need to consider ecosystem services and social-ecological systems thinking in all adaptation decision making contexts.

Adopting the EbA as an "approach' enable its application to a wide range of adaptation problems. When considering climate risk and how to manage them, it is important to clarify the asset or focus of concern and that precisely is "at risk". Difference foci or 'adaptation entry points' can be identified. In the context of small island developing states these include (i) good governance, (ii) the integrity of ecosystems or built assets, (iii) the serviceability of infrastructure and (iv) community health and wellbeing. The EbA approach is relevant to all these focus as it aims to ensure the benefits to people and nature from ecosystem services is maintained and continues to contribute to climate resilient development.

8.2. How do the differing social and economic contexts in the Pacific impact the outcomes for ecosystems when selecting climate change adaptation responses in the coastal zone?

Exploring the context is critical in adaptation decision making. To unpack the role of social, economic, cultural and environmental contexts in supporting community wellbeing, work was undertaken to model climate change impacts and a series of proposed EbA actions at a range of different scales across Vanuatu.

This work, representing the synthesis of efforts across all theme areas within EcoAdapt, explores community wellbeing at the Port Resolution, Tanna Island, Port Vila and Vanuatu scales, enabling explicit evaluation of changes in social and economic contexts and their impacts on adaptation outcomes to be revealed.

Vanuatu is at a crossroads.

The risks from climate change, overlaid with development pressures and with a recently implemented Customary land Management regulation are a unique combination of factors that require systemic thinking and considerations in all development and planning processes.

Our research has explored how development pathways can further strengthen or weaken adaptation options and outcomes in Vanuatu, expanding on the current SES models, we explored future scenarios and outcomes driven by changes in climate change response, wealth, distribution of resources and a range of other policy-level changes that have been modelled as future pathways. Analysis to date reveals that changes in access to ecosystem services will be marked for communities across

Vanuatu depending on the development pathway selected. In essence, this work highlights where EbA has the most potential for supporting the integrity of ecosystems and community wellbeing and the degree to which the opportunity for EbA may be lost in a development focused industrialised world.

8.3. What information and decision support processes are required by stakeholders to adopt an ecosystem-based approach to adaptation?

EbA, at its core, explicitly seeks to link the integrity of ecosystems and the services they provide to the wellbeing of communities. As a result, understanding of the links between ecosystem services and communities is critical to supporting the uptake of EbA. While earlier work exploring barriers and limitations to the success of EbA highlight a range of conditions that can reduce the efficacy of EbA, the new conception of EbA as an approach, which seeks to embed EbA thinking into all adaptation decision making, simply requires the appreciation that ecosystems and human communities are intimately connected and supporting (and enhancing) service flows and provisions will lead to positive outcomes both for ecosystems and the communities that rely upon them.

We employed a range of participatory and collaborative methods to garner understanding from the perspective of the people involved on the ground – community members, local planners, national policymakers among other – which shed light on what the most suitable support processes and tools for this purpose. This question is therefore addressed more specifically in the following sections, reflecting the ongoing work to embed the research outputs into practice.

9. EMBEDDING EBA INTO PRACTICE: A SUMMARY OF KEY FINDINGS

The EcoAdapt project has generated a wealth of new knowledge, created change outcomes on the ground, and established important relationships and opportunities to build on the work of the project to continue to build capacity and embed scientific knowledge about climate risks, climate action and adaptation into the Vanuatu climate adaptation system as well as to transfer the lessons across other islands and Pacific SIDS.

A wide range of findings across the different streams and over the five years have been identified in each of the studies. The following high-level lessons and recommendations are synthesised from across the different research streams that would, if implemented, support embedding an EbA approach into practice.

Key Finding 1. Different adaptation 'entry points' will influence the capacity for ecosystem-based outcomes

Decision makers often bring their different perspectives to adaptation planning based on their purpose and objectives and particular climate risks they are seeking to address. These purposes lead to multiple different 'entry points' which frame the scope, activities and therefore outcomes of the adaptation intervention. Four common entry points for adaptation are managing risks to:

- good governance;
- the serviceability of built assets including capital works;
- community wellbeing and sustainable development; and
- the integrity ecosystems and species.

Adaptation decision regarding climate risks tot these different entry points may require very different kinds of interventions. Development pathways will structure and re-shape the capacity of the people and the ecosystems to adapt and respond to climate change threats for generations to come.

Some adaptation pathways that focus on the above points in isolation may modify the landscape leaving negative 'upstream' or 'downstream' legacies that are difficult or costly to change and reduce the opportunity for EbA, creating disconnections and loss of resilience in social ecological systems.

The research demonstrated that EbA is often a low-cost option over the long-term (and also often in the short-term) compared to engineering and infrastructure options, and provides multiple social and wellbeing co-benefits, which are commonly experienced as non-excludable common pool resources and public goods.

Recommendations 1

- Ecosystem protection, maintenance and restoration is given priority in all new development and adaptation planning decisions.
- Due consideration is given to long-term legacy of isolated adaptation projects and decisions

Key Finding 2. EbA as an integrated systems approach, goes beyond project-scale thinking

Adaptation is still commonly considered on a project-by-project basis for a particular area or situation. At a single intervention level, EbA can be considered one end of a nature-capital works spectrum, where interventions that maintain or improve the integrity and functioning of ecosystems and the services they provide are a primary objective.

It is recognised that each option may be appropriate in different places at different times, however, once infrastructure assets (e.g., roads, seawalls) are built, certain pathways may be locked in or out, reducing the capacity to undertake EbA activities in the future. By limiting adaptation planning to project-scale activities or by only looking at impacts in one of the four entry points (see point 1 above), opportunities to support long-term system-wide improvements are overlooked.

An EbA approach views adaptation through a social-ecological systems thinking lens that considers the interactions and interconnections within and across community, culture, governance, economies and ecosystems and considers how ecosystem services and community wellbeing are maintained or enhanced over the long-term. In considering what decisions to make, an EbA approach weighs up the costs and benefits

of particular options and impacts in combination as well as cumulative impacts over time and whether options in future are restricted because of choices made now.

Recommendation 2

- Adopt an EbA approach incorporating systems thinking in adaptation and development planning that considers influences and impacts across ecological, social and economic factors.

Key Finding 3. When it comes to adaptation, context is everything

Climate change impacts and adaptation options are highly specific to the context in which they are applied. Local, national and regional contexts - land, water, climate, people, and economies –all create unique situations which influence the options available in that context. In the case study area of Tanna and Vanuatu key influencing factors identified include:

- Vanuatu is at a crossroads. There is extreme pressure to develop infrastructure and economies, supported by international financing, that put pressure on natural resources and will undermine availability of ecosystem services to local people in the future without an integrated and systems approach to adaptation planning.
- Vanuatu is located in a high climate risk area, vulnerable to natural disasters including cyclones, floods and on Tanna an active volcano adds additional complexity - providing opportunities (for tourism) and constraints (affecting crop production)
- Tanna's coral reefs provide a multitude of services being affected by climate change of which the tourism and fishing industries are the most vulnerable.
- A highly unique governance arrangement sets the stage for adaptation - where customary land management - 'kastom' (decentralised and traditional) is recognised within the more centralised (Westernised) governance processes being imposed at the national level, this provides additional complexity but also opportunites for climate resilient planning and managememnt.

Recommendations 3

- Decision-makers draw on studies that work at the smaller, local scale, to identify the ecological, social, cultural, technological, political, governance and economic context in which climate risks, impacts and options for adaptation are situated.
- Mapping local to broader context and how the local systems interact and are shaped or reinforced with this setting as a foundation for understanding appropriate adaptation options and how they can be scaled up.

Key Finding 4. Establish local baselines and annual monitoring programs

Local baselines and monitoring are a foundation for evidence-based adaptation planning and decision-making. To empower local communities and governments to plan accordingly, based on evidence, a significant program of data collection and monitoring is needed to establish local baselines and monitor change over time. Much of the climate modelling is based on large scale regional and global models which do not give an accurate picture or projection of processes and impacts in particular places, therefore impacting effectiveness of decisions made based on this information.

Recommendations 4

- A significant program of appropriately designed data collection and monitoring is needed to establish local-scale processes and interactions at the island scale and to inform evidence-based decision-making.
- Monitoring programs should include capacity building of local people in new tools and knowledge to support their decision-making.
- Future scenario modelling at the local scale should be continued to better plan and implement effective EbA.

Key Finding 5. Complex climate-related risks and feedback loops are recognised and inform adaptation planning

Scenarios that consider not only the possible impacts of climate change, but how these interact and feed into one another will be important to consider the range of possible futures that may arise at the local level, given the local, regional and global factors at play. First, second and third order impacts may play out differently. Interactions and feedback loops between systems, such as community activities, policy initiatives, economic development activities and coral reefs, for example will be non-linear and difficult to measure, but it is necessary to build the knowledge base to understand

these multiples scales of impacts, shifts over time and cumulative impacts to be able to plan for possible future situations.

Recommendation 5

- Building on a good scientific and traditional knowledge base for adaptation, the complex interactions and feedback loops that shape future scenarios should be articulated and integrated into coastal and development planning processes.

Key Finding 6. Participatory processes are integrated into adaptation planning at all levels, recognising the importance of local culture in shaping adaptation

Collaboration between all relevant stakeholders can ensure that decision making processes support development of sustainable livelihoods. Particular emphasis should be on coastal adaptation and development planning informed by local people, that considers the values, perspectives, customs and interactions of locals with ecosystems. Given the localisation of climate change impacts and adaptation options this approach is a necessary foundation for identifying national policies and plans.

In Vanuatu and Tanna in particular, 'kastom' is a strong influence on how resources are used and managed and customary land management is recognised at the national level. Adaptation planning must integrate scientific understanding with local knowledge and management processes to find fit-for-purpose, fit-for-place adaptation interventions.

Recommendations 6

- Establishing local knowledge hub and online portals to support scientific studies plus utilising local knowledge and know-how is critical for building local capacity and social learning for EbA.
- Integrate diverse perspectives and knowledge into all aspects of projects through collaborative and participatory processes.

Key Finding 7. Capacity building activities and education programs accompany EbA activities

Given the importance of local communities in effective EbA, support through collaborative research programs, sharing of research findings, and education programs to build understanding of underlying issues and opportunities will be an important mechanism to support sustainable outcomes into the future. As highlighted during the pandemic, with restricted travel and support from external actors, supporting local government agencies, community groups, leaders and members to conduct their own assessments and evidence-based decision-making will be essential.

Building local community skills through training and breaking down barriers to access to scientific knowledge as well as facilitating dialogue between scientists, community members, civil society organisations and governments and community leaders should be part of any research program. Targeted programs can support community members with technical and scientific knowledge and researchers, government and other agencies with understanding local perspectives and management approaches. This collaborative and interdisciplinary approach is necessary for full impact to be realised.

Recommendations 7

- Education facilities and training programs are made available to local community leaders and members.
- Education pathways for professional development of planners and policy decision-makers build on the latest research findings.
- All scientific research projects incorporate and work with local and provincial governments to channel new knowledge into accessible formats and outreach activities

Key Finding 8. Identify and declare protected areas in collaboration with communities

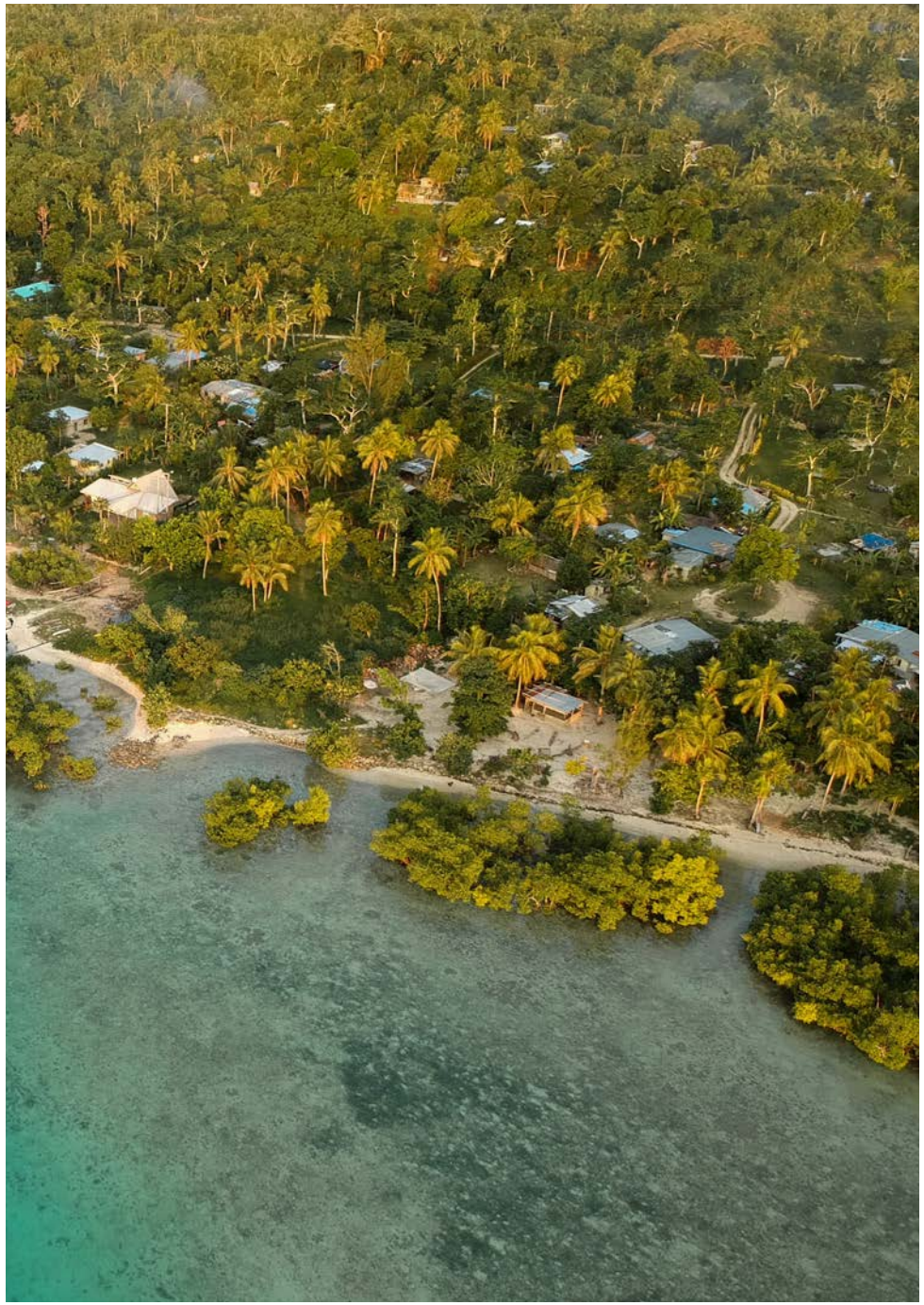
Declaration of protected areas, especially community conserved areas, is essential for maintaining the integrity of ecosystems and building resilience to coastal hazards and climate change impacts. For example, avoiding dredging and placing seasonal taboos that prohibit fishing enables fringing coral reeds to be protected and restored. Similarly, preventing land-based sources of pollution such as nutrients from sewage or fertilizers damage the reef helps maintain their natural resilience to climate impacts.

Healthy coral reefs in turn provide ecosystem services that benefit people. They absorb wave energy during storm events protecting local communities and provide a sustainable source of protein contributing to their food security. To be effective, protected areas need conservation management plans that work in collaboration with communities and provide them with opportunities for training, employment and sources of income. For example, management plans that involve communities

in monitoring biodiversity and guard against illegal uses help build local capacity and support.

Recommendation 8

- Identify suitable protected areas in collaboration with communities to ensure buy-in and long-term success of both protecting ecosystems as well as providing for sustainable livelihoods.



10. FUTURE DIRECTIONS AND ONGOING WORK

Although the EcoAdapt project has reached completion, the EcoAdapt team is continuing to try and work with other researchers and in-country partners in building the knowledge base of ecosystem-based adaptation in practice in Vanuatu, to embed this knowledge in practice and improve the uptake and integration of EbA principles in policy, planning and implementation of projects.

10.1. Stakeholder engagement activities

The EcoAdapt project involved a number of participatory processes to support different phases of research including data collection with communities through interviews, surveys and Q Method; stakeholder interviews, stakeholder input to and guidance on research methods and activities; and co-design of decision support tools have taken place throughout the life of the EcoAdapt project.

Figure 10.1: EcoAdapt Research team meeting with the representatives of the Tanna Council of Chiefs in Lenekal, November 2019.

During 2021-2022, the EcoAdapt team at Griffith University will continue to find ways to work with the key partners established through the project, including the TAFEA Provincial Government, National Government Office of Climate Change, Department of Water, University of South Pacific, Council of Chiefs (see Figure 10.2), and communities themselves to support uptake of and embedding an EbA approach to climate change adaptation in practice. We are looking to establish the Pacific EcoAdapt website as an online knowledge hub for local action on EbA in Vanuatu and work with the stakeholders to expand the work to other islands, as well as promote the research to the South Pacific Regional Environment Programme (SPREP) and the Melanesian Spearhead Group (MSG) to design a program of action research to roll out across the region.

10.2. Launching online portal and knowledge hub

The online portal is envisioned to be a platform for communicating research and knowledge from the EcoAdapt project and a tool for decision-makers and locals in Vanuatu to be able to learn about and support their activities. As already discussed in this report a public website has been created at www.pacificecoadapt.org (Figure 10.2) as a repository and online place for the EcoAdapt research outputs. We have involved the Tafea Provincial Government during development of the website and key decision support tools to ensure relevance to them. The site can now be communicated to a wider audience of key stakeholders including the national government and regional organisations, other researchers and civil society organisations working on ecosystem-based adaptation in the region.

There is an opportunity to build this into an online knowledge hub by creating a 'members area' where key stakeholders have access to data and tools that are not available to the general public. Further resources are needed to enable continuing content updates and maintenance of the site and to ensure all projects and activities operational in the province are being documented. This requires ongoing engagement

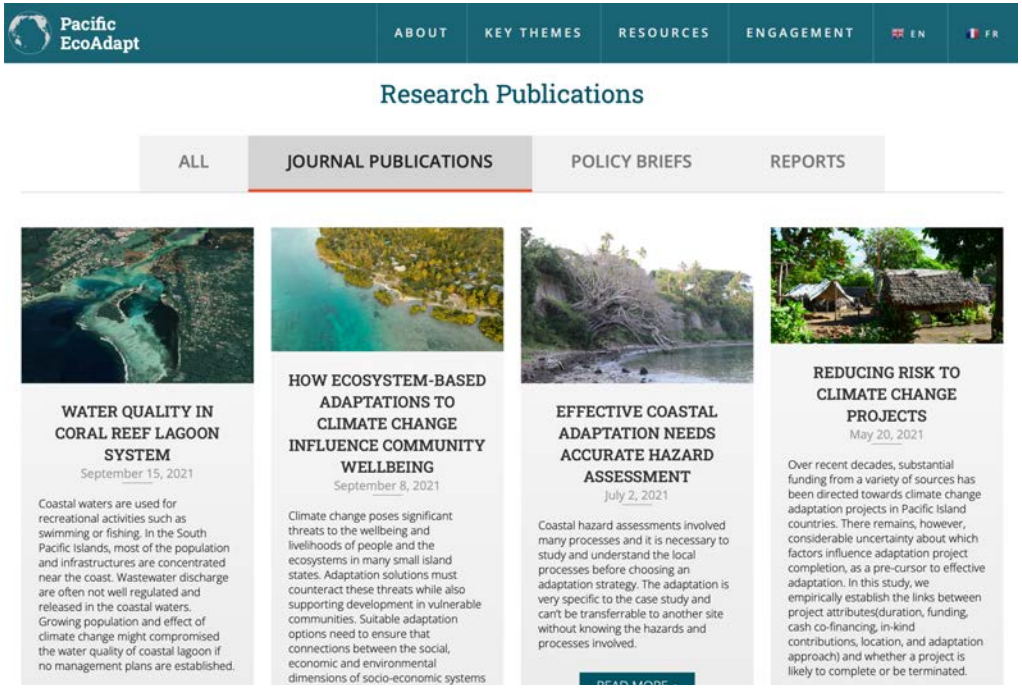


Figure 10.2: Pacific EcoAdapt Website example page screenshot.

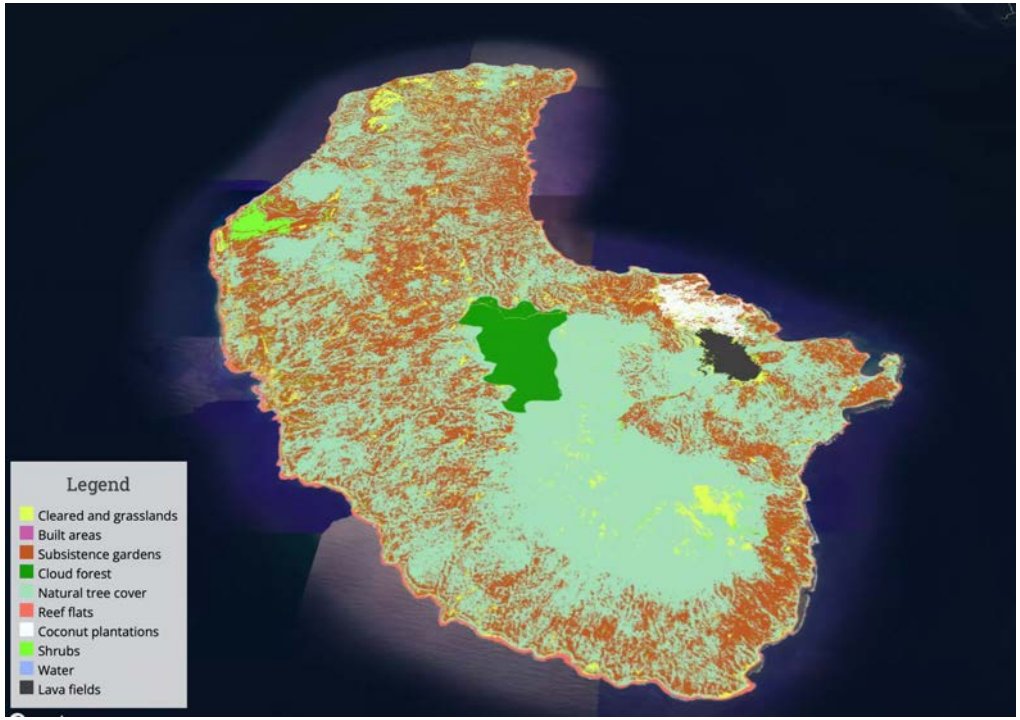


Figure 10.3: 3D visualisation of the new land cover map for Tanna Island.

with other international stakeholders working in the region to facilitate input of data and results of studies onto the site.

10.3. Decision support tools

A major challenge working in small island developing states is the gaps in the required scientific data the difficulty and expense of obtaining the data and information needed to support adaptation decision making. Over the course of this project, we have developed and applied methods for generating key data sets, including base line data for ecosystem assessments.

- *Monitoring the integrity of coral reef ecosystems* – we applied a method developed by Griffith University researchers for measuring and monitoring coral reefs. This method is straightforward and local community members, especially youth, can be readily trained to undertake these surveys and apply them on a regular basis.
- *Land cover map* – the "ridge to reef "approach that is essential for small islands requires accurate, high-resolution maps on the major land cover classes including natural forest, subsistence gardening, cash crops, and cattle grazing. Furthermore, these maps are needed in a digital format so that they can be used in a Geographic Information System (GIS) which is now a fundamental tool used for spatial planning. Unfortunately, conventional approaches to mapping land cover are expensive and require extensive ground-based measurements to be accurate. We have applied a new approach that used freely available time series satellite data and cloud-based computer analysis coupled to local expert knowledge (Figure 10.3).

This digital map was a key project output recommended by the Tafea Provincial Government Planners throughout consultation with them. Our method is able to utilise local knowledge of what is on the ground in particular locations. Therefore, the

digital map layer can be readily updated based on information the Provincial planners provide from their regular outreach field trips.

- *Dynamic coastal process simulation model* – the project has made a significant contribution to the Vanuatu's capacity to model the impact of climate related impacts on the coastal zone through the calibration of high resolution mathematical simulation models of coastal processes concerning near-shore currents, waves and water quality.
- *Integrated climate risk assessment tool for Eb*A - we are also now seeking funding to continue the development and application of our integrated climate risks assessment tool. This tool is based on: establish baselines conditions for the integrity of ecosystems; developing an understanding of the focal social-ecological system; involving local community and other stakeholders in formulating preferences and options; and taking into account different development pathways.

We have also generated a range of other spatial data for Tanna Island and Port Vila especially in the coastal zone. These data will be useful for the Provincial Government Planners and will be made available through the project web portal.

10.4. Training and capacity building

A significant need and opportunity have been identified to support capacity building within agencies in Vanuatu and on Tanna Island tasked with local land use, coastal, development and infrastructure, and climate change adaptation planning. Also identified were various mechanisms for supporting communities to plan for and undertake EbA. The EcoAdapt team will be seeking new financial support to conduct collaborative and appropriately targeted training and capacity building activities with key stakeholders.

10.5. Development pathways model

Ongoing work by the EcoAdapt team seeks to explore how development pathways can further strengthen or weaken EbA options and outcomes in Vanuatu. This work expands on the current SES model to explore future scenarios and outcomes driven by changes in climate change response, wealth, distribution of resources and a range of other policy-level changes that have been modelled as future pathways. Analyses reveal that changes in access to ecosystem services will be marked for communities across

Vanuatu depending on the development pathway selected. In essence, this work highlights where EbA has the most potential for supporting the protection and restoration of ecosystems as well as community wellbeing and the degree to which the opportunity for EbA may be lost in a development focused industrialised world.

10.6. Policy briefs

Key findings from our research have been 'translated' into short, accessible formats suitable for general audiences rather than academic audiences. There is potential to continue this process across a range of topics and findings from the research to support understanding and engagement with the research

10.7. Language translation of key resources

Literal translation of materials is another mechanism that would support engagement of the project resources and the website by Ni-Vanuatu and other users across the region. Bislama, French as well as 'plain English' translation of some of the highly complex scientific data could support further uptake of the information and research into practice.

10.8. Continued development of decision support tools

During the annual research symposium, a facilitated session was dedicated to identifying suitable decision support tools. These include coastal planning decision tree for EbA, short training videos suitable for community or government stakeholders,

There is significant momentum and potential generated by the EcoAdapt project that can be built on to facilitate knowledge into learning into practice as well as expanding the scope and application of the research to other communities and to encompass further topics and sectors. The EcoAdapt team will be actively seeking to continue this work with key partners and funding agencies.

MORE INFORMATION

See www.pacificecoadapt.org for further detail on the project and its outputs including links to associated publications.

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Final Report