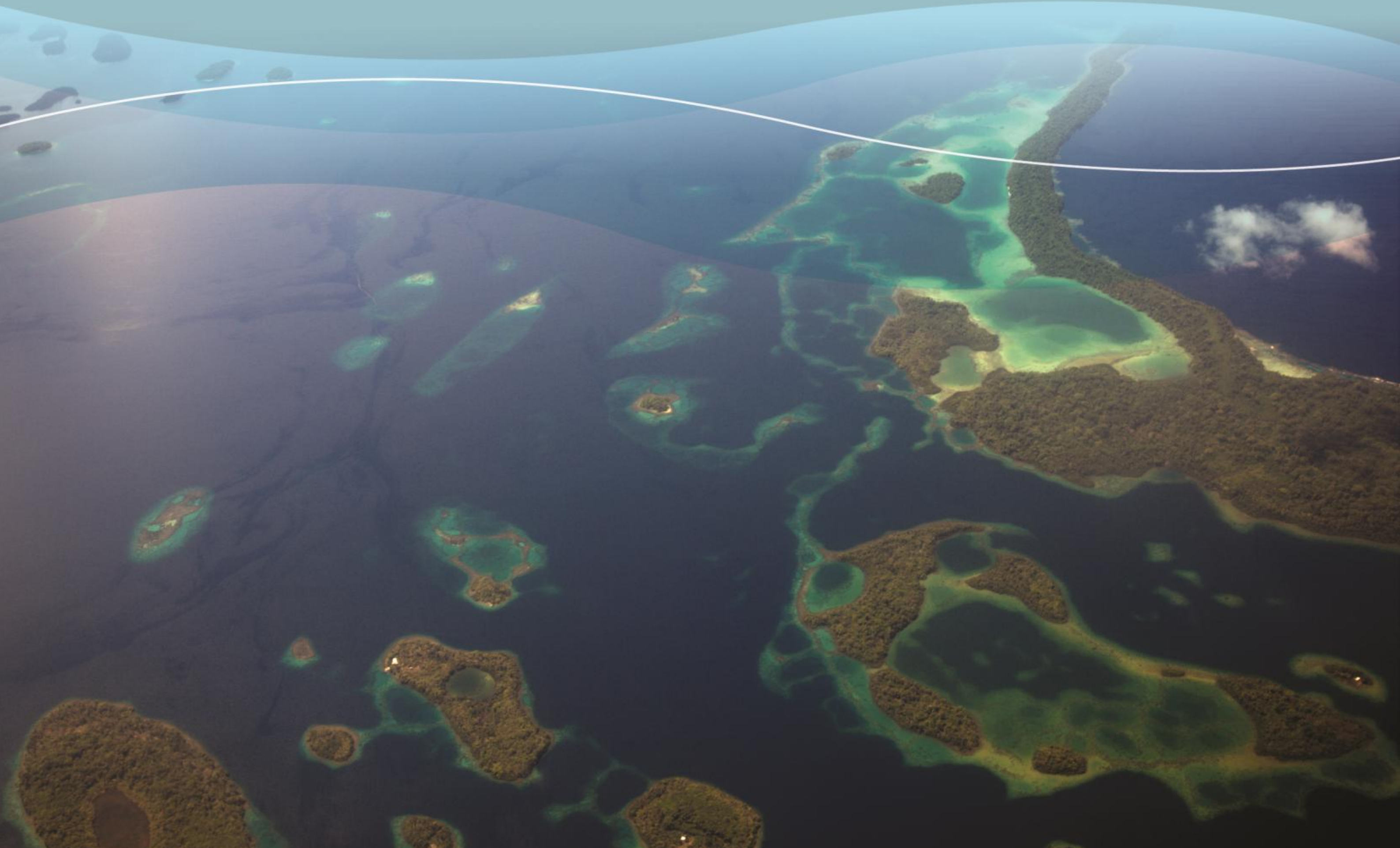
UNDERSTANDING THE COSTS AND BENEFITS OF CLIMATE ADAPTATION IN THE PACIFIC

Case Studies



Pacific Adaptation Scenarios (Cost and Benefits)

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Acronyms

AAD	Average Annual Damage
AEP	Annual Exceedance Probability
ARI	Average Return Interval
AUD	Australian Dollar
BCR	Benefit Cost Ratio
BoM	Australian Bureau of Meteorology
CBA	Cost Benefit Analysis
CePaCT	Centre for Pacific Crops and Trees
CHICCAP	Choiseul Integrated Climate Change Programme
CSIRO	Commonwealth Scientific and Industrial Research Organisation
ENSO	El Niño-Southern Oscillation
FAO	Food and Agriculture Organisation
HH	Household
ITCZ	Intertropical Convergence Zone
IPCC	International Panel on Climate Change
MCA	Multi-Criteria Analysis
M&E	Monitoring and Evaluation
NPV	Net Present Value
PACC	Pacific Adaptation to Climate Change
PACCSAP	Pacific-Australia Climate Change Science and Adaptation Planning Program
PICs	Pacific Island Countries
PV	Present Value
RCP	Representative Concentration Pathway
RDI	Recommended Daily Intake
SBD	Solomon Islands Dollar
SPC	Secretariat of the Pacific Community
SPCZ	South Pacific Convergence Zone
USAID	United States Agency for International Development
V&A	Vulnerability and Adaptation
VUV	Vatu Vanuatais
WHO	World Health Organisation
WPM	West Pacific Monsoon

EXECUTIVE SUMMARY

Traditionally, development policies and activities have been based on our understanding of the historical climate. Continuing to develop and implement projects without recognising the implications of the changing climate can result in substantial economic and social costs. To cost-effectively respond to climate change and other development challenges, decision makers require robust information and analysis to select the most appropriate adaptation options. Cost Benefit Analysis (CBA) is a framework that builds on information gathered from the investigation of climate change risks (including for example information on potential losses and damages) and on the same platform brings in the benefits and costs of adaptation options to manage identified risk. This allows evaluation of adaptation options in an objective and reliable way that also considers impacts on a community over time.

The Pacific-Australia Climate Change Science and Adaptation Planning (PACCSAP) Program aims to develop the capacity of Pacific Island Countries (PICs) to manage climate risks. Ultimately climate change adaptation involves the management of identified climate change risks. This project is a component of PACCSAP, and aims to increase the capacity of decision makers in PICs to make informed decisions on climate change adaptation using CBA. By investigating two case studies this PACCSAP project has tested the application of CBA for managing climate risks in the Pacific. The project has also highlighted some of the common challenges to applying CBA and has provided lessons to overcome these challenges.

In the first case study, CBA was applied to a food security project implemented in Choiseul Province Solomon Islands, by the Secretariat of the Pacific Community (SPC) and the United States Agency for International Development (USAID). Both qualitative and quantitative CBAs were used to analyse the net benefits of adaptation options aiming to improve food security (conservation agriculture, built-up contour terraces and vetiver contour terraces). The CBA demonstrated that certain adaptation options can provide net benefits to the community and help them to be better prepared for climate change impacts. The case study also highlighted the synergies between the analysis of climate change adaptation options and CBA, and some key challenges such as the lack of empirical data and lack of capacity of local stakeholders to undertake some of the key adaptation and CBA tasks. Through an active engagement with, and training delivered to local stakeholders these challenges were partially overcomes.

In the second case study a detailed CBA was applied to a Pacific Adaptation to Climate Change (PACC+) project implemented by Public Works Department (PWD) in North Epi Island (Vanuatu). The CBA considered the costs and benefits of constructing a new road and making the existing network ‘all weather roads’ with concrete slabs, drainage and culverts. These activities will improve accessibility in the island and reduce the current vulnerability to landslides, extreme rainfall and storms. The CBA demonstrated the net monetary benefits for the transport and agricultural sectors. Benefits to the health, education and employment sectors were also identified, however, these could not be monetised due to a lack of data. Despite the diversity of environments and the different project types investigated in the Solomon Islands and Vanuatu, applying CBA in a climate change context has yielded some common lessons:

- CBA can be used to weigh up the costs and benefits of large or small projects. For large projects with sufficient data, a quantitative CBA can be undertaken. For small projects or when significant data gaps exist, a qualitative CBA can be performed.
- CBA and the analysis of climate change adaptation options can be complementary and combining them can result in greater effectiveness and more robust decision outcomes.
- Data required for CBA can be generated by utilising existing information, drawing on technical or regional experts and the knowledge of local communities.
- Communicating the results of a CBA is equally important as undertaking the analysis, particularly from the perspective of raising the profile of the practice and building regional capacity.
- CBA is best incorporated early in the project process. This provides the time to consult with stakeholders, collect data and appropriately inform a final decision.
- The CBA framework helps to identify knowledge gaps about the impacts of climate and non-climate risks and the expected benefits of adaptation.
- The application of CBA and climate change adaptation remains limited in the Pacific. Additional time and resources need to be dedicated to build the capacity of local technical staff to support and conduct CBA of climate adaptation options.

INTRODUCTION

This Project

The PACCSAP program aims to develop the capacity of PICs to manage climate risks. The Pacific Adaptation (Costs and Benefits) Scenarios study is a component of PACCSAP, and aims to increase the capacity of decision makers in PICs to make informed decisions using CBA.

This report can help to inform climate resilient development in PICs through economic analysis of impacts and adaptation options in priority development sectors, in response to a range of future climate change scenarios. The main outcome of economic analysis for climate change adaptation options will be to provide information and insight to ensure adaptation measures are taking into account climate risk. The intended audience is country decision makers, regional organisations and other donors who support decision making processes.

In addition to this report a Summary for Policy Makers has been prepared to summarise/explain key steps in the CBA process, and more generally, raise awareness of how and why CBA could be used to manage climate risk.

Under this PACCSAP project two training sessions (one in Vanuatu and one in Solomon Islands) were also delivered to local stakeholders; the vast majority of the training attendees were employees from both countries' government agencies in the finance, environmental, agricultural and infrastructure sectors. The training sessions focused on CBA and climate change adaptation (including risk management).

CBA Framework to Inform Adaptation

CBA and the analysis of climate change adaptation options can be complementary and combining them can result in greater effectiveness and robustness. A structured analysis of potential risks posed from climate change involves identifying, analysing and evaluating climate risks and possible risk treatments (or adaptation options). This structured analysis enables practitioners and decision makers to focus on and prioritise the most threatening risks. It can also help characterise loss and damages (risk consequences) which can then be monetised to inform the economic analysis.

CBA is a tool to assess the costs of the impacts and compare them with the expected costs and benefits of the adaptation options. Both frameworks provide consistent analytical guidance, allowing better comparison of results and replication.

CBA can be used to select the adaptation option most likely to generate highest returns net of costs (*exante* CBA), prior to implementation. CBA can also be undertaken following project implementation and can be used to assess and report on the impact of an adaptation project, (expost) often useful in project replication and advocacy efforts.

Further details on the methodological concepts and tools are presented in Section 1.0 of this report.

Structure of this document

This document is aimed at practitioners seeking to apply CBA for climate change adaptation problems. It is primarily aimed at practitioners in PICs, but the concepts can certainly be adapted for use in other settings. The report provides a combination of methodological explanations and guidance (Part I), two case studies illustrating how these various tools and principles have been applied in a project context (Part II and Part III) and lessons learnt in relation to the application of CBA for climate change adaptation in the Pacific (Part IV). Appendix A and Appendix B provide some templates that can be used to undertake CBA for managing climate risk. Appendix C and Appendix D present some of the detailed information associated with the Solomon Island case study investigating food security.

Rather than duplicating existing guides on CBA[1] this document aims to focus on the application of CBA for climate change adaptation. Therefore this document provides limited background information on CBA and how to undertake the tasks informing a CBA.

The general structure of the document is shown below.

Part I – Methodology and Application	Provides an overview of the methodology used to apply CBA in a climate change adaptation context. This includes direct instructions on applying the various tools and concepts.
Part II – Solomon Islands Case Study (Food Security)	Illustrates both qualitative and quantitative CBA of a food security activity for communities in Choiseul Province.
Part III – Vanuatu Case Study (Infrastructure)	Illustrates how CBA is applied to infrastructure improvement activities in Epi Island (Shefa Province) through a quantitative CBA.
Part IV – Lessons Learnt	Synthetises the various lessons learnt identified through both case studies.
Appendices	Detailed information for climate change impacts on crops and agro-forestry species. The Appendices also include a template for climate risk management and CBA. These tools are referenced with the guidance material in Part 1 (methodology) where relevant.

[1] Such as the *Cost-benefit Analysis for Natural Resource Management in the Pacific*, Buncle et al, 2013, published by PREP/SPC/PIFS/Landcare Research and GIZ and GIZ, and *Informing-climate resilient development: the application of cost-benefit analysis (CBA) in the Pacific Adaptation to Climate Change (PACC) Programme* : experiences and lessons learned in the application of CBA to PACC demonstration projects / Aaron Buncle – Apia, Samoa : SPREP, 2013.

PART I
METHODOLOGY AND APPLICATION

Australian Aid

1.0 METHODOLOGY AND APPLICATION

1.1 Overview

This methodology has been developed to guide informed decision making on climate change adaptation in any sector or country context. A range of CBA guidance materials already provide information/ instruction on how to conduct CBA in the Pacific. For example, the SPREP/SPC/PIFS/Landcare Research and GIZ 2013 CBA guide provide extensive details on the way to conduct CBA in the Pacific (without a focus on climate risk management). The methodology presented here seeks to highlight how aspects of CBA can complement decision making associated with the selection of climate adaption option options to manage priority climate risks.

As previously mentioned, CBA can be used as a tool to assess the costs of the impacts of a baseline or "business as usual scenario" and compare them with the expected costs and benefits of adaptation options – creating a level playing field for evaluation and decision making to occur. While the approach presented here covers a range of activities required to comprehensively assess climate change risks, it focuses on the incorporation of CBA into a structured investigation of climate risks and associated options to manage priority risks. The approach has been tested and adjusted through two case studies investigating food security in the Solomon Islands and critical infrastructure in Vanuatu.

The methodology outlined in this document is replicable and applicable for:

- Identifying, assessing and prioritising the risks arising as a result of climate change impacting communities, activities, natural and built assets and services.
- Understanding the costs associated with these key risks (the "cost of doing nothing").
- Identifying and short listing a range of adaptation measures.
- Assessing the likely costs and benefits of each shortlisted adaptation measure through the application of CBA.

The proposed approach draws on classic risk management, and associated techniques to manage climate risk. The framework is articulated around four overarching elements: situation analysis, problem analysis, solution analysis and decision making. Figure 1 (below) is a stylised example of the costs involved in managing climate risk. Over time, the impacts of climate change are expected to result in greater costs as a result of loss and damage, however with the right adaptation some of the costs can be reduced or avoided. It outlines the cost of doing nothing in the face of a changing climate, and the benefits of adaptation.

Figure 1 Conceptual diagram of cost implications in a climate change context (AECOM 2012)

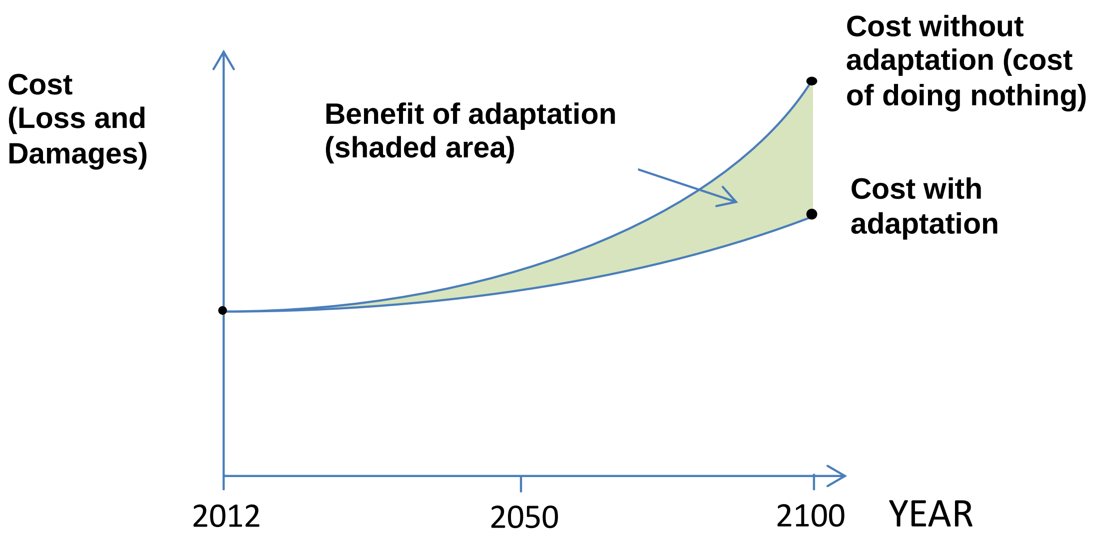

Figure 2 provides an overview of the process, including the key stages, and the required information to complete each stage. It can be used as a quick reference checklist to make sure that all of the key steps have been completed, and the required information has been gathered and processed. The process assumes that an overarching need has already identified to investigate a problem associated with climate change, for example increasing losses associated with extreme weather events, or concern about the ability maintain transport connectivity in the face of increasing coastal erosion.

Figure 2 CBA for climate risk management

Situation Analysis should include:

- An assessment of the weather and climate driven hazards
- An assessment of the social and economic, and biophysical conditions relevant to the project, or area under investigation.
- Historical trends and current status of key climate parameters
- Future climate projections to provide: the state of the environment for the project, and how it is likely to change over the life of the project.

The **problem analysis** is aligned with a risk based approach and using a defined risk framework (e.g. see Appendix A) should:

- Identify, analyse and finally prioritise the key risks posed by climate change.
- Identify the types of costs that would stem from these risks.

This stage is frequently overlooked, which can lead to adaptation investment decisions that do not address the most threatening risks.

Solution analysis involves:

- Identifying and assessing adaptation options for priority risks
- Identifying the likely costs and benefits, if these options are implemented.
- Compiling a shortlist of adaptation options.

Typically, the benefits of any given adaptation option should be greater than the potential cost of the risks being managed.

The **Decision Support** or **Review** stage (either before or after project implementation) should include:

- Assumptions and other information used to estimate the costs and benefits of each option, including a description of non-quantified factors;
- Sensitivity of the outcomes to changes in key assumptions e.g. different climate scenarios, or changes in the costs of key inputs;
- A matrix showing who receives the benefits from the project and who incurs the costs;
- The results in summary form of the cost benefit and risk analysis undertaken to arrive at the present value of each option.

Together these stages of analysis contribute to an informed decision on the most appropriate response to climate change. Each stage is broken down in steps and activities (described in further detail in the following sections.).

1.2 Step 1: Situation Analysis

1.2.1 Weather and Climate Hazard Assessment

Purpose and objectives

To (i) characterise current climate patterns, (ii) determine historical patterns of weather and climate driven natural hazards and (iii) understand likely climate scenarios for the area and how these changing climatic variables are likely to alter weather and climate driven natural hazard patterns (for later use in the Problem Analysis).

Key activities

- The available climate data obtained from local weather monitoring stations characterises the **current climate**. This includes identifying seasonal patterns of temperature, rainfall and other key climate and climate-driven variables (e.g. sea level).
- Collect and analyse **historical patterns** to identify key changes to climate. Ideally, this analysis should be based on a continuous dataset covering at least a 30-year period. Information on natural hazard patterns should be collected and analysed with consideration of frequency, intensity, seasonality, latitudinal and altitudinal range of hazards as well as exacerbating and triggering factors. This analysis should provide a comprehensive assessment of the weather/climate natural hazards occurring in the region.
- Obtain **future climate projections** and climate scenarios relevant to the area being considered. To ensure that there is an 'internally consistent future scenario'; climate projections should be collected from the same modelling exercise and should not be assembled from different sources. Ideally this analysis should also include an assessment of the likely changes in terms of weather and climate driven hazard patterns. The emission scenarios, climate models and modelling techniques should be clearly documented.

Data required

- **Current climate observations** to determine existing climate patterns. This includes mean and extreme air temperature, mean and extreme rainfall, potential evaporation and relative humidity.
- **Historical information** on weather and climate related hazards, such as droughts, floods and cyclones. A range of data can be used to determine hazard patterns; the most common are frequency and intensity of hazards.
- **Future climate projections and climate scenarios** generated for the area under investigation. The climate scenario should be developed according to the expected design life of the project; e.g. for project activities being designed and implemented for the short (5 years), medium (10-20 years) or long term (20-100 years). If the project is only designed for the short or medium term, it is recommended to use the RCP (Representative Concentration Pathway) 8.5 scenario. For long term projects, it is recommended that two RCP scenarios (RCP 8.5 and RCP 6) are used to account for a range of plausible futures.

At the end of this process practitioners should be able to summarise the observed and projected values for different climate variables of interest. Table 5 in the Solomon Islands Case Study provides an example of how one of these summary tables can be presented.

Where to obtain information on past, current and future climate?

http://www.bom.gov.au/climate/pccsp/ Portal providing historical information on observed weather and trends for the Pacific, including temperature, rainfall and various extreme event indices.

http://www.bom.gov.au/cyclone/history/tracks/ Portal providing historical information on tropical cyclones in the Pacific.

http://www.pacificclimatechangescience.org/ Website providing research reports and web based tools on past and future climate change including country specific information.

Try to contact the department or service of meteorology from your own country.

1.2.2 Socio-economic and Biophysical Condition Assessment

Purpose and objectives

Provide a base of information to conduct the subsequent analysis by characterising the key aspects of local socio-economic and biophysical systems. Ideally, the assessment includes a description of the current status of demographic, economic and population information as well as any identified trends in key characteristics.

Key activities

- Collect and analyse published data on **socio-economic** systems. Additionally, primary data collection can be organised if available information is scarce. This typically includes consideration of:
    - Demography
    - Health
    - Economic activities, employment, industry and income sources
    - Culture
    - Livelihood systems
    - Governance and institutional arrangements.
- Collect and analyse published data on **biophysical** systems. This typically includes a consideration of:
    - Ecosystems
    - Water resources
    - Soil and topography
    - Known threats (pollution, habitat destruction, invasive species and over-exploitation)
    - Current conservation mechanisms.
- Provide environment-specific data (e.g. coastal, lagoon, rainforest, etc.); this task sometimes overlaps with the natural hazards analysis (completed in Section 1.2.1). For instance, characterisation of coastal hazards would typically include a comprehensive description and analysis of the coastal environment.

Data required

Data required is as listed in the above key activities, with National census information (if available) being a useful starting place for the types of information needed.

How can you obtain data on social, economic and environmental conditions?

Most countries have census data either available online or through a request to the relevant agencies. This will provide you with detailed information on local demographics, employment and other statistics.

The health department is likely to also have health data on local communities; this can include hospital admissions, prevalence of disease and other baseline health conditions (such as malnutrition). The WHO (World Health Organisation) might have done previous assessments or collected relevant data; try to visit the WHO website or contact the WHO country or regional officer.

Previous reports and projects undertaken in the area or the broader region can also be provided to you with relevant background information. All these existing sources of information can be complemented by targeted primary data collection such as:

- A household-targeted survey to collect specific information, including livelihood system profiles, health conditions, food and agriculture practices, employment and sources of revenue, water and sanitation, etc.
- Technical survey and modelling work such as fauna and flora surveys and coastal morphology assessment.

In all instances, engaging with the community and local stakeholders will help to complement existing information.

1.3 Step 2: Problem Analysis

1.3.1 Define the Risk Framework

Purpose and objectives

To define the risk framework (if one does not already exist) that will be used to assess and evaluate risks posed by climate change.

Key activities

- Determine in consultation with key stakeholders, a risk management framework. Climate change risk is typically analysed as a function of the associated consequences and the likelihood of occurring risks. A description of the different levels of likelihood and consequences resulting in various levels of risks provides a consistent analytical framework to assess risks and compare them.
- Identify key stakeholders in managing risks, and collectively define a 'risk appetite' by describing which ones are acceptable and unacceptable. An example of a risk management framework is provided in Appendix A. These examples can be used as a template to prepare a risk management framework for your organisation or project. It also provides general guidance for the risk management process as described in Sections 1.3.2, 1.3.3 and 1.4.1.

Data required

- Existing risk management framework used in the country (if any).
- Any information that could help to establish a risk management framework; this could include strategic management and development plans.

Risk Framework – What does it look like?

Risk is characterised through the likelihood of the risk occurring and the consequences if the risk occurs.

A risk management framework aims to provide a consistent and replicable analytical framework to analyse risks. It provides a common definition of consequences and likelihood. Risk is often expressed as a product of the likelihood of the risk occurring and the expected extent of its consequences. Therefore, consequence is a function of vulnerability (sensitivity to a particular impact or consequence and adaptive capacity to respond and deal with the effects).

1.3.2 Identify and Analyse Risks

Purpose and objectives

By looking at the potential effects of climate change on socio-economic and biophysical systems (from Step 1 Situation analysis), this step aims to identify the range of risks to be considered, and analyse their significance.

Key activities

- Provide a discussion on the past and current risks, as a result of climate and weather events. Climate change typically makes existing risks worse rather than creating new risks, therefore an understanding of previous or current risks is an important component of the problem analysis. The range of risks should be based on the situation analysis; the identification of interactions between social and economic factors, biophysical systems and climate/weather events, and should be translated into risk scenarios for subsequent analysis.
- Prepare each risk considered in a “condition – consequence format”, in other words, given a certain condition (e.g. extreme rainfall event) a certain consequence could result (flooding, damage, etc.). The detailed risk analysis then uses the risk management framework identified in 1.3.1 as an analytical tool and the situation analysis in Step 1 as inputs to assess each risk in detail. The likelihood and the consequence of the risk should then be assessed, to come up with an overall level for that risk (see Appendix A for templates and further guidance on this process).
- Compile a long list of risks scenarios, describing how climate change impacts influence the likelihood and consequences of each risk, and the level for each risk.

Some tips when identifying, analysing and prioritising risks

Risk analysis is almost always subjective; conducting risk analysis as a group (e.g. in a workshop) will help remove some of the individual perceptions and bias.

Climate change has the potential to affect both likelihood and consequences; you can define likelihood and consequences either in quantitative or qualitative terms. If there are multiple consequences, choose the worst one for the rating but document all the consequences. You need to consider the wider consequences, not just the immediate consequences, for your project. If two risks have the same level, consider their consequences in order to prioritise them. Responses should focus on the most threatening risks. Some of the risks might require further investigations.

Data required

- The assessment draws on a wide range of data sources including national and regional data bases, technical publications, peer-reviewed literature and evidence collected from consultation with key stakeholders.
- Primary data collection is required if limited available data is identified during the situation analysis.
- In some cases detailed information on climate and weather events may not be available due to a lack of information. In these cases, it may be possible to use information collected first hand from consultation with local communities and stakeholders.

1.3.3 Prioritise Risks

Purpose and objectives

To identify which risks are the most threatening and require adaptation options to be implemented.

Key activities

- Review the list of risks, discuss and agree on the risks requiring treatment, and then prioritise from the most threatening/least acceptable to the least threatening/most acceptable risks. Some of the risks can be grouped into broader risk situations (for instance, when several risks have similar sources and consequences, and are likely to be addressed by the same risk treatments).

Data required

Outputs from the detailed risk analysis, describing likelihoods and consequences for each risk, and the resulting risk level for each.

1.3.4 Understanding potential costs associated with the risks (loss and damages)

Purpose and objectives

Identify the likely loss and damages associated with key risks in the detailed analysis – the cost of doing nothing.

Key activities

- Use the information collected in the Situation Analysis to consider the frequency and intensity of different weather and climate hazards and where possible, calculate the costs of these hazards. In some cases historical information can be used to approximate potential costs (for example knowing the cost of damage from a previous Category Three cyclone). In other situations where high quality data and historical information is available, it may be more feasible to quantitatively develop these costs.
- Settle on costs for different events, and agree on the frequency of each event, so that for each key risk, there is consistent information that can be fed into CBA. For example a bridge over a certain river may suffer from minor flooding once a year after intense rainfall. The cost to repair this bridge can be calculated, or may be known from previous years. If that particular rainfall event is projected to become more frequent as a result of climate change, then a clear cost of climate change and cost of doing nothing can be established.

Data required

All of the information required should be available from the previous stage, including data on past weather and climate-related hazards, records for costs of damages and losses associated with previous hazard events, information on frequency and intensity of weather, and climate-related hazards (for example, a project area experiences one cyclone every ten years on average).

1.4 Step 3: Solution Analysis

1.4.1 Identify Adaptation Options

Purpose and objectives

To identify adaptation options for priority risks that need to be managed.

Key activities

- Review existing management practices and risk control measures; this can include formal and planned practices as well as informal and individual practices.
- Collect information on the possible adaptation options in the short, medium and long term. Where possible, look for examples in the region that have been successfully used to manage similar issues.
- Document the options under consideration and any relevant details about them (cost, material requirements, community acceptability, feasibility, etc.). This information can then be used to help shortlist options.

Data required

The points below provide a range of aspects to consider and document for each potential adaptation option. Typically these points would be used to either select a preferred option, or rule out unacceptable options, and on this basis the information is being collected to assist in shortlisting potential options (see next step). This list is not exhaustive, and it may be that information is not available for all aspects; however it is best to try and collect information on the same aspects for each option, to allow easier comparison.

- Will the community and stakeholders like the option?
- How effective would the option be compared to other options?
- How easy is it to build or setup compared to other options?
- What are the long term maintenance requirements?
- When would the option start?
- When does it become effective?
- What does it cost?
- Who benefits from the option?

1.4.2 Shortlist Adaptation Options

Purpose and objectives

Where there is a long list of potential options, this step can be used to refine a shortlist of adaptation options for implementation (two or three options).

Key activities

- Discuss the merits, obstacles and negative consequences of each adaptation option with the aim of identifying the most appropriate options for implementation. This discussion can be strictly qualitative and undertaken without the use of an analytical framework, and without being documented.
- Try to identify any particular issues that immediately make an option unfeasible, for example unacceptable environmental impacts, a lengthy period before it becomes effective, or prohibitive and unrealistic cost.

A number of approaches to shortlist are available, including decisions strictly based on specialist and experiential judgment, and not including detailed analysis and justification. Where a combination of quantitative and qualitative information is available, a common practice to shortlist options is using some scoring mechanism based on a Multi-Criteria Analysis (MCA) (see box “What is Multi-Criteria Analysis”); the list of factors mentioned in the ‘data required’ of Section 1.4.1 can be used to determine relevant criteria.

What is Multi-Criteria Analysis (MCA)?

MCA is a comparative assessment of options, taking into account several simultaneous criteria. It is mainly used to assess impacts that either cannot be readily quantified in monetary terms or at stages of development options; where detailed cost implications have not yet been developed.

The advantage of MCA is that it accounts for environmental and social impacts which cannot be quantified or cannot easily be assigned monetary values. In the context of refining a long list of potential options under consideration, MCA can be used to rank options and to shortlist a limited number of options for subsequent detailed appraisal, or simply to distinguish acceptable from unacceptable possibilities. The objective is to determine the performance of a number of options to a set of criteria for different relevant options.

The disadvantage of MCA is that it does not provide easy comparison of projects when multiple benefits arise, it is subjective and may lead to considerations of inappropriate trade-offs.

Data requirements

Information on the adaptation options (see previous step for a likely range of relevant aspects).

1.5 Step 4: Decision Support and Decision Review

Purpose and objectives

Use CBA as a decision support tool to determine whether the benefits of an adaptation option outweigh its costs, and by how much relative to other alternatives. The purpose of this is to:

- Determine whether the adaptation option is (or was) a sound decision or investment; and/or
- Compare alternative options, and make a decision on the preferred option.

Key activities and data required

- The *Cost-Benefit Analysis for Natural Resource Management in the Pacific – A Guide*[2] provides a comprehensive and user-friendly guide to CBA, with a focus on application in the Pacific. To avoid duplication, this guide is put forward as the standard reference for CBA, and practitioners should refer to it for any detailed questions relating to CBA. The following discussion is based on the approach put forward in the Guide.
- All of the previously collected information and analysis will help to determine if and adaptation decision is a sound investment (or in the case of decision review, whether it was an appropriate option for implementation). Broad objectives for adaptation decision making can be derived from the results of the **Situation Analysis** and the **Problem Analysis**. The **Solution Analysis** forms the basis of the options to be considered in the CBA. The Guide sets out a number of key steps to complete a CBA, including:

    1) **Identifying the costs and benefits** of each option, and also a base case (without adaptation) over a fixed period of time into the future. This information can be sourced from the costs of doing nothing (see Section 1.3.4), and also the key information documented for each adaptation option (see Section 1.4.1).

    2) **Valuing the costs and benefits**, by attaching financial values to the costs and benefits documented in the previous step. Where costs or benefits cannot be monetised, practitioners should clearly document the information that is available to assist in making a decision; this might be, for example, the information collected in Section 1.4.1.

    3) **Discounting the benefits and costs projected into the future to the present year**. This allows each option to be compared on a level playing field. The discount rate to be applied will be a rate appropriate to investment impacting intergenerational issues, particularly those involving environmental impacts. The Guide presents a range of considerations that are relevant when applying a discount rate, and depending on the project and the source of funding, a number of different discount rates could apply.

    4) **Testing the confidence in the results**. Many different sources of uncertainties may be experienced when conducting CBA, including data errors, missing data, or out-of-date information. Uncertainties may also arise due to poorly understood scientific knowledge about future climate conditions, and their expected consequences. The Guide identifies a number of more advanced CBA techniques to provide even greater confidence in the results, these include Sensitivity Analysis, applying different discount rates, dealing with uncertainty, and scenario modelling.

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[2] Cost-benefit Analysis for Natural Resource Management in the Pacific, Buncle *et al*, 2013, published by PREP/SPC/PIFS/Landcare Research and GIZ and GIZ

5) **Documenting and reporting the process and outcomes** so that decision makers, community members and other stakeholders can review the basis on which decisions around adaptation are being made. In addition, the reporting should include:

   a) Assumptions and other information used to estimate the costs and benefits of each option, including a description of non-quantified factors.

   b) Sensitivity of the outcomes to changes in key assumptions.

   c) Matrix showing who receives the benefits from the project and who incurs the costs.

   d) The results in summary form of the cost, benefit and risk analysis undertaken to arrive at the present value of each option.

At times, the scale and scope of climate change adaptation intervention may be too small or empirical data is not available to warrant a detailed assessment of costs and benefits in monetary terms. A CBA framework can still be used in such circumstances to make informed decisions. This includes comparing options based on available information about the costs of doing nothing ('business as usual') and the cost savings expected from implementing options. Such a comparison will be done using qualitative and/or quantitative information, adopting a 'with and without' cost analysis, together with the cost of the initiative.

Conclusion:

CBA is used in a range of fields outside of climate change risk and adaptation management. The methodology outlined here, through the **Situation Analysis**, **Problem Analysis** and **Solution Analysis,** generates the majority of inputs that are required for a CBA (the **Decision Support**). At the same time, it provides rigour in determining the key risks that need to be managed from a climate change adaptation perspective. The methodology highlights the complimentary nature of a combined climate risk management and CBA process.

CBA can also be used to facilitate a **Decision Review**, whereby the same process is used with updated information after a project has been completed (typically on costs as implemented and benefits as observed). The process can provide an indication on the merits of investment decisions made for climate adaptation, and further inform future climate adaptation work that may be undertaken elsewhere.

PART II
CASE STUDY 1: FOOD SECURITY IN THE SOLOMON ISLANDS

Acknowledgements

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2.0 FOOD SECURITY IN THE SOLOMON ISLANDS

2.1 Introduction

2.1.1 About this Case Study

This Solomon Islands case study demonstrates the application of CBA to food security interventions in a changing climate. The case study includes a qualitative and quantitative evaluation of options to address food security concerns (*exante* CBA) as well as a quantitative review of effectiveness of options post implementation (*expost* CBA). The case study follows the approach outlined in the methodology section (Section 1.0) as shown below:

Section 2.2 provides an overview of the current situation in terms of community profile, food security profile, past and future climate trends for both the Sepa and Loimuni communities in Choiseul Province.

Section 2.3. Describes the potential food security impacts impacts associated with climate change through the identification and analysis of key climate change risks on.

Section 2.4. Presents the food security improvement activities implemented under the SPC-USAID project.

Section 2.5. A qualitative application of CBA to select agroforestry based farming activities relevant to two communities (Sepa and Loimuni), using cost effectiveness and feasibility decision-criteria (**qualitative *exante* CBA**).
Section 2.6. A quantitative CBA to assess economic viability of the improved agroforestry measure selected by the SPC-USAID project (**quantitative *exante* CBA**)

Section 2.7. A quantitative CBA of a food security demonstration initiative implemented by SPC-USAID project in Sepa **(quantitative *expost* CBA).**

NOTE: Unless otherwise states all monetary value in this case study are expressed in Solomon Islands Dollar (SBD).

2.1.2 Food Security

Food security is a major concern for the Solomon Islands, as it is for the rest of Pacific. There are many different components to food security as defined in Table 1.

Table 1 Five Pillars of food security in the Pacific (SPC, 2011)

Pillar	Definition
Adequacy	Enough food sourced from own production, local and imported food bought from outside sources, food gifts from family and friends.
Availability/Access	Ability of households and individuals to acquire food
Stability	Resilience of food supplies to external shocks, such as natural disasters, and economic conditions such as inflation, exchange rates and markets and trade
Utilisation	The ability of household level to utilise foods, which generally depends on human development condition of the household
Safety and Nutrition	Freshly prepared and or preserved foods for healthy diet.

The relative importance of each factor in determining local food security status varies between households, community and countries. Food security is affected by meteorological and climatic risks (e.g. cyclones, droughts and floods). Non-climatic risks associated with increasing population, land availability, poor farm management and unsustainable catchment management also impact local households food security conditions.

2.1.3 Climate change Adaptation - SPC-USAID Project

The Choiseul Province is the westernmost province of Solomon Islands with about 500 communities and just over 26,000 inhabitants (see Figure 3).

Figure 3 Location of Choiseul Province (Google Earth 2014)

In the Choiseul Province, food security challenges are severe. Many development partners, including SPC-USAID, under Choiseul Integrated Climate Change Programme (CHICCAP) are supporting local communities to implement specific climate change adaptation initiatives directly targeting crop production system. These initiatives also indirectly aim to improve income levels. SPC-USAID is undertaking demonstration projects in Sepa and Loimuni focussing on improving food security to increase preparedness for climate change. Sepa and Loimuni villages are located on south-western and northern sides of the Choiseul Province. Loimuni is located close to the town of Taro, the capital of Choiseul Province (see Figure 4). Sepa on the other hand, can only be reached by sea from Taro and thus transport is a major limiting factor in getting to local markets.

Figure 4 Choiseul Province communities and location of Sepa and Loimuni (from SPC/SPREP/USAID/GIZ 2013)

Geographically the two communities differ in terms of their reliance on flat and hilly lands for gardening, and thus their susceptibility to climatic risks. Almost 50% of the Sepa households have their gardens on both flat lands on river banks as well as hilly areas; gardens on flat lands are prone to flooding whereas hilly lands are susceptible to soil erosion and landslides during heavy rains (Table 3). The rest of Sepa's residents either have land only on flat areas or no land for gardening. They therefore rely on external sources of food. Loimuni's residents on the other hand largely rely on flat land for their gardens, with only about 5% to 10% of gardens being located on hilly land. Loimuni community, located in an area away from any river and creek are largely susceptible to dry conditions.

Sepa experiences extreme rainfall-induced flooding and landslides, causing extensive crop losses. Loimuni is largely affected by droughts that reduce crop output. Such effects of climatic conditions affect resident's energy and other nutrient consumption. In both communities, access to good arable land is limited, including land that is not prone to natural disasters.

The project is articulated around three main activities for improving food security:

- **Contour-based improved agroforestry** together with **conservation agriculture**. An Improved Agroforestry demonstration project includes the introduction of climate ready crops sourced from Center for Pacific Crops and Trees (CePaCT); the introduction of trees and crop species diversity; and local food crop bulking for distribution to farmers. It is complemented by conservation agriculture with key activities such as composting, integrated farm management and integrated pest management.

- **Increasing household production and consumption of animal protein** and energy sources through **demonstration goat farming** and the **introduction of more suitable chicken and pig varieties**. A livestock strategy also includes improvements in chicken husbandry management so that consumption of eggs is more regular and meat is readily available for families to eat at daily meals rather than used as a crisis food.
- **Increased income generating opportunities** focussing on assessing the feasibility of establishing **virgin coconut oil production**; and **honey farming** based on European honey bees species (*Apis mellifera*).

The SPC-USAID project also includes exploration of aquaculture opportunities in the villages (focusing on tilapia and some crustaceans) and training on food preparation/cooking practices that prevent loss of nutritional values during cooking.

2.1.4 Application of CBA for the Solomon Islands and Food Security Case Study

In this case study, the application of CBA for climate rick management is demonstrated focussing on improved agroforestry-based farming as a food security adaptation measure in Sepa and Loimuni.

The improved agroforestry initiatives in Sepa and Loimuni under the SPC-USAID project are designed to demonstrate contour-based farming on hilly lands to reduce exposure to flooding, and reduce soil erosion and landslides. Improved conservation agriculture comprises increased fallow, increased composting and integrated nutrient and pest management. It also includes establishment of a community nursery for producing planting material of a diverse range of crops and climate smart crops, including key fruit and tree species for distribution to local villagers.

It is acknowledged that food security improvements are also possible by addressing other drivers of food security, including increasing household income and increasing chicken and other livestock production (as described above). The SPC-USAID project does address these aspects of food security, but they are not included in this analysis as these activities were still at a very early stage and there was limited information and experience to inform the CBA.

The CBA of improved agroforestry farming system involved analysing costs and benefits of an adaptation intervention (‘with adaptation’) as compared with the ‘business as usual’ gardening approach but recognising the impact of projected climate change risks and non-climatic risks (‘without adaptation’). Benefits of the adaptation measure are estimated in terms of changes in crop output and household food security. The economic value of increased food security is estimated using value of energy equivalent derived from rice, which is a close substitute for key traditional crops.

2.1.5 Information sources

Information about ‘with and without adaptation’ costs and benefits is usually derived from published scientific information, primary data collection, modelling exercises and/or experiments. Household and industry surveys are typically conducted to gather context specific social and economic information, including empirical data required to estimate costs and benefits of current activities and those related to specific adaptation interventions.

In this project, due to resource and time constraints, the analysis had to rely on available and readily accessible information. However, much of the empirical data required to undertake CBA of adaptation options suitable for addressing food security in Choiseul Province is limited or non-existent. This situation is common to most Pacific countries and other emerging countries.

In the presence of limited context specific scientific information a combination of methods was used to generate the required empirical data about ‘with and without adaptation’, including extrapolating available baseline data, changes based on limited technical analysis and best/plausible estimates provided by people with technical and experiential knowledge about agriculture in the Pacific, and Choiseul in particular.

2.2 Situation Analysis

Under the 'without adaptation' scenario, it is assumed that households would continue with the same livelihood system based on subsistence farming, outside income generating activities, and consumption of local foods produced, bought and received as gifts. Households will continue to be exposed to non-climatic as well as current and projected climatic risks, without any adaptation initiatives. All these factors underpin food security status at the household level.

CHICCHAP partners identified a number of climatic and non-climatic sources and drivers of risks using Vulnerability and Adaptation (V&A) assessment in 2013 (see Table 2), including extreme rainfall, droughts, high temperatures, poor farm management, poor infrastructure and reliance on limited natural resources for income.

Table 2 Key climatic & non-climatic risk factors, sensitivity, adaptive capacity and responses identified by CHICCHAP partners using V&A Assessment (SPC/SPREP/USAID/GIZ 2013)

	Sepa	Loimuni
Observed climatic factors	- Erratic weather patterns - Increasing temperatures - Prolonged/frequent rainfalls - Droughts (associated with El Niño phenomenon) - Sea level rise & extreme high and low tides, and shifts in their seasons	- Increasing temperatures - Prolonged/frequent rainfalls - Drought - Sea level rise & Extreme high and low tides
Non-climatic factors	- Increasing population - Wild pigs - Pests (beetles/slugs) and diseases - Poor farm management practices – shifting cultivation, slash and burn - Logging	- Increasing population - Localised coastal pollution - Wild pigs - Poor farm management practices – shifting cultivation, slash and burn - Pests and diseases - Overharvesting of marine resources
Sensitivity	- High dependence on root crops and fish - Income dependent on natural resources - Gardens and homes on alluvial terraces and flat lands near river and streams	- High dependence of root crops & local marine resources - Income dependent on marine resources
Adaptive capacity	- High dependence on root crops and fish - Income dependent on natural resources - Gardens and homes on alluvial terraces and flat lands near river and streams	- Low income - Limited awareness about climate change, resource management - Poor infrastructure - Limited technical assistance from government
Assets, resources & livelihoods affected	- Coastal erosion - Loss of garden productivity - Soil erosion (too much rain) - Shift of crop harvesting seasons - Increase in crop pests and diseases - Frequent flooding	- Coastal erosion - Saltwater intrusion into wells - Loss of garden productivity - Top soil erosion - Increase in pest and diseases - Food insecurity

	Sepa	Loimuni
Adaptation measures identified	- Relocation of homes and infrastructure to higher grounds and away from river (buffer) - Contour planting on slopes - Improve agricultural practices - Afforestation on old garden areas - Improve cocoa fermenting facilities - Watershed and riparian forest restoration and conservation - Reduce gardening on river terraces - Plant native trees species for riparian strengthening (buffer zones)	- Continue set-back of homes and infrastructure - Improve agricultural practices - Replant mangroves and maintain current mangrove strips - Improve natural resource management practices - Encourage planting of cocoa

Other factors affecting food security commonly found in the Pacific include increased population growth-induced pressure on limited arable land, land tenure affecting access to land, and limited income generating opportunities.

Table 3 Socio-economic characteristics of Sepa and Loimuni Communities, Choiseul Province (SPC/SPREP/USAID/GIZ 2013; Susumu, Nonga et al. 2013)

	Sepa	Loimuni
Number of Households (HHs)	54 HHs	52 HHs
Population (persons)	244 p	263 p
No of persons/HH	4.5 p /HH	5.1 p/HH
Average land area (ha)	1.2 ha	0.54 ha
% gardens on flat land*	95-100%	90-95%
% of gardens on hilly land*	95-100%	5-10%
Volume of traditional crops produced and consumed, exchanged and sold (Grams/person/day)	185 (g/p/d)	167 (g/p/d)
Energy consumption (Kcal/person/day)	1534 (Kcal/p/d)	1992 (Kcal/p/d)
Energy derived from local foods (Kca/person/day) and percentage of total daily energy consumption (%)	353 (Kcal/p/d) (23%)	320 (Kcal/p/d) (16%)
Percentage of energy derived from imported foods (%)	77%	84%
Weakly HH income in SBD (% HH indicated not having sufficient income to meet their basic needs)	SBD 80 / 63% of HHs	SBD 120/ 81% of HHs

***# Note Sepa residents tend to have farms on both flat lands as well as hilly areas where households have access to both types of lands (personal communication, SPC-USAID technical staff, April 2014.)**

2.2.1 Traditional crop production and food security status

Both communities depend on their gardens and marine environment for their food and nutritional needs, in addition to foods received from family members as gifts. Sepa and Loimuni households grow a range of crops, including taro, sweet potatoes, bananas, breadfruits and a range of leafy vegetables, fruit trees and nuts. Leafy vegetables include ferns and slippery cabbage or bele. Fruits commonly consumed are pawpaw, lemons, and bananas. Swamp taro is a food of last resort, usually when other crops are lost to natural events. Other sources of food are marine resources and other animal products such as chicken and pigs. Local chickens are used as an important source of protein during and after disasters when gardens are destroyed, and during rough weather when fishing is difficult.

Households in Sepa consume on average 1534 Kcal/p/d, of which 23% is derived from locally produced food crops. One household in Sepa typically consumes on average 471,143 Kcal of energy per year. Over three quarters of energy (77%) is derived from imported foods, such as rice, flour and meats.

In Loimuni, the energy consumption is 1992 Kcals/person/day of which 16% of energy consumed is obtained from locally produced traditional crops. This is equivalent to 517,518 Kcal/person/ year. Loimuni derives 84% of their energy from imported foods (Table 4). Natural climate variability is believed to be one of the key reasons behind such a high level of reliance on imported foods (Susumu, Nonga et al. 2013).

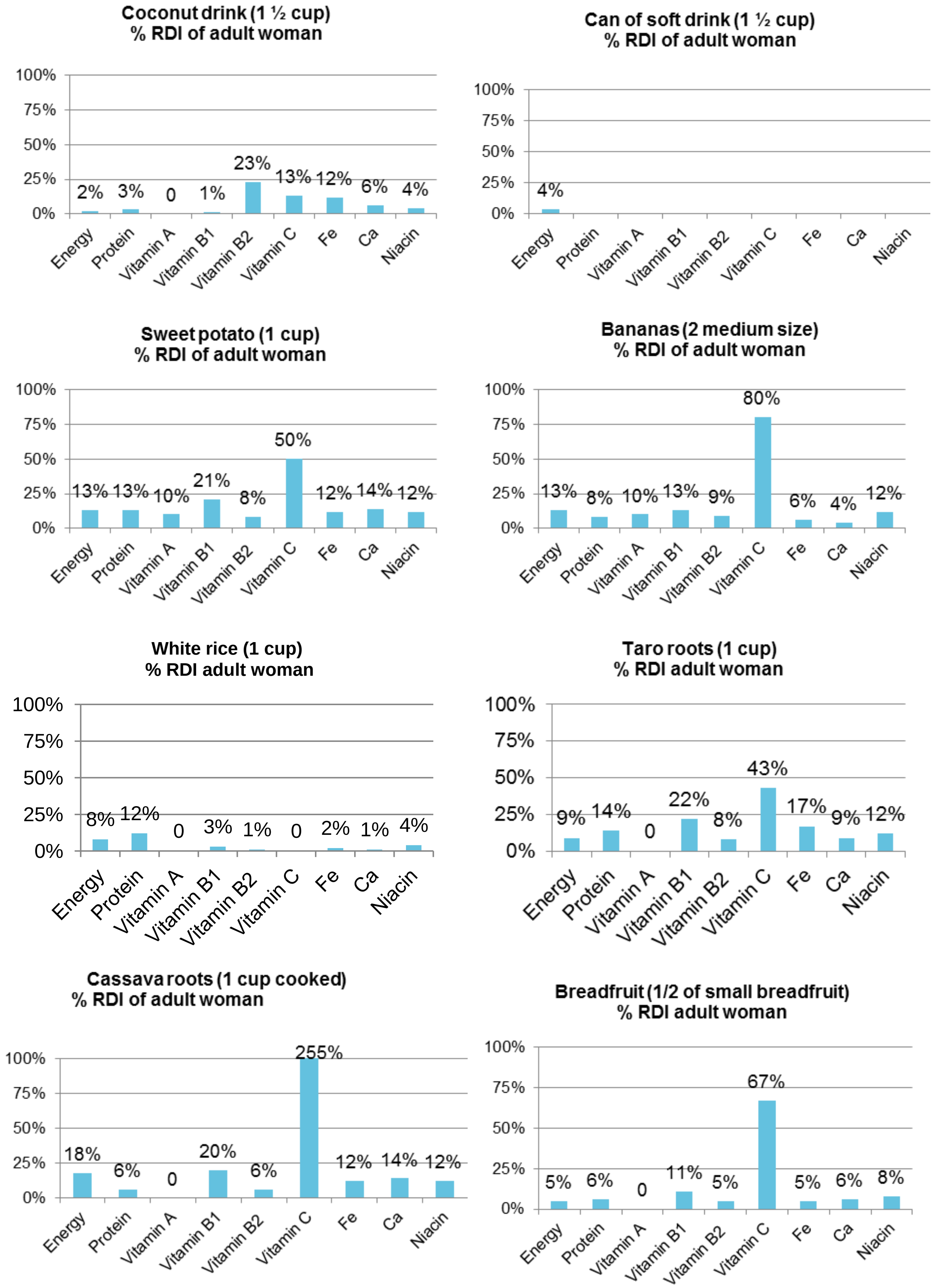
Table 4 Food Security Status of Sepa and Loimuni (Susumu, Nonga et al. 2013)

			Sepa	Loimuni
Total Energy from non-protein foods	**Local Production/ person/day**	Grams	185 g	167 g
	Energy consumption from local foods	Kcal/person/day	296 Kcal/p/d	291 Kcal/p/d
	Imported foods	Grams	305 g	415 g
	Energy consumption from imported foods	kcal/person/day	1103 Kcal/p/d	1507 Kcal/p/d
Total Energy from protein-foods	**Total Local**	Grams	39 g	29 g
		Kcal/person/day	57	30
	Imported Food	Grams	40 Kcal/p/d	88 Kcal/p/d
	Energy consumption from imported foods	Kcal/person/day	78 Kcal/p/d	165 Kcal/p/d
Total from all foods	**Total Consumption**	Grams	569 g	698 g
		Kcal/person/day	1534 Kcal/p/d	1992 Kcal/p/d

Note: SPC suggests minimum average energy requirement of 2100 Kcal/person/day (Susumu, 2013); WHO-FAO reported a weighted average minimum energy requirement of 1700 Kcal/person/day, based on the age demography in SI in 2006-2008 (FAO nd). Numbers have been rounded.

Traditional foods provide the majority of vitamins and other nutritional needs. The level of vitamins and minerals derived from local foods compared to imported foods by members of household is not known. It is generally accepted that they contain higher nutritional value than imported foods. For example, a cup of sweet potatoes would provide 50 % RDI (Recommended Daily Intake) of vitamin C, 12% iron and 21% of vitamin B1 required by an adult woman. On the other hand a cup of rice would provide negligible quantity of vitamin C, less than 3% of vitamin B1, and only about 2% of iron (see Figure 5).

Figure 5 Nutritional Content of Key Traditional Foods



2.2.2 Current and past climate

The climate of Choiseul Island in the Solomon Islands is typically tropical with monsoonal influences. Wet season, *Komburu,* extends from November to April and a dry season, *AraI,* from May to October. Annual rainfall amounts to over 3300 mm at Taro. Mean air temperature shows little seasonal variations and the mean annual air temperature at Taro (Choiseul Island) is around 27°C.

There is a marked inter-annual and interregional variability in rainfall due to the influence of ITCZ (Intertropical Convergence Zone), SPCZ (South Pacific Convergence Zone), WPM (West Pacific Monsoon), ENSO (El Niño-Southern Oscillation) and tropical cyclones. The interregional rainfall differences are determined by the intensity of the SPCZ and the ITCZ during the year. El Niño brings dryer conditions and La Niña events produce wetter conditions. In the Pacific, there have been 8 El Niño events (including two 'extreme' El Niño) in the past 30 years (1979-2009) for six La Niña over the same period.

Analysis of weather monitoring data at Honiara indicates a warming trend during the second half of the 20th century while rainfall data exhibit no significant trends over the same period. Sea level measurements from tide gauge data (available since 1993) indicate a significant rising trend of over 8 mm per year (BoM/CSIRO, 2011).Between 1970 and 2010, up to eight tropical cyclones passed within 200 km of Taro Island but none have passed within 50 km of the island (BoM 2012 in SPC/SPREP/USAID/GIZ 2013). Due to the high variability of tropical cyclone variability and relatively sparse data it is not possible to determine any historical trends (BoM/CSIRO, 2011).

With significant year to year and inter-seasonal climate variability, communities in Choiseul are regularly exposed to extreme weather conditions, including extreme rainfall and drought. During the rainy season, flooding is common in many low lying areas. Sepa experiences on average, at least one extreme rainfall event every 1-2 wet seasons, causing serious flooding and landslides. On the other hand, Loimuni community is regularly exposed to drought, experiencing 2-3 droughts in a 5 year period or a drought every 2-3 years. In 2013 neither of the communities reported extreme rain or drought related weather events. Rainfall records from BoM at Taro suggest 2012-13 were 'average' years.

2.2.3 Climate change

Latest global climate change modelling suggests that in the short to medium term, greenhouse gas emissions are already tracking above the upper limit of emission projections, and RCP (Return Concentration Pathway defined in IPCC AR5 report) of 8.5 is likely. This will bring significant changes to the incidence and intensity of extreme events such as rainfall/flooding and droughts.

CSIRO and BOM modelling projects that Solomon Islands in the short to medium term is expected to experience increased mean rainfall and temperatures, more hot days and warm nights. It is projected that there will be increased frequency of extreme rainfall events. On the other hand, drought and cyclones are expected to be less frequent. However, in all cases extreme events are likely to increase in intensity (BoM and CSIRO 2011 b). In the longer term, by 2090, the projection is that extreme rainfall events (1 in 20 year events) will become 1 in 4-6 years (RCP8.5) Lough et al (In Press).

In this assessment, the combined effect of climate change and ENSO is assumed where Sepa residents could experience doubling of the flooding frequency, resulting in flooding at least twice a year. Projections also show that under climate change the incidence of drought is projected to decrease in Solomon Islands, and there is a projected increase in frequency of days and intensity of extreme heat (BoM and CSIRO 2011 b). This suggests that Loimuni could expect reduced frequency of droughts, from 2-3 times in every five years to once in every five years assumed in this study.

Table 5 Summary of observed and projected climate change in the Pacific with reference to 1986-2005 as the base period (central for temperature and sea-level projections) (Lough et al (In Press))

Climate variable	RCP	Observed	2030	2050	2090
Air Temperature	RCP2.6	Significant warming 0.18^{o}C/decade, 1961-2011	0.75^{o}C	0.75^{o}C	0.75^{o}C
	RCP4.5		0.75^{o}C	1.0^{o}C	1.5^{o}C
	RCP6.0		0.75^{o}C	1.0^{o}C	2.2^{o}C
	RCP8.5		0.75^{o}C	1.5^{o}C	3.0^{o}C
Temperature extremes		4-fold increase in frequency of warm days and nights and decrease in cool days and nights, 1951-2011	Becoming more frequent and intense through 21st century and higher emissions scenarios		1 in 20 year extreme daily temperature will be 2-4^{o}C warmer than present extremes RCP8.5
Rainfall	RCP2.6	No significant change - still dominated by natural variability	Becoming wetter across much of region especially near-equatorial Kiribati and Nauru with magnitude of change increasing through 21st century and higher emissions scenarios.		
	RCP4.5				
	RCP6.0				
	RCP8.5				
Rainfall extremes		No significant change - still dominated by natural variability	Becoming more frequent and intense through 21st century and higher emissions scenarios.		1 in 20 year extreme daily rainfall will occur every 7-10 years (RCP2.6) and every 4-6 years (RCP8.5).
Sea Level	RCP2.6	Significant global +19 cm rise since early 20th century		24 cm	40 cm
	RCP4.5			26 cm	47 cm
	RCP6.0			25 cm	48 cm
	RCP8.5			30 cm	63 cm
Tropical cyclones		No significant change	Similar number or fewer tropical cyclones but those that occur more intense.		
ENSO events		No significant change but central Pacific ENSOs more frequent than eastern Pacific ENSOs	Continued source of interannual variability; associated rainfall extremes intensify and extreme El Niño's (e.g. 1982-83, 1997-98) double in frequency during 21st century.		

Data sources

There is only one weather monitoring station on Choiseul Island; the station is located on Taro Island (WMO number 91502, 6.70°S/156.38°E). The station has not been operated continuously and there are significant data gaps (e.g. missing mean rainfall data in 1994 and between 1996 and 2006, missing mean temperature in 1982, 1989 and 1990 and between 1994 and 2007).

As part of the Pacific Climate Change Science Program the *Climate Change in the Pacific: Scientific Assessment and New Research Volume 1 and Volume 2* (BoM/CSIRO, 2011) was published. This report provides an overview of past and future climate in the region and relatively detailed country profiles.

The research and analysis used to develop this report was coordinated by the CSIRO (Commonwealth Scientific and Industrial Research Organisation) and the BoM (Australian Bureau of Meteorology).

The Choiseul Province Climate Change Vulnerability and Adaptation Assessment Report Solomon Islands was published in 2013 through a joint effort by SPC, SPREP, GIZ and USAID. The report provides some information on past and current climate and climate projections but largely relies on the BoM/CSIRO (2011) publication.

Limits

The lack of a continuous data set and significant data gaps (as mentioned above) for the Taro weather monitoring station prevents a statistical analysis of local changes in the climate. Instead past climate trends for Honiara (about 500 km to the south-east of Choiseul) were presented.

Climate projections are associated with a number of important uncertainties including:

- Uncertainties with the emissions scenarios. Emissions scenarios are based on plausible estimates of levels of development, population and per capita emissions in the future. By definition these will be uncertain at both the local and global scale.
- Uncertainties associated with climate modelling and climate scenarios. Climate models are the best available tools to estimate what the future climate is likely to be. However, some of the biophysical and chemical processes are poorly represented in climate models as a result of the inability to represent or simulate some key processes (e.g. carbon cycle responses, ice sheets, permafrost melt, ocean convection, atmospheric convection), particularly feedback processes.
- Downscaling uncertainties. There is no consensus on how best to downscale the results from coarse-resolution global climate models to regional and local scales for use in impact and risk assessments.

Some of the uncertainties are even more marked for small islands including Solomon Islands. For further details see BoM/CSIRO (2011).

2.2.4 Non-climatic risks

Both communities are highly vulnerable to yield declines as a result of high population growth and poor farm management. This situation is further compounded by limited access to land and local land tenure.

Sepa and Loimuni are amongst the largest villages in Choiseul with over 190 people (top 5%). They have a population of 244 and 263 and an average household size of 4.5 and 5.1 respectively (see Table 3). With an annual population growth rate of 2.8%, the pressure on existing gardens is significant. Households have access to about half an hectare in Loimuni (0.54 ha), and just over an hectare in Sepa (1.2 ha). In both communities there are many households with less than 0.1 ha. Households also have limited opportunity to access alternative lands for farming because of the local land tenure system (SPC/SPREP/USAID/GIZ 2013; Susumu, Nonga et al. 2013; CHICCAP Partners 2014).

Empirical evidence about the effect of poor farming practice on crop yield in Solomon Islands and the Pacific in general is limited. In Papua New Guinea, sweet potato declined from 8 t/ha from farms that came out of a 2-5 year fallow, to 50%, or 4 t/ha in gardens that were about to go into fallow. This decline was linked to inadequate N, K and S nutrition in the soils (Kapal, Taraken and Sirabis 2010).

For Choiseul Province, annual crop yield due to increased pressure on land and poor farm management is estimated to be about 5-10% annually (Mark Biloko, SPC-USAID, personal communication, February 2014.)

2.3 Problem Analysis- 'without adaptation'

2.3.1 Risk Framework

The original SPC-USAID project did not strictly follow a risk management process. The project was instead supported by a vulnerability assessment. To facilitate the CBA and building on the relevant information already collected and analysed, the PACCSAP team undertook a risk assessment, consistent with the international standard for risk management ISO 31000, using the following risk matrix to determine the risk levels of particular scenarios (with the risk level being a function of the scenario's consequences and its likelihood).

Table 6 Risk matrix

		Consequences				
		Insignificant (1)	Minor (2)	Moderate (3)	Major (4)	Catastrophic (5)
Likelihood	Almost certain (5)	Medium (5)	Medium (10)	High (15)	Extreme (20)	Extreme (25)
	Likely (4)	Low (4)	Medium (8)	High (12)	High (16)	Extreme (20)
	Possible (3)	Low (3)	Medium (6)	Medium (9)	High (12)	High (15)
	Unlikely (2)	Low (2)	Low (4)	Medium (6)	Medium (8)	Medium (10)
	Very Unlikely (1)	Low (1)	Low (2)	Low (3)	Low (4)	Medium (5)

2.3.2 Risk Identification

Prior to completing the risk assessment however, potential risks needed to be identified, via a process of risk screening. Based on previous assessment (SPC/SPREP/USAID/GIZ 2013) and several group sessions with local stakeholders (technical staff from the SPC-USAID project), the following risk screening matrix was completed by flagging where there was a potential relationship between a particular project component and a particular climate driven hazard.

Table 7 Risk screening matrix used for the project

		Component			
		Agriculture	Homes and property	Human Health	Environment
Rainfall	Annual average rainfall	✗	-	-	-
	Extreme rainfall events (flooding)	✗✗	✗✗	✗✗	✗✗
	Drought	✗	-	-	-
Temperature	Annual average temperature	-	-	-	-
	Extreme temperature events	✗	-	✗	-
Wind	Cyclones	✗	✗	-	-
Sea Level Rise	Extreme high and low tides	✗	✗	-	✗

Strong relationship	✗✗
Potential relationship	✗
No apparent relationship (or uncertain)	-

The results of the risk identification were then used to develop the risk scenarios. Risk scenarios were collaboratively developed using a “condition consequence” format. Given a certain condition (typically mediated by a climate driven hazard), a particular consequence could result. The results of this exercise are presented in Section 2.3.3.

2.3.3 Risk analysis

#	Risk Statements	Risk Level	Score	Likelihood	Likelihood Statement	Consequence	Food security Consequence Statement
1	**There is an increased risk of flooding and landslides, in Sepa with the projected increase in the frequency and intensity of extreme rainfall events under climate change**	**Extreme**	20	Almost Certain (5)	Current climate conditions cause flooding at least once every 2 years in Sepa. With climate change, flooding is expected to be at least twice a year	Major (4)	Under current extreme rainfall events causing flooding and landslides once in every 2 years, 70% crops are damaged. The impact lasts for 3 months, by which time the new crop of early maturing crops such as sweet potatoes can be harvested. With climate change, flooding is expected at least twice a year, causing 80% crop loss, and the effects lasting for 6 months in Sepa. Communities are forced to rely on imported foods supplied by family and friends from Honiara and elsewhere, or bought locally from scarce household income. Increased rainfall causes increased humidity, incidence of pests and diseases, such as taro leaf blight. Increased rainfall also causes soil erosion, affecting ecological services on land. (Due to data constraints, changes in pest and diseases and the effects of soil erosion on crop yield were not included in the CBA analysis of adaptation options for Sepa).

#	Risk Statements	Risk Level	Score	Likelihood	Likelihood Statement	Consequence	Food security Consequence Statement
2	**Climate change is expected to reduce frequency of droughts, but the intensity of drought is expected to be higher in Loimuni**	High	15	Almost Certain (5)	Under current climatic conditions, drought occurs twice in a 5 year period. With climate change, drought is expected to occur once in a 5 year period	Moderate (3)	Drought – twice in 5 years, with crop loss of 50%, and the effects on food security lasting for 4-6 weeks With climate change, drought is expected to occur once in every five years, with higher intensity, causing 60% loss and the effects on traditional crop output is expected to last 4-6 weeks.
3	**Climate change is expected to increase extreme air temperatures affecting crop outputs in Sepa and Loimuni.**	Medium	12	Very likely (4)	Very likely. Four-fold increase in frequency of warm days and nights and decrease in cool days and nights have been observed between 1951-2011. Average and extreme temperatures are expected to increase with climate change (Very likely)	Low to Medium (3)	Extreme temperatures are expected, affecting plant growth as well as the incidence of pests and diseases. Different crops will react differently to such changes and the actual magnitude of impacts is not known with certainty (see Appendix C and Appendix D). The effects of changes in temperature on food security are expected to be constant with and without improved agroforestry farming.
4	**With sea level rise and changes in tropical cyclone intensity, there is a greater risk coastal flooding in Sepa village**	High	16	Likely (4)	The projected increase in sea level rise and tropical cyclone intensity is likely	Major (4)	When a storm occurs, coastal flooding is common, affecting gardens in Sepa community, including salinisation of garden soils. As the extent of the damage is unknown it has not been included in the CBA.
5	**With a projected increase in cyclone intensity, there is a greater risk of landslides and flooding in Sepa and in Loimuni**	Medium	9	Possible (3)	The projected increase in cyclone intensity is possible although there is a great degree of uncertainty.	Moderate (3)	During large cyclone events, combined with extreme rainfall, crop damage is common together with loss of gardens through landslide. As the extent of the damage is unknown it has not been included in the CBA.

#	Risk Statements	Risk Level	Score	Likelihood	Likelihood Statement	Consequence	Food security Consequence Statement
6	**High rate of population growth combined with limited access to land increases food security risks in Sepa and Loimuni**	**Extreme**	20	Almost certain (5)	Population growth rate of 2.8% is highly likely, given recent population growth trend in Choiseul province	Major (4)	High population growth of 2.8% in Solomon Islands, combined with limited access to land on Sepa and Loimuni (average land area of 1.2 ha for a household of 4.5 persons), has led to increased pressure on land, causing reduced fallow periods resulting in decreased soil condition and soil fertility. Annual decline in traditional crop yield is estimated to be 3-10% in both Sepa and Loimuni (assumed base measure of 5%).

2.3.4 Risk Evaluation

The detailed risk assessment has highlighted that the key risks likely to be the most threatening to food security for both communities are associated with flooding, drought and population growth. These risks will be the focus of the adaptation options presented hereafter.

2.4 Solution Analysis - Adaptation options

A spectrum of adaptation measures has been identified to address non-climatic and climatic risks in the agriculture sector (see Figure 6).

Figure 6 Examples of food security related document and climate risk management measures in the agricultural sector of the Pacific (McGray et al. 2007)

In Sepa, as many households have access to hilly lands, contour-based farming on such lands was identified by SPC-USAID as an appropriate response to regular flooding on flat lands. It will also help address problems of soil erosion and landslides for gardens on hilly lands.

Loimuni, located on largely flat land is mostly vulnerable to drought effects, and deteriorating soil condition due to population pressure, could benefit from improved farm management practices that improve soil nutrient content and soil texture.

Conservation agriculture focuses on improved farm management, through no till farming, increased fallow, crop cover and mulch, integrated nutrient management, and integrated pest management. 'It aims to conserve, improve and make more efficient use of natural resources through integrated management of available soil, water and biological resources combined with external inputs. It contributes to environmental conservation as well as to enhanced and sustained agricultural production. It can also be referred to as resource efficient or resource effective agriculture' (FAO, 2006). Research in the Caribbean and other parts of the world suggest an increase in crop yield and net present value from the adoption of conservation agriculture.

In Papua New Guinea, limited trials demonstrate that farms with mound composting had a higher yield of sweet potatoes than similar farms without composting. The effect of composting was highest in soils that were of poor quality soil, with low S and K (Kapal, Taraken, Sirabis 2010).

Contour based farming could be based on engineering solutions constructing physical walls using stones or live vetiver (and gliricidia[3])-based contour systems (Figure 6). In addition, taking a holistic approach to development and risk management challenges, improvements in farm management are also important (Figure 6).

Thus possible improved agroforestry farming-based adaptation solutions in Choiseul Province include:

- Engineering based contour farming;
- Vetiver grass (live) based contour farming;
- Conservation agriculture; and
- Combination of live-contour-based farming and conservation agriculture

Contour farming

Contour-based system reduces soil erosion and improves soil texture and conditions. While empirical evidence of soil conservation benefits of contour farming in the Pacific is not available, experimental plots in Colombia showed soil losses were reduced to 1.4 tons per hectare compared to 143 tons per hectare for a bare fallow control.

Contour based mixed agroforestry farming on hilly lands involves establishing gardens along contour lines protected by hedges of soil retaining plants, such as vetiver grass. Contour lines are marked at 2-3 m spacing and designed using 'A-frame'. On the contour boundaries options using rocks and boulders or as is the case in Choiseul Province, vegetation, such as vetiver grass are planted with a spacing of 10 cm between grass strips. Tree plants such as Gliricidia species are also commonly used. Often tree stumps are used on contour boundaries while vetiver grass/glicidia plants get established. Vetiver grows to a height around one meter but performs best when maintained to height of about 500 mm.

Vetiver is a live system as it 'grows' with the deposition of sediment, as compared with engineered bunds and contour drains, which are fixed in height, and would require serious maintenance and rehabilitation over time.

In between the contour lines, crops which are traditionally grown in home gardens are planted, such as taro, sweet potato, bananas, cassava, pineapple and vegetables such as tomatoes, chillies, eggplant, cabbages and island cabbage. Usually along the garden boundaries different types of fruit and timber species, such as lemon, teak, mahogany, and eucalyptus are also grown. These, too, can be grown in mixed contour-based gardens[4].

Currently only a few households (less than 5%), in Sepa and Loimuni, grow local and introduced timber species in separate wood lots.

Conservation agriculture

The primary feature of conservation agriculture is the maintenance of a permanent or semi-permanent soil cover, be it a live crop or dead mulch, which serves to protect the soil from sun, rain and wind and feed soil biota. It helps promote more stable soil aggregates as a result of increased microbial activity and better protection of the soil surface. Water run-off reduces by almost half when mulch is used as compared to when gardens are subject to burning of residue. Mound farming, such as for sweet potatoes, is an integral element of this. Planting of leguminous crops, such as Mucuna beans, as a cover crop during fallow is also common. Amongst the benefits are; increased soil fertility and moisture retention, resulting in long-term yield increase, decreasing yield variations and greater food security. It also encourages stabilisation of soil and protection from erosion, as well as leading to reduced downstream sedimentation (Knowler and Bradshaw (2007) and Hobbs (2007)).

[3] In this report, vetiver grass is the chosen for planting along the contour lines. Similar steps can be used if gliricidia based contour system is to be adopted.
[4] http://permaculturenews.org/2009/01/19/vetiver-grass-a-hedge-against-erosion; Live and Learn (Live and Learn 2011); and Mark Biloko, SPC-USAID project Officer (personal communication, February 2014)

2.5 Decision Support (qualitative exante)

Initial screening and short listing of possible adaptation solutions can be made using only qualitative information. Such an analysis can be conducted without having detailed empirical data (including lack of monetised estimates of costs and benefits). The relevance/suitability of the options can initially be compared using largely qualitative technical data readily available with expert judgements and local knowledge, obtained via input from key stakeholders.

For each of the possible option information may include the cost of initial inputs required, including physical material and labour inputs, ongoing maintenance costs as well as resource constraints in the village. This qualitative assessment is provided (see Table 8) for the following solutions:

- Engineering based contour farming.
- Vetiver grass (live) contour-based farming.
- Conservation agriculture only.
- Combination of live-contour-based farming and conservation agriculture.

Table 8 Identification of benefits and costs of alternative adaptation options using CBA framework (Elevitch and Wilkinson (2000) and SPC-USAID technical staff (pers communication, February-May 2014)

	Benefits	Costs	Comments
Conservation agriculture	- Conserve and/or improve ecosystem services, such as soil texture and soil nutrients through crop cover and composting. - Reduced use of expensive agrochemicals. - Increased output.	- Increased labour input – expected to be minimal, as it involves changed farming practice using composting techniques, adopting integrated pest management techniques. - Conservation agriculture may add an additional 1 day/week compared to current practice	- Targeting only one cause of risk – population induced decline in soil conditions, and subsequently decline in crop yield - Useful on flat lands as well as hilly lands - Suitable under current and projected climate change conditions.

	Benefits	Costs	Comments
Engineering based contour/terraces	- Minimise soil erosion - Increased top soil depth. - Reduced shallow landslides. - Expected increase in crop output.	- Require rocks and stones - High capital costs, high level of labour required to collect, transport rocks/ stones and construct physical contour boundaries - Regular inputs required to maintain/ rebuild physical structure as soli deposits increase in height	- Targeting soil erosion and landslides and to a limited extent soil conditions - Suitable for gentle and steep hilly lands. - Applicable to situations where cropping on hilly lands is required, and where stones and rocks can easily be accessed. - It is less likely to be adopted because of high and difficult labour input required.
Vetiver grass-based contour boundaries	- Increased top soil - Benefits of reduced loss of soil; reduced landslides - Improved soil content and texture and reduced use of fertilizer - Expected doubling of output	- Initial sourcing of vetiver grass from government nurseries, and cost of transport from Taro to villages - Minimal initial labour input (no capital inputs required) - Additional labour cost for maintaining vetiver grass supply - Additional labour cost for maintaining vetiver grass once established along contour lines	- Vetiver grass would need regular cultivation and distribution - Other plants such as gliricidia also suitable - Targeting soil erosion and landslides and to a limited extent soil condition - Suitable for gentle and steep hilly lands. - Is flexible as soil builds up

	Benefits	Costs	Comments
Vetiver Contour-based farming and conservation agriculture	- Increased top soil - Benefits of reduced loss of soil; reduced landslides - Improved soil content and texture and reduced use of fertilizer - Expected doubling of output within a year of establishment (here assumed to take 3 years to realise doubling of output)	Minimal initial labour inputs, no capital inputs required, minimal regular maintenance required	- Suitable for hilly land under current and projected weather and climate conditions, as well as non-climatic risks associated with decreasing soil condition. - Combined benefits of contour-based farming and conservation agriculture

Given the climatic and non-climatic risks currently experienced in Sepa and Loimuni, and the identified benefits and costs listed in the table above, the relative suitability of each option was compared and ranked based on the expert judgement of the analyst completing the assessment. A simple scoring mechanism as shown in Table 9 was used to assist in selecting a preferred alternative.

Table 9 Comparing, scoring and ranking alternative adaptation options, for Sepa and Loimuni

	Sepa	Loimuni
Climatic & non-climatic hazards		
	Flooding and landslide Declining crop yield because of decreasing soil condition due to high population growth	Regular drought induced crop yield decline Declining crop yield also because of decreasing soil condition due to high population growth
Adaptation Option		
Conservation agriculture	+++ (applicable in all HHs)	+++ (applicable to all HHs)
Engineering based contour farming	+ (applicable only in 45-50% of HHs); key constraints is associated with availability of rocks and stones	Applicable only in less than 10% of HHs
Live-vetiver based contour farming	+++ (applicable only in 45-50% of HHs with land on slopes)	Applicable only in less than 10% of HHs where HHs have hilly land
Integrated contour-based Agroforestry and conservation agriculture	+++++ (applicable only in 45-50% of HHs)	Applicable only in less than 10% of HHs

Note: Number + indicates the level of benefit expected, in the opinion of the analysts completing the assessment. Therefore 4 + (++++) for integrated contour plus conservation agriculture has a higher value than 3+ (+++) of just vetiver-grass based contour farming, and which has a higher net benefits than engineering based contour farming with 1 + (+)

Based on this simplified analysis, the combination of contour farming system and conservation agricultural practices was seen as the most suitable option, scoring the highest comparative score. Detailed CBA of the four adaptation options could also be undertaken. However for many small scale activities, for which there is a good understanding of the underlying problems and feasible solutions (taking into account, geophysical, socio-economic characteristics) a simple application of qualitative CBAwas considered sufficient.

Design of improved agroforestry-based farming

Once the preferred option was selected, the first step in the CBA wass to define the scale and scope of the adaptation intervention. Using experiential knowledge in Choiseul Province, a 50 m x 50 m contour farming system, together with conservation agricultural practices such as composting, integrated pest and nutrient management was found to be the most appropriate design to meet the needs of average household inputs (see Table 10).

Table 10 Inputs required in establishing and maintaining contour based agroforestry farming system in comparison with current agroforestry gardening practice (Mark Biloko, pers comm. February-May 2014)

Activities	Labor in Persons per Day(p/d)	Days required with all persons to complete the task(d)
Land clearing	5 p/d	1 d
Mark Contour and build frames	3 p/d	1 d
Plant vetiver		
Cutting vetiver/ gliricidia	3 p/d	5 d
Transport & planting	2 p/d	1 d
Vehicle / boat hire + fuel/ trip		
Cost of establishment (without fixed costs of tools etc.)		
Maintenance (contours) (annually)	1 p/d	3 d
Major Maintenance Costs (every five years)	3 p/d	3 d
Family labour inputs required per week (on contour farms)	1 p/d	4 days a week / 45 weeks a year
Family labour inputs required per week (in current gardens)	1 p/d	3 days a week / 45 weeks a year

The benefit of such an intervention was aimed at addressing food security needs at the household level.

Detailed CBA was then undertaken to determine if such a project is economically feasible. In other words do the benefits of the initiative outweigh its costs? This is demonstrated in the following section.

2.6 Decision Support (quantitative exante)

Detailed CBA of improved agroforestry-based farming options involves assessing the benefits derived from implementing the adaptation measure, net of its costs, ('with' adaptation scenario) and comparing these with the net benefits of 'business as usual' farming practice under climate change but 'without' adaptation initiative, including changes in non-climatic risks. Where short listing resulted in only one desired option, detailed CBA did help assess economic viability of the selected initiative. The application of CBA to assess economic viability of the improved agroforestry option is demonstrated below.

The 'with and without' CBA steps used for Sepa and Loimuni households were similar. In both communities, the baseline 'without' scenario was defined in terms of the economic value of energy derived from the consumption of locally produced traditional crops, locally produced animal proteins and imported crops, meat and seafood. The key difference was in different climate risks considered.

In Sepa, the climate risk was associated with extreme rainfall causing flooding and landslides-induced crop losses. In Loimuni climate risks were associated with the effect of drought on crop yield. In both communities non-climatic risk due to population increase and resulting impact on per capita crop yield were considered.

In both communities the adaptation option considered was the same – improved agroforestry-based farming. For Sepa it included both contour-based farming and conservation agriculture activities. In Loimuni, with almost 90% of the households with gardens on flat lands, the option involved mainly conservation agriculture.

2.6.1 'Without' adaptation scenario

To determine the 'without adaptation' costs, the impacts of climatic and non-climatic risks on food security without any intervention were assessed:

1) Quantify annual loss in crop output and food security due to climatic risks.
2) Quantify annual loss in crop output and food security due to population-growth induced crop decline.
3) Quantify annual loss in crop output and food security due to combined climatic and non-climatic risks.

'Without adaptation' crop output and food security status

Both communities are relatively food insecure. Their average daily energy intake is less than the recommended nutritional requirement of 2100 Kcal/person/day stipulated by WHO-FAO for Solomon Islands.

Based on the 2013 vulnerability assessment (Susumu, Nonga et al. 2013) current daily consumption of energy, derived from local traditional crops, seafood and imported foods, is 1534 Kcal/person/day and 1993 Kcal/person/day in Sepa and Loimuni respectively. Each household has on average a food security deficit of 566 Kcal/person/day or 2557 Kcal/HH/day in Sepa, while households in Loimuni have an energy deficit of 108Kcal/person/day or 544 Kcal/HH/day. This is equivalent to, assuming no population growth and changes in weather and climatic risks, a current food security gap of 900,186 Kcal/HH/year in Sepa, and 191,597 Kcal/HH/year in Loimuni.

Households in both the communities are largely reliant on imported foods for their daily needs. Loimuni, being closer to Taro, derived 84% of energy intake from imported foods, compared with 77% in Sepa. This is despite the fact that such foods are often difficult to obtain in these remote villages as all imported goods come from Honiara.

High consumption of imported foods is believed to be largely due to declining yield caused by population induced pressures on limited land, and regular impact of current weather and climatic events such as flooding and drought (Susumu, Nonga et al. 2013). While information about past levels of crop production and traditional food consumption in Sepa and Loimuni is unavailable, this conclusion is similar to what was observed in Ontong Java, where consumption of imported food had increased by 1400% between 1970 and 1986, and which was attributed to climatic conditions and increasing population and associated pressure on limited land resources.

High reliance on imported foods may also explain the incidence of malnourishment in children in both these communities. In 2011, in Sepa, 15% of the children under two years of age were reported as malnourished as compared to 30% in Loimuni (WHO Western Pacific Region 2012).

With a respective average weekly income of $80 and $120 per HH, communities in both Sepa and Loimuni are considered to have insufficient resources to meet their HH needs. In Sepa, relatively fewer (61%) families indicated they did not have sufficient income to meet their needs. In Loimuni, despite having a higher weekly income, 81% of households indicated their income was insufficient, and had to rely on family gifts and borrowing.

Impact of current and projected extreme climatic conditions

The impacts of weather and climate events on crops are not uniform. Crops vary in their tolerance to extreme weather and climate events. Although it is difficult to estimate the expected changes in the output of different crops due to limited scientific information and empirical data on past extreme events it is expected that climate change will in most instances lead to a decline in outputs of traditional crops. This includes crops such as bananas, sweet potatoes, and taro in Choiseul Province. Sweet potato seems to be the most affected by changes in rainfall patterns and intensity. See Appendix C for a full list of traditional crops and tree species, their optimum climate range and tolerance to climate extreme (generated specifically for this case study).

These impacts will further exacerbate existing household food insecurity in both Sepa and Loimuni. The impacts of extreme events will be felt not only during the duration of the extreme events but also beyond; impacts will be significant in the short term (to 2030) while long term changes in temperature and rainfall patterns are likely to result in significant impacts from 2050 onward (see Appendix D). A detailed description of the risks is provided in Section 2.3.3.

In addition to these direct impacts of weather and climatic conditions, there are also other indirect effects of weather conditions, including increased pest and disease incidences, such as taro leaf blight and slugs and beetles. Taro, for example, is highly sensitive to increased night temperatures and high humidity, expected with climate change (Appendix C). Other crops, such as sweet potatoes and yams are also highly susceptible to increased rainfall, affecting their yields (Appendix D). Such impacts are not included in this analysis, due to lack of scientific evidence about the extent of damages from such pests and diseases experienced in Choiseul Province (or for that matter in Solomon Islands). Taro Leaf Blight (TLB) though is known to be the reason for reduced consumption of taro and increased reliance on sweet potatoes in Solomon Islands (Liloqula, Saelea et al. 1992).

Impact on food security

Under current conditions, weather and climatic extreme events when they occur are expected to cause a further decrease of 497 Kcal/HH/d due to damag to traditional foods crops in Sepa. Loimuni losses due to weather and extreme climate event are estimated at 413 Kcal/HH/day.

With climate change (but without any adaptation intervention, *i.e*. without adaptation), the incremental food security gap is expected to be 568 Kcal/HH/day when the event occurs in Sepa. In Loimuni, with the decreased frequency but with increased intensity, food insecurity gap is expected to be 579 Kcal/HH every five years (see Table 11).

Table 11 Food security situation under different risk conditions

Risk conditions	Sepa	Loimuni
Business as usual ('before') - Current **food security gap** in 2013 (without climatic or non-climatic risks) (Kcal/HH/d)	2,557 Kcal/HH/d	544 Kcal/HH/d
Current weather & Climate risks: Incremental change in food security gap due to current weather related events without CC (Kcal/HH/d)	497 Kcal/HH/d	413 Kcal/HH/d
Climate Change Risks: Incremental change food security gap due to changes in the weather & climate extremes with climate change (post 2020) Kcal/HH/d	568 Kcal/HH/d	579 Kcal/HH/d

Non-climatic risks - Population growth induced decline in food security

Households in Sepa and Loimuni are expected to continue their gardening of traditional crops on hilly and flat lands. Both communities report concerns about decreasing yields due to growing population and poor farm management, including reduced or no fallow periods and limited use of organic/ compost material to improve soil. These are expected to cause increased reduction in soil nutrient, soil texture, and declining crop yields.

An annual loss of 5% to 10% in crop yield due to reduced fallow and poor farm management is estimated by local technical staff for both the communities. In this study an annual 5% decrease in local crop yield due to poor farming practice is assumed; additional sensitivity analysis are also conducted assuming 3% and 10% declines.

Based on the current population growth rate of 2.8%, and current food production and consumption summarised in Table 3, the food insecurity gap is expected to rise by 23,557 Kcal/HH/year in the first year in Sepa, and 25,876 Kcal/HH/year in Loimuni, assuming a 5% annual decline, and thereafter increasing as population increases; The Loimuni gap is higher, despite having a lower current deficit, because of the larger current household size of 5.1.

'Without adaptation'- combined effect of climatic and non-climatic risks on food security

Taking into account the probability of non-climatic risks and current weather and climate risks as well as the number of days impacted (including recovery period), both villages are expected to experience an increased food insecurity gap of 44,420 Kcal/HH/year in Sepa and 31,664 Kcal/HH/year in Loimuni in the first year (Table 12), and increasing with population growth.

Taking into account projected climate change scenarios from 2020, and increased HH size due to population growth by 2020, food insecurity is expected to be 237,501 Kcal/HH/year in Sepa and 160,978 in Loimuni; impacts on food security are lower in Loimuni because of a lower effect of climate change.

Table 12 'Without adaptation' - expected climatic & non-climatic risk induced incremental food insecurity

	Sepa	Loimuni
Current food security gap(Kcal/HH/year)	900,186 Kcal/HH/y	191,597 Kcal/HH/y
Increase in food insecurity due to non-climatic risks (population growth induced yield decline of 5%) (first year) (Kca/HH/year) in the first year	23,557 Kcal/HH/y	25,876 Kcal/HH/y
Current weather and climatic related losses (% of total crop), duration, Annual probability of event	70% loss; 3 months; 50%	50% loss, 4-6 weeks; 40%
Expected increase in food security gap from current weather & climate risk (i.e. without climate change), 2020 (Kcal/HH/year)	20,863 Kcal/HH/y	5,788 Kcal/HH/y
Projected weather and climatic related losses as a result of climate change (% of total crop), duration, Annual probability of event	80%, 6 months, 50%	60% loss; 4-6 weeks; 20%
Expected food security gap from climate risk (starting 2020) (Kcal/HH/year)	47,687 Kcal/HH/y	4,862 Kcal/HH/y
Additional food security gap (pop growth + CC post 2020) without adaptation (Kcal/HH/year)	237,501 Kcal/HH/y	160,978 Kcal/HH/y

The above assessment of 'without adaptation' scenarios suggests that without any intervention, current food security conditions would deteriorate significantly due to extreme climatic events and pressures due to population growth.

The situation will rapidly deteriorate under modest assumption of changes in climate conditions. It also suggests that any effort made to increase food production and consumption, either through increased crop and meat production and improved income allowing increased access and consumption, will improve human development conditions and improve food security status.

2.6.2 'With adaptation' – impact on crop output and household food security

To assess 'With adaptation' benefits, the following steps were followed:

1) Quantify expected output of traditional crops, and food security, with the adoption of contour-based agroforestry farming system in Sepa under assumed climate change projections.
2) Quantify expected output of traditional crops, and food security, with the adoption of conservation agriculture-based agroforestry farming system in Loimuni under assumed climate change projections.

'With' improved agroforestry and conservation agriculture, output of traditional crops is expected to on average double in a mixed agroforestry cropping based 50m x 50m farm (Mark Biloko, pers comm., February-May 2014). This would mean that if a household were to adopt contour planting plus conservation agriculture it could expect to harvest twice their current mixed crop output from contour farming on an equivalent garden area. Similar doubling of crop output is expected from the adoption of conservation agriculture on flat lands as well.

Sepa's energy output per year with contour-based improved farming is expected to be 866,196 Kcal/HH/year, assuming no weather and climatic extreme conditions are experienced. Loimuni could produce an equivalent of 1.03 million Kcal/HH/year by adopting conservation agriculture, assuming no weather and climatic extreme conditions are experienced.

Households in Sepa and Loimuni can also improve their other nutritional status by producing and consuming increased quantities of traditional crops.

In this CBA, households are expected to gradually increase their crop output, reaching twice their current production after three years from adopting improved agroforestry farming practices. Sensitivity analysis was also undertaken assuming only a 50% increase in output, instead of a 100% increase. In addition, households are also expected to be able to access many planting materials for various types of fruit trees, such as oranges, lemons, mandarins, pawpaws, guavas, and Malayan apples from the community nursery established under the SPC-USAID project. This will add to their nutritional values, the benefits of which are not directly included in the CBA.

2.6.3 'With and without adaptation' – impact on crop output and household food security

In summary, adoption of an improved agroforestry-based farming system in Sepa and Loimuni will considerably improve household food security status now, with or without climate change. It is a good example of a 'no-regrets' adaption option that addresses not only current food insecurity concerns but also an expected rise in food insecurity with population growth. Improved agroforestry based farming system would also prepare households to improve their resilience to future climate change.

The following annual 'with and without' baseline profile is used to estimate economic costs and benefits of contour-based agroforestry and conservation agriculture in Sepa and Loimuni (see Table 13).

Table 13 'With and without' Contour based farming production/ consumption and damage profile (Kcal/HH/year)

	Sepa		Loimuni	
Household size (person)	4.5 p		5.1 p	
Annual Population Growth rate (%)	2.8%		2.8%	
Crop Yield decline due to population induced pressure on land, including reduced fallow (% of total crop)	3-10% (base measure of 5%)		3-10% (base measure of 5%)	
	Without adaptation	**With adaptation**	**Without adaptation**	**With adaptation**
Total Energy Consumption* from all foods (local & imported energy foods and seafood) (Kcal/HH/y)	2,439,903 Kcal/HH/y	3,215,823 Kcal/HH/y	354,7067 Kcal/HH/y	4059,600 Kcal/HH/y
Energy production/consumption from traditional crops (without weather & climate extreme events, without yield decline (Kcal/HH/y)	527,363 Kcal/HH/y	866,196 Kcal/HH/y	517,518 Kcal/HH/y	1,025,066 Kcal/HH/y
Current weather and climate scenario	Extreme rainfall 1 in 2 years; causing 70% damage to crops,		Drought event twice in five causing 50% decline in output	
Current weather & recovery	6 months	4-6 weeks	4-6 weeks	4-6 weeks
Climate change scenario, 2030	Annual 2 flooding, occurring 1 in every 2 years, causing 80% crop		Drought event one in every five years, with higher intensity, causing 60% loss;	
Climate change scenario – recovery period	6 months	4-6 weeks	4-6 weeks	4-6 weeks
Gardening – variable inputs**	1 person per day * 3 times a week* 45 weeks a year	1 person per day * 4 times a week* 45 weeks a year	1 person per day * 3 times a week* 45 weeks a year	1 person per day * 4 times a week* 45 weeks a year

* - Calculated using Kcal/person/day estimated by the SPC-USAID team (Susumu, Nonga et al. 2013); average number of persons per HH and 352 days; ** Based on expert judgement of SPC-USAID technical officers, Mark Biloko; Gibson Susumu, Nichol Nonga and Choiseul Province Chief Agricultural Officer, Andrew Menandu

2.6.4 'With and without' adaptation- Monetising benefits and costs of climate change adaptation

The 'with and without' net benefits of climate change adaptation were assessed in terms of the changes in economic value derived by households from the consumption of locally produced traditional crops under current and projected climatic conditions. Both 'with' and 'without' scenarios, included considerations of the effects of non-climatic risks associated with increasing population. The consumption of locally produced meat products and seafood and imported foods was assumed to be constant.

Total food and nutritional value of foods consumed are equivalent to total economic value of the energy content plus the value of vitamins and microelements content, and other traits of the food. Using hedonic approach[5], the economic value to consumers of traditional crop is equal to the sum the marginal implicit value of the trait times the level of that crops characteristics, in this case energy and nutritional content. Economic value of energy consumed was determined using a proxy price based on the price of rice, the closest and most frequently eaten substitute for commonly consumed traditional crops. Rice provides 1230 Kcal/kg (Dignan, Burlingame *et al*. 2004) and the price of white rice sold in Taro is $24 for a 10 kg bag, giving a proxy value of each Kcal of food consumed equivalent to $0.0195/Kcal. Other nutrient content of rice is negligible in comparison to the nutritional value of many traditional foods (see Figure 5).

Implicit value of the vitamins and nutrients was difficult to estimate as there were no easily identifiable close substitutes. The price of their closest substitutes - vitamin and micronutrient supplements available in local pharmacies - could be used as a proxy value. However, vitamin supplements are not common in Solomon Islands, and increased consumption of traditional foods is promoted for improving nutritional status. McGregor, et al (2012) assumed an economic value of vitamins and micronutrients contained in traditional foods to be equivalent to at least the economic value to the energy content of a crop. In this study, a similar approach was used to estimate economic value derived from increased consumption of vitamins and minerals resulting from the adoption of improved agroforestry based farming as an adaptation option.

Economic costs of weather and climatic risks

Economic costs of the impact of weather and climate extreme events was the economic value of the crop losses due to flooding and landslides in Sepa and decreases in crop output due to drought in Loimuni. These costs were estimated using the expected frequency and intensity of extreme events under current and projected climate conditions. The costs were estimated in terms of the equivalent value of the loss in energy and nutrient consumption during extreme weather events and the recovery phase. Different risk estimates were used for Sepa and Loimuni to reflect their respective sensitivity to the hazards, effects on crop output and expected recovery phase required after flooding and drought respectively (Table 14).

Economic costs of non-climatic risks of population growth

Economic costs associated with increased population growth was estimated using economic cost of annual decline in crop yield resulting from population growth-induced decreased fallow period resulting decline in soil nutritional value and texture. Economic cost of the decline in crop yield, too, was estimated in terms of the equivalent value of the decrease in energy and nutrient consumption.

[5] Whereby an assumption is made that goods can be considered aggregates of different attributes, some of which, as they cannot be sold separately, do not have an individual price.

Costs of adaptation – improved Agroforestry farming

Contour farm equivalent of 50m x 50m, sufficient to support an average household, was established using local labour, design input from contour design specialists and the SPC-USAID project team. The cost of land-clearing, contour marking, obtaining and transporting vetiver grass from a government nursery in Taro, and planting of vetiver grass in Sepa was estimated to be SBD 1,410. Annual maintenance costs for contour hedges were SBD 150 (with SBD 450 every five years when major maintenance work is expected). In addition there was the labour cost of gardening. The actual labour costs under current farming practice were not known and difficult to estimate without baseline surveys. However, with improved agroforestry practice, an additional labour input of a day per week wass estimated to be required in Sepa as well as Loimuni (Table 10). Given other social obligations in the village, additional input of 45 person-days was assumed.

Family labour cost was assumed to be equivalent to 50% of the normal wage rate in Choiseul Province; a further sensitivity analysis was conducted assuming opportunity cost of family labour at 25% wage rate.

Table 14 Economic value of foods

Term	Value
Economic value of a crop	sum of the implicit value of the *energy content* + *implicit value of the vitamins content* + *implicit value of the micronutrients contents*
Economic value of energy content	Marginal implicit value of t*otal energy content derived of crops + seafood and other animal products* level of energy content*
Economic value of energy consumed from traditional crops	*Price of energy X Total Energy consumed (*$Kcal_{taro} + Kcals_{weet\ potato} + Kcals_{bananas} + Kcal_{cassava} + Kcals_{fish} + Kcals_{pigs} + Kcal_{chicken}$
Economic value of other vitamins and nutrients	Implicit p*rice of each vitamin and nutrient) x Total content of each vitamin and nutrient derived from each traditional crop*

Based on (Lancaster 1966; Blaylock, Smallwood et al. 1999; Unnevehr, Eales et al. 2010)

2.6.5 Results of the Quantitative CBA

Sepa and Loimuni households are expected to have a net positive gain in their food security condition from adopting improved agroforestry based farming under climate change. The 'with and without adaptation' net present value of increased energy consumption is expected to be SBD 141,043 and SBD 76,845 respectively for Sepa and Loimuni.

In Sepa, for every dollar spent in establishing and maintaining a contour garden plus conservation farming, replacing current garden systems, about SBD 5 can be expected by households. In Loimuni where farms are largely on flat land and adaptation would involve focussing on conservation agriculture, households can expect about SBD 4 for every dollar invested in improving their farming practice (Table 15).

Table 15 Cost Benefit analysis of improved agroforestry based adaptation for Sepa and Loimuni (SBD)

	Sepa (contour-based improved Agroforestry & Conservation farming)			Loimuni (Conservation farming)		
	Without adaptation	**With adaptation**	**With and without' adaptation**	**Without adaptation**	**With adaptation**	**With and without' adaptation**
PV(Food production/ Consumption	SBD **488,826**	SBD **662,473**	SBD **173,647**	SBD **743,715**	SBD **845,925**	SBD **102,211**
Incremental cost of contour and conservation agriculture (Sepa)	**-**	SBD **32,604**	**-**	**-**	**-**	**-**
Incremental cost of conservation agriculture (Loimuni)	**-**	**-**	-	**-**	SBD **25,367**	**-**
Net Present Value (with and without)			SBD **141,043**			SBD **76,845**
BCR (Net Benefit/Net Costs in real terms)			**5.3**			**4.0**

Assumption: Economic benefits are based on the value of energy content of only key traditional crops regularly cultivated and consumed in Sepa and Loimuni (taro, cassava, sweet potatoes, bananas); and proxy value of unit energy price equivalent value in rice; discount rate of 5%; opportunity cost of family labour is 50% of market rate. **Sepa with adaptation**: Contour farming plus conservation farming produces on aggregate double the current level of traditional crops, due to improved soil conditions and farming management. Without adaptation: climate change results in 2 flooding events in Sepa with a probability of occurrence 50%, with a total loss in crops of 25% occurring after 2020. **Loimuni with adaptation**: conservation agriculture doubles the level of traditional crops, reduced incidence of drought is experienced from 2020, with a probability of occurrence 20% or 1 drought every 5 years, with an increased intensity that causes 60% of crop loss (an increase from 40 %)

Using the most plausible parameter estimates, this CBA suggests that adopting any initiative that improves current farming practice to increase crop production is a good development strategy, regardless of future climate conditions. It is a ‘no regrets’ adaptation strategy as it addresses current development needs, and is suitable under alternative climatic conditions. It will also improve the household capacity to cope with future changes in climate, as their base food security status would be much higher. Given the natural variability in climate of the Solomon Islands, and projected changes in rainfall and temperatures in the future, such a ‘no regrets’ adaptation option – contour-based farming with conservation agriculture for households with access to hilly lands in Sepa and conservation agriculture on flat lands in Loimuni – is expected to provide very high net returns, 5.3 and 4.1 respectively.

The BCRs are expected to be high particularly because the selected adaption option is not particularly capital intensive. It requires low initial capital outlay and involves relatively small incremental costs of maintaining vetiver grass contours and only periodic replanting. Conservation agriculture, too, requires easy-to-follow farm improvement techniques, such as maintaining crop cover using vegetation residues, composting and integrated pest management, and only small additional labour input that can readily fit in with current village lifestyle.

Relative costs of climatic and non-climatic risks

The CBA also suggests that current food security risks faced by households due to the effect of non-climatic risks (like population growth) is likely to be of much greater significance than from the continued effects of extreme weather events or from the effects of climatic change (Table 16). It suggests that to achieve and sustain food security, attention also needs to be given to such drivers of non-climatic risks.

Table 16 Present value of incremental cost of food insecurity due to key factors over 2015-2030

Risk factors	Sepa	Loimuni
Crop yield decline (5%) associated with population growth	32,241	35,414
Current weather conditions	4,590	1,273
Climate change, post 2020	9,900	733

Assumptions: Sepa - current extreme weather event – one flooding event in 2 years & 70% crop loss; CC – two annual flooding events in two years & 80% crop loss. Loimuni - current extreme weather event – two drought events in 5 years & 50% crop loss; CC – one drought event in five years & 60% crop loss; Population induced crop yield decline of 5%; Discount rate of 5%

2.6.6 Uncertainty analysis

The above CBA analysis is based on many assumptions of key parameter estimates that define the likelihood and consequence of unfavourable climatic and non-climatic events. There are many uncertainties in these parameter estimates because of poor knowledge about current farming practices and food security statuses, about the likelihood that assumed climatic or other events will occur and/or poor knowledge of the consequence of relevant climatic or other events should they occur. Sources of uncertainty in this study include:

- Missing time series data about past weather and climate conditions, past flooding and drought events and their intensity, as well as non-climatic changes such as population and their impact on local crop production and household food security.
- Limits with climate models and understanding of hazards patterns, such as parameter values, or dynamic and poorly understood systems (e.g. projections of changes and variability in daily/monthly/seasonal rainfall, flooding incidence and intensity in Solomon Islands).
- Limited data on crop responses to climate change and also the indirect impacts from biotic stresses.
- Difficulties in determining the impact of proposed adaptation options on current and projected crop output and food security conditions.

Different techniques are available for dealing with uncertainties, depending on the nature of the variables involved and associated uncertainty, and the availability of scientific information required to underpin such parameter estimates.

Ideally, sophisticated techniques, such as Monte Carlo simulation and real options analysis, are used if the probability distribution for values of the uncertain variable can be determined with confidence. In this case study, such approaches are not possible due to the lack of quantitative information. As a minimum, in the presence of uncertainty, sensitivity analysis can provide a more nuanced picture by varying key parameter values.

Sensitivity analysis

In this case study, sensitivity analysis has been used to identify how key conclusions about the relevance of improved agroforestry-based farming system would change under different assumptions for key parameters. To demonstrate sensitivity analysis, CBA was conducted using a range of estimates of factors such as, expected increase in crop output due to the adoption of improved agroforestry practice; projected impact of population-induced crop losses; rate of time preference or discount rates and a varying a combination of these simultaneously (Table 17).

Table 17 Key Parameter estimates used in the study

Key Parameters	Parameter
Key parameters	Parameter estimates used
Population growth induced crop yield declines	3%; 5%; 10%
Probability of occurrence of extreme weather event under current conditions	50% (flooding); causing 60% crop loss 40% (drought), causing 50% crop loss
Probability of occurrence of extreme climate event with climate change from 2020	50% (flooding); causing 80% crop loss 20% (drought), causing 60% crop loss
Residual impact with improved agroforestry farming, without CC	10%
Residual impact with improved agroforestry farming with CC (2020)	25%
Incremental Impact of adaptation initiative	Increase in traditional crop output – 50%, 100%
Discount rate	3%; 5%; 10%

The above set of sensitivity analysis parameters suggests that decision-makers can have high levels of confidence in their conclusion about the relevance of improved agroforestry farming as a 'no-regrets' adaptation option. CBA analysis suggests positive net returns from the adoption of improved agroforestry farming and the BCR is greater than 1 under different assumptions, and parameter estimates.

2.6.7 Expected change in crop output under adaptation

Changing the expected effect of improved agroforestry-based farming from 100% increase to a 50% increase does not change the conclusion about its relevance and overall benefits. Net benefit estimates are still positive and BCR ratios are greater than 1, albeit at lower rates, when the output of traditional crops is assumed to be only 50%, instead of double (see Table 18).

Table 18 Sensitivity analysis; costs and benefits associated with changing the parameter estimate for expected effect of adaptation in Sepa and Loimuni under climate change measured in terms of NPV and BCR ratio

	Sepa		Loimuni	
	100% increase	50% increase	100% Increase	50%Increase
NPV	SBD 141,043	SBD 93,116	SBD 76,845	SBD 27,325
BCR (real terms)	5.3	3.9	4.0	2.1

Other assumptions: Sepa - current extreme weather event – one flooding event in 2 years & 70% crop loss; Under CC – two annual flooding events in two years & 80% crop loss. Loimuni - current extreme weather event – two drought events in 5 years & 50% crop loss; CC – one drought event in five years & 60% crop loss; Population induced crop yield decline of 5%; Discount rate 5 %

Rate of time preference

As population increases, and as the effects of climate change become more obvious in the future, assumed here to be post-2020, the choice of rate of time preference becomes important. Internationally, the higher discount rate is often assumed where high Capital Expenditure (CAPEX) is involved, and lower discount rates used where initiatives are based on low capital. Using different discount rates does not affect the fundamental conclusion – that improved agroforestry-based farming system makes financial sense given expected climate change impacts, see Table 19.

Table 19 Sensitivity analysis; costs and benefits of improved agroforestry-based farming system assuming different discount rates measured in terms of NPV and BCR

	Sepa			Loimuni		
	Discount rate			Discount rate		
	3%	5%	10%	3%	5%	10%
NPV	SBD 167,199	SBD 141,043	SBD 96,402	SBD 121,252	SBD 76,845	SBD 51,640
BCR (real terms)	5.5	5.3	1.9	4.1	4.0	3.9

Other assumption: Sepa - current extreme weather event – one flooding event in 2 years & 70% crop loss; CC – two annual flooding events in two years & 80% crop loss. Loimuni - current extreme weather event – two drought events in 5 years & 50% crop loss; CC – one drought event in five years & 60% crop loss; Population induced crop yield decline of 5%

Noting that there are many combinations and permutations of key parameters that may be plausible, a decision-maker would be interested to know how these various scenarios may affect the information supporting his/her decision. The conclusion of this study does not change even if a different combination of scenarios is assumed for example, about the effectiveness of the adaptation initiative and discount rates (Table 20).

Table 20 Sensitivity analysis; costs and benefits of improved agroforestry-based farming system assuming different output rates under adaptation and a range of discount rates

	Sepa		Loimuni	
	Discount rate		Discount rate	
	3%	5%	3%	5%
NPV (100% Output increase	SBD 167,199	SBD 141,043	SBD 121.252	SBD 76,845
BCR(100% Output increase (real terms)	5.5	5.3	4.1	4.0
NPV (50% Output increase	SBD 110,605	SBD 93,116	SB 33,059	SBD 27,325
BCR(50% Output increase (real terms)	5.5	3.9	2.1	2.1

Other assumption: Sepa - current extreme weather event – one flooding event in 2 years & 70% crop loss; CC – two annual flooding events in two years & 80% crop loss. Loimuni - current extreme weather event – two drought events in 5 years & 50% crop loss; CC – one drought event in five years & 60% crop loss; Population induced crop yield decline of 5%

Population-induced decline in crop yield

The benefit of the improved agroforestry farming system is clear for both Sepa and Loimuni, even if a 3% rate of decline in crop yield due to population growth is assumed. Notwithstanding, while there is often greater attention given to the effects of extreme weather and climate risks, for many communities in the Pacific, non-climatic risk factors may require equal attention.

Incremental increase in vulnerability due to factors such as population growth induced pressures on farming land, limited access to good farming land and local land tenure together with poor farm management would largely be unnoticed. In Sepa and Loimuni, the impacts of these non-climatic factors on food security would not require immediate attention, although should not be ignored as population growth, and the pressure on available land resources continues.

In conclusion, these different sensitivity analyses confirm that given the low capital intensive nature of the adaptation intervention, and marginal costs of maintaining the adaptation investment and changes to farm management, improved farming system is a 'win-win' solution. It makes good economic sense even in situations without climate change. It is a good 'no-regrets' adaptation option under current weather and climatic and non-climatic risk conditions.

2.7 Decision Review (quantitative expost)

To advocate for replication of a SPC-USAID project in Sepa and Loimuni, an *expost* CBA was used highlight the expected benefits from the project, as implemented. This involved a CBA of the following demonstration activity - community nursery for production of local planting material and their bulking. It also included an assessment of other income generating activities, such as bee farming, pig husbandry and improved chicken breeds for local farming, promoted under the project.

A partial analysis was attempted here to demonstrate key CBA steps involved, and how both private and public costs and benefits were explicitly considered to understand if the SPC-USAID 'demonstration activity' made economic sense.

This analysis addressed the central question: **Did the SPC-USAID program of activities generate a net positive benefit to Solomon Islands and to the development partner?** The expected benefits to the Sepa community were the focus of this partial analysis.

This CBA focused on improved agroforestry-based activities combined with a community nursery, assuming that the community nursery produced climate smart crop varieties as and when required. It is only a partial analysis as not all types of nursery outputs were included because of difficulties in defining the scope, scale and nature of targeted crops and tree species that were expected to be produced in the community nursery. These aspects of the nursery were not defined in the project document and were still evolving. It was also difficult to get proxy information/empirical data about such a community nursery even from other community nurseries already operational in Choiseul Province. Empirical information about the costs and benefits of alternative income generating activities were unavailable because they were in the early stages of implementation.

This 'with and without' analysis thus focused on net benefits to the Sepa community, net of establishment costs, of the contour-based demonstration farm, and the establishment and running costs of the community nursery. The cost of producing improved varieties of traditional crops was also considered, drawing on TLB resistant taro production for Solomon Islands.

2.7.1 'Without adaptation' SPC-USAID 'project'

Under the 'without' SPC-USAID 'project' scenario it was assumed Sepa households would continue their 'business as usual' farming of their flat and hilly lands (see Section 2.6.1).

2.7.2 'With adaptation' SPC-USAID 'project' – cropping scenario

The 'with' SPC-USAID 'project' scenario analysis requires information about a plausible trajectory for the expected adoption of an improved farming system. In Sepa, contour-based farming is applicable to only about 45% of the households that have access to hilly land (Mark Biloko, pers, April, 2014). About 24 households are expected to adopt contour-based agroforestry plus conservation agriculture. For the rest of community (55% of the households) only conservation agriculture is suitable as these households have their gardens on flat lands and do not have access to hilly land.

It was assumed that it takes about three years before all these households can successfully operate their improved agroforestry-based gardens. It is also assumed that the community nursery produces of a mix of climate-smart traditional crops, such as taro, sweet potato, breadfruit, bananas and island spinach, which tolerate future climate conditions (see Appendix C). Another assumption was made that key climate tolerant varieties of traditional crops, such as sweet potatoes, taro, cassava and bananas are available by 2020.

The community nursery is also expected to produce planting material of key timber species, such as teak, sandalwood, mahogany and eucalyptus, for which households have expressed interest in planting in their gardens. The benefits of these tree species to households are not included in the CBA.

2.7.3 'With adaptation' SPC-USAID community nursery

The design of the community nursery used in this study is based on practices advocated by the Solomon Islands Department of Forestry , Basil Guha (GIZ Project Manager) and crop propagation and bulking processes used for producing vegetatively propagated traditional crops (Mark Biloko, pers, February 2014). Details are provided in Table 21.

Table 21 Inputs used in establishing and maintaining contour farming and community nursery

	No of person-days	Frequency
Contour farms		
Land clearing	5	One off
Mark contour and build frames	3	One off
Cutting vetiver grass	15	One off
Transport & planting	2	One off
Maintenance	1	Annually
Community Nursery		
Material	Posts, cyclone mesh, green house material, nails etc.	One off
Choose site, clear site, removing trees	9.5	One-off
Community nursery, including green house	5	One off
Germination beds (raised and on the ground)	5	One off
Planting, maintenance, uprooting	14	Weekly

The establishment cost of a community nursery is expected to be SBD 30,067 (based on actual project invoice and labour input estimates provided by technical staff on SPC-USAID and GIZ projects). Operational costs are expected to be an additional SBD 36,400 annually. That means the present value of the costs of establishing and operating community nursery till 2030 is expected to be about SBD 320,000 to SBD 500,000.

2.7.4 CBA of SPC-USAID results

Investment in improved crop variety development

If the assumption that improved varieties are available from CePACT or elsewhere in the region is unrealistic, SPC-USAID or other development partners would need to invest in the production of improved cultivars of traditional crops germplasm suitable for conditions in Choiseul. However, before a breeding program is undertaken, field collection of locally available cultivars known to have specific climate tolerant features, may also be required.

Crop breeding capacity in Solomon Islands is limited, and investment is likely to be needed to support CePACT to develop such new climate smart cultivars. To produce climate smart crop varieties, there are additional expected costs. For example, to produce taro leaf blight- resistant taro varieties in regional CePACT and in Samoa, about AUD 85,000 was invested over a 10-year period (McGregor, Kaoh et al. 2011). Taking into account also the extension costs over a ten year period in Samoa, and 10 year AUD to SBD average exchange rates, a present value of SBD 102,000 is expected.

If similar costs were to be incurred for the needs of Sepa community only, SPC-USAID and partners can still expect positive net returns. Society can expect to generate almost 30 dollars for every dollar invested in addressing current food security issues in Sepa. This BCR is significantly underestimated, as once the improved germplasm are made available for Sepa community, they are expected to be available to other communities with similar climatic risks.

Conclusion

This CBA illustrates the steps needed to complete a review of activities required to improve food security at the community level. It demonstrates that in a CBA, the whole system of activities that ultimately lead to improved food security need to be considered. The total costs and benefits of each suite of activities and sub activities need to be assessed to determine net benefits of an adaptation initiative.

The partial CBA demonstrates that SPC-USAID's initiative to improve output from traditional crops can expect high net returns.

Improved agroforestry-based farming activity alone can expect to generate a BCR of over 50, even taking into account the cost of establishing and operating the community nursery, and assuming Solomon Islands had access to improved crop varieties that met the current and projected climate conditions till 2030 (Table 22). It is difficult to predict the availability of crop varieties suitable for projected climate extremes. By 2030 it is possible that communities in Sepa and Loimuni may need to adopt a more transformational adaptation strategy.

Table 22 'With and without' improved agroforestry-based farming plus community nursery (100% attributed to crops)

	Discount Rate		
Costs	**3%**	**5%**	**10%**
PV Total Costs (with and without) + attributable nursery costs (without germplasm improvement)	SBD 1,642,970	SBD 1,454,695	SBD 1,123,700
PV Replication + climate smart crops planting material	SBD 95,560,445	SBD 80,675,916	SBD 54,938,148
BCR	68.8	65.3	57.0

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PART III
CASE STUDY 2: INFRASTRUCTURE IN VANUATU

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Australian Aid

LONG GOD YUMI STANAP

3.0 CRITICAL INFRASTRUCTURE IN VANUATU

3.1 Introduction

3.1.1 About this Case Study

This Vanuatu case study demonstrates the application of CBA to road transport infrastructure challenges in a changing climate. The case study includes quantitative (*exante)* CBA. The case study follows the approach outlined in the methodology section (Section 1.0) as shown below:

Section 3.2. Provides an overview of the current situation in terms of infrastructure profile, past and future climate trends.

Section 3.3. Describes the potential road infrastructure impacts associated with climate change through the identification and analysis of key climate change risks.

Section 3.4. Presents the road improvement activities implemented under the PACC + project.

Section 3.5 presents a quantitative CBA to assess the economic viability of the proposed Pacific Adaptation to Climate Change (PACC) road activities implemented by the Department of Public Works (PWD), using best available data and context specific scientific and experiential understanding (***exante* CBA**).

NOTE: Unless otherwise states all monetary value in this case study are expressed in Vatu Vanuatais (VUV).

3.1.2 Overview of the PACC Project (Epi Island)

Epi Island presently has as 5,200 inhabitants and is located to the north-east of the Shefa Province (see Figure 7).

Figure 7 Location of Epi Island (Google Earth 2014)

The Pacific Adaptation to Climate Change (PACC) project is a multi-agency project aiming to improve climate resilience in Vanuatu. The Vanuatu PACC team includes: PACC Project Management Unit (PMU), Climate Change Meteorology, Environment, Lands Survey, Geology and Mines, Public Works, Fisheries, Shefa Provincial Government and Vanuatu Broadcasting and Television Corporation. It is funded through the Global Environment Facility (GEF) with support from United Nations Development Program (UNDP) and South Pacific Regional Environment Program (SPREP). More recently, additional resources have been provided by the Australian Government under the PACC-Plus program. While the focus of the PACC-Epi project is on road improvement, it also includes activities related to income generation. The PACC strategy is articulated around three main elements:

1) Adaptation demonstration works executed by communities for (1) road & drainage works, (2) forestry (3) agriculture and fisheries.
2) Technical knowledge training for communities to enable them to implement adaptation works.
3) Mainstreaming adaptation at the community, provincial and national levels.

Various activities have already been implemented through the PACC project since 2008 and some of the future detailed work includes:

- **Labour Based Road and Drainage** - Resilience building activity 1.
- **Forestry Nursery and Tree Planting** - Resilience building activity 2.
- **Fisheries Aqua Culture** - Resilience building activity 3.

This case study will focus on some of the work carried out under the resilience building activity 1 (Labour Base Road and Drainage), which had the objective of improving the trafficability of roads, through improved drainage infrastructure and enhanced design outcomes.

3.1.3 Labour Base Road and Drainage

After a series of scoping assessments undertaken for Epi in 2013, the PACC team observed that the Epi communities have over the years built 4WD tracks to access their villages, gardens and plantations. The local drivers tried to fix some of the worst spots on the road by shaping and spreading gravel to improve the road condition. There is no machinery on the Island to rehabilitate the roads and transporting machinery to Epi Island is considered to be very expensive.

For these reasons, and for the additional community benefits, the PACC team envisages that a local labour based approach should be used to carry out the road rehabilitation and improvement activities, as compared with relying on PWD contractors sourced from Port Vila.

As there is an existing PWD program funded by Ausaid (Vanuatu Transport Sector Strengthening Program), it is envisaged that the PACC project should replicate their local labour based approach for Epi. This local labour proved to be very successful in Tanna, Malekula and Ambae. Roads and drainages activities using local labour and construction techniques taking into account climate variables and extremes helped meet the PWD road and drainage standards.

Where heavy machinery is required to assist the communities especially on the quarrying works and haulage of road construction materials to construction site, a PWD procurement process is used (typically from Port Villa).

3.2 Situation Analysis - 'without adaptation'

3.2.1 Socioeconomic characteristics

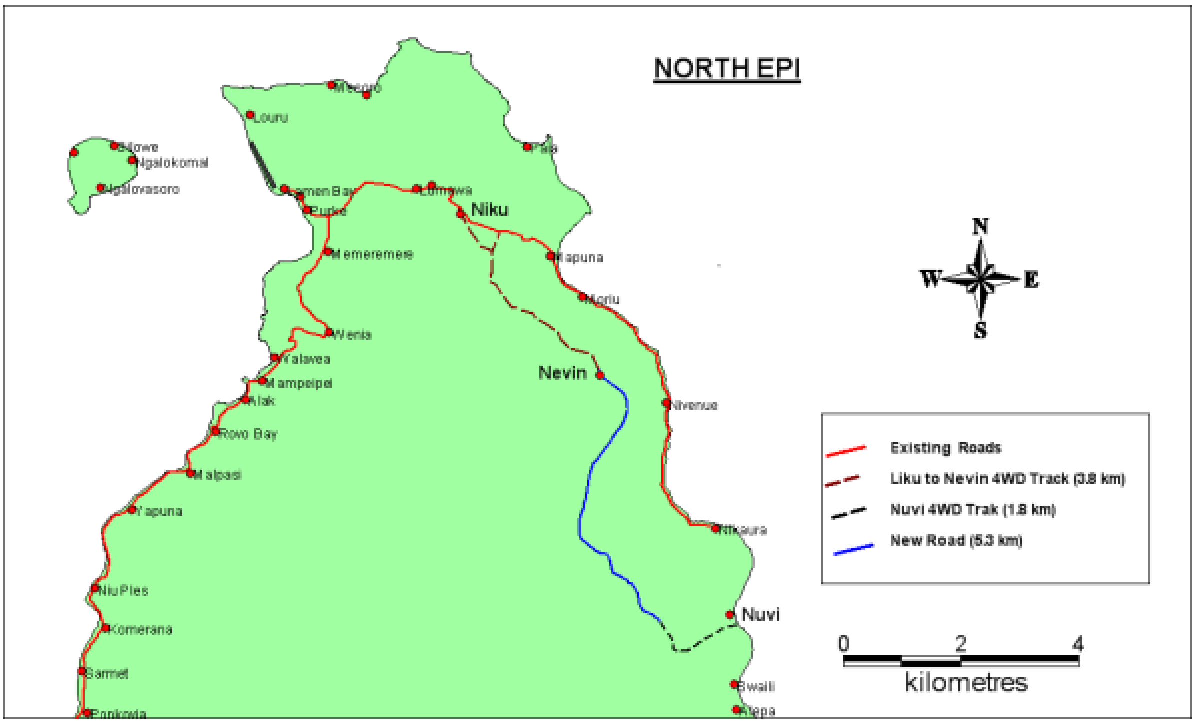
According to the 2009 Census report by the Vanuatu National Statistic Office, Epi has a population of 5,648 people (2,881 males and 2,767 females) and 1,127 households, pointing to an average household size of five persons. Most households are predominantly dependent on subsistence agriculture (World Bank, 2010).

Epi is serviced by two airports: Valesdir in the south and Lamen Bay in the north. A poorly maintained road runs between Votlo in the south and Nikaura in the northeast, but this can be obstructed in the wet season as rivers rise. The rest of the island is accessible by walking tracks. The PWD is responsible for 'national roads', while responsibility for 'feeder roads' rests with the Shefa Province.

3.2.2 Existing road infrastructure

Under the PACC project, a number of assessments have been made to evaluate the condition of the road network (focusing on the North Epi Road and the airport located at Lamen Bay (see Figure 8).

Figure 8 North Epi Island Road Network (Vanuatu PWD 2014)



The road network in North Epi is almost entirely made of unsealed roads and tracks in various conditions. The track starting from Nuvi toward Nevin does not connect all the way through and stops near the Ngervin village. Most of the tracks are between five and six metres in width and are not 'all-weather roads'. Due to the lack of seal and slope they are impractical to use during part of the wet season.

Table 23 Key information on North Epi network (from PWD)

	Road section			
	Rovo Bay – Lamen Bay	Lamen Bay - Vaemali	Vaemali - Niku	Niku - Nikaura
Length (km)	10 km	6 km	5 km	5.5 km
Typical number of vehicles per day	12	12	5	5
Typical number of days per year that road cannot be used by vehicles	30	30	120	120
Typical number of accidents per year				
Number of persons killed	0	0	0	0
Number of persons seriously injured	2 (2006 / 2010)	1 (2007)	2 (2010 / 2013)	0

The typical cost of transport from Lamen Bay to Nuvi is about VUV 9000 for a light vehicle. The cost for the same vehicle between Lamen Bay and Rovo Bay is about VUV 4000.

PWD has an established rotational four-year maintenance program. PWD has machinery, specialists and a ship available for all Vanuatu islands, which rotates activities between the various islands. The maintenance activities and associated costs are shown in Table 24.

Table 24 Maintenance activities and associated costs (from PWD)

	Lamen bay - Rovo bay	Moriu Via Nuvi - Lokopui	Lamen Airport - Moriu	Total
Road Length (km)	10 km	10.5 km	6.6 km	27.1 km
Road Surface Type	Unsealed (Earth)	Unsealed (Earth)	Unsealed (Earth)	N/A
Proposed Intervention Type	Reconstruction	Reconstruction	Reconstruction	N/A
Mobilisation Cost for Each Road Section	VUV 5,000,000	VUV 5,000,000	VUV 2,000,000	VUV 12,000,000
Cost for Carriage Way Works for Each Road (VUV)	VUV 5,000,000	VUV 5,250,000	VUV 3,300,000	VUV 13,555,000
Estimated Number of Drainage Structures (Culverts) Per Road - Assumed Every 400m	24	26	17	67
Unit Culvert Costs (VUV) - Based on MCA Past Cost	VUV 300,000			
Estimated Cost for Cross Drainage Per Road (VUV)	VUV 7,200,000	VUV 7,800,000	VUV 5,100,000	VUV 20,100,000
Total Estimated Intervention Costs for Each Road (VUV)	VUV 17,200,000	VUV 18,050,000	VUV 10,400,000	VUV 45,650,000

During the road inspection conducted in 2013, the most degraded areas noted were the steepest sections of the 'hilly roads' and the watercourse crossings. During heavy rain, light 4WD vehicles struggle to negotiate these sections of the road sections and heavier vehicles (light trucks) are simply not used.

Vanuatu PWD has previously constructed some concrete tracks for two hilly sections of North Epi: Vaimali Hill (about 150m long x 3m wide) and Wenia Hill (150m X 3m wide). For these construction activities, PWD trained the local labour force rather than using Port Vila contractors. Figure 9 provides some illustrations of the construction activities and local training.

Figure 9 Illustration of the work conducted by PWD to construct concrete tracks and train local labour (Ian Lercet / PWD 2013)

The inspection found that these works greatly improved accessibility to these road sections, but also that a large part of the network is lacking this type of improvement. The inspection also included the lack of erosion control measures to maintain access at watercourse crossings, landslide controls and degradation of the track surface.

The lack of machinery and construction materials on the island is a significant barrier to a corrective maintenance program. In some instances, local drivers have dumped materials (sand, gravel and soil) in the holes as a temporary fix to the potholes in the roads.

During extreme weather conditions, such as a storm surge or extreme rainfall, damages occur on the road network in the form of shallow landslides on the hilly roads and fallen boulders on the coastal roads. If the damage is minor, the community usually clears the road with hand tools. If the damage is extensive, (e.g. large boulders that cannot be removed by hand, or large landslides) the community contacts PWD, which then organises an 'emergency repair'. If the ship to transport PWD machinery is unavailable, it can take up to three months to repair the road.

3.2.3 Current and past climate

The climate of Epi Island is typically tropical with monsoonal influences. Mean air temperature shows some seasonal variations with a slightly cooler period between June and October. Mean rainfall is influenced by the monsoon with the wet season between November and April (the highest rainfall between January and March) and the dry season between May and October; annual rainfall amounts to over 2,200 mm at Port Vila (see *Limits*). There is marked inter-annual rainfall variability.

Analysis of weather monitoring data at Port Vila indicates a warming trend during the second half of the 20th century, while rainfall data exhibits no significant trends over the same period. Sea level measurements (tide gauge data is available since 1993) indicates a significant rising trend of over 8 mm per year (BoM/CSIRO, 2011).

Between 1970 and 2010, 94 tropical cyclones passed within 400 km of Port Vila with a very high year to year variability. Due to the high variability of tropical cyclones and relatively sparse data, it is impossible to determine any historical trends (BoM/CSIRO, 2011).

3.2.4 Future climate

The following two sections highlight key trends for gradual changes and extreme event patterns. Table 25 provides a synthesis of the key trends.

Gradual changes

Air temperature is projected to continue to increase during the 21st century over Vanuatu; there is a very high degree of confidence in the direction of that trend and a high degree of confidence in the magnitude of that trend. It is projected that mean air temperature should slightly increase by 2030 (less than 1°C) with a marked increase toward the end of the century with up to + 2.5 °C by 2090 (BoM/CSIRO, 2011).

Mean rainfall is projected to increase during the wet season (an increase is also projected for the annual mean) and decrease for the dry season; there is moderate confidence in the direction of that trend and a moderate degree of confidence in the magnitude of that trend. The models show little change by 2030 (less than 5%) and the majority of the models show a change of more than 5% by 2090 (both for increase and decrease). The analysis notes that it is impossible to determine if there will be changes in the inter-annual variability of rainfall (BoM/CSIRO, 2011).

It is expected that mean sea level will continue to rise between 5 cm and 15 cm by 2030 and between 20 cm and 60 cm by 2090. There is a very high degree of confidence in the direction of that trend and a moderate degree of confidence in the magnitude of that trend (BoM/CSIRO, 2011).

Changes in extreme patterns

The intensity and frequency of days with extreme heat is projected to increase; there is a very high degree of confidence in the direction of that trend and a low degree of confidence in the magnitude of that trend.

Both the intensity and the frequency of extreme rainfall are expected to increase throughout the 21st century; there is a high degree of confidence in the direction of that trend and a low degree of confidence in the magnitude of that trend.

There are no projected changes in the incidence of drought over Vanuatu with a low confidence in the projections of future drought conditions. Moderate and severe drought occurrences should remain relatively stable during the 21st century. Climate projections exhibit a decrease in the number of tropical cyclones with a possible increase of the most severe events (BoM/CSIRO, 2011).

Table 25 Synthesis of key trends

Variable	2030		2055		2090		Confidence
	Medium	High	Medium	High	Medium	High	
Surface Air Temperature (°C)	+ 0.7 ± *0.4*	+ 0.7 ± *0.3*	+ 1.4 ± *0.6*	+ 1.4 ± *0.3*	+ 2.2 ± *0.9*	+ 2.6 ± *0.6*	Very High/ High
Mean Annual Rainfall (%)	+ 2 ± *9*	+ 2 ± *6*	+ 5 ± *10*	+ 4 ± *9*	+ 9 ± *11*	+ 9 ± *12*	Low/Low
Wet Season Rainfall (%)	+ 2 ± *11*	+ 1 ± *17*	+ 3 ± *15*	+ 3 ± *16*	+ 3 ± *19*	+ 8 ± *20*	Moderate/ Moderate
Dry Season Rainfall (%)	+ 1 ± *20*	- 2 ± *22*	- 1 ± *24*	- 1 ± *27*	- 5 ± *25*	+ 2 ± *31*	Moderate/ Low
Sea Level Rise	Between 5 cm and 15 cm		N/A		Between 20 cm and 60 cm		Very High/ Moderate

Variable	2030		2055		2090		Confidence
	Medium	High	Medium	High	Medium	High	
Maximum Temperature (ARI 20/°C)	N/A		+1.5 ± *0.7*	+ 1.5 ± *0.5*	+ 2.0 ± *1.9*	+ 2.3 ± *1.8*	Very High /Low
Extreme Rainfall (ARI 20)	N/A	N/A	+ 15 mm for ARI 20	N/A	N/A	+ 25 mm for ARI 20 / ARI 20 becomes ARI 4	High/ Low
Drought	8-9 mild droughts every 20 years / No changes to severe droughts		N/A		7 to 8 mild droughts every 20 years / No changes to severe droughts		Low
Tropical cyclones	Possible decrease in the number of tropical cyclones with a possible increase in the occurrence of the most severe tropical cyclones.						Moderate/ Moderate

Note: Medium emission scenario is A1B; high emission scenario is A2. Projections are given for three 20-year periods centred on 2030 (2020–2039), 2055 (2046–2065) and 2090 (2080–2099), relative to 1990 (1980–1999). Values represent the multi-model mean change ± twice the inter-model standard deviation (representing approximately 95% of the range of model projections), except for sea level where the estimated mean change and the 5–95% range are given (as they are derived directly from the Intergovernmental Panel on Climate Change Fourth Assessment Report values). For more details see BoM/CSIRO, 2011.

Data sources

There is no weather monitoring station on Epi Island. The closest station with continuous and a robust data set is located at Bakersfield Airport in Port Vila (WMO number 91557, 17.70°S/168.30°E).

As part of the Pacific Climate Change Science Program, the *Climate Change in the Pacific: Scientific Assessment and New Research Volume 1 and Volume 2* (BoM/CSIRO, 2011) was published. This report provides an overview of past and future climate in the region with relatively detailed country profiles. The research and analysis used to develop this report was coordinated by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Australian Bureau of Meteorology (BoM). This report is available online, and represents the best available information for the project.

Limits

The lack of available information from Epi itself, presents a gap in the understanding of the specific local weather patterns, and any observed trends. On this basis any trend information is derived from the Bakersfield station as noted above. In addition, climate projections are associated with a number of important uncertainties including:

- Uncertainties with the emissions scenarios. Emissions scenarios are based on plausible estimates of development levels, population and per capita future emissions. By definition, these will be uncertain at both the local and global scale.
- Uncertainties associated with climate modelling and climate scenarios. Climate models are the best available tools to estimate what the future climate is likely to be. However, some of the biophysical and chemical processes are poorly represented in climate models as a result of the inability to represent or simulate some key processes (e.g. carbon-cycle responses, ice sheets, permafrost melt, ocean convection, atmospheric convection), particularly feedback processes.
- Downscaling uncertainties. There is no consensus on how to best downscale the results from coarse-resolution global climate models to regional and local scales for use in impact and risk assessments.

3.3 Problem Analysis - ‘without adaptation’

3.3.1 Risk Framework

The original PACC project did not follow a risk management process. The relevant information had been collected and considered by the project team, but the analysis was not undertaken using a risk management analytical framework. During the PACCSAP CBA and climate risk management training, delivered to PWD staff in Port Vila in June 2014, the key risks were collectively documented. Table 26 contains the likelihood and consequence ratings presented in Appendix A. The risk matrix was used during the training session and reviewed and agreed for use in this case study with PWD.

Table 26: Risk matrix

		Consequences				
		Insignificant (1)	Minor (2)	Moderate (3)	Major (4)	Catastrophic (5)
Likelihood	Almost certain (5)	Medium (5)	Medium (10)	High (15)	Extreme (20)	Extreme (25)
	Likely (4)	Low (4)	Medium (8)	High (12)	High (16)	Extreme (20)
	Possible (3)	Low (3)	Medium (6)	Medium (9)	High (12)	High (15)
	Unlikely (2)	Low (2)	Low (4)	Medium (6)	Medium (8)	Medium (10)
	Very Unlikely (1)	Low (1)	Low (2)	Low (3)	Low (4)	Medium (5)

3.3.2 Risk Identification

During the risk identification phase, two main infrastructure components were considered: The **"Coastal Road"** from Nuvi (as shown in Figure 10) is located between the coastline and the foot of the steep ridge running in the eastern part of Epi Island.

Figure 10 Illustration of the "Coastal Road" (Google Earth and I. Iercet)

The **"Hilly Road"** section connects Nuvi with Nevin, Moriu Station and Lamen Bay, Niku and Nevin. These sections of unsealed road are built in steep parts of the islands (up to >25%) and cleared through the dense vegetation (Figure 11).

Figure 11 Illustration of the "Hilly Road" (Google Earth and I. Iercet)

During a group exercise these two infrastructure components were assessed for their ‘sensitivity” against various climate variables and climate extremes, by flagging where there was a potential relationship between a particular project component and a particular climate driven hazard (see Table 27 for the results from the exercise).

Table 27: Risk screening matrix used for the project

		Component	
		Coastal Road	**Hilly Road**
Sea	**Sea level rise**	××	-
	Storm surge	××	-
	Surface temperature	-	-
	Ocean Acidity	-	-
	Currents	×	-
Rainfall	**Annual average rainfall**	-	×
	Extreme rainfall events (flooding)	××	××
	Drought	-	-
Temperature	**Annual average temperature**	-	-
	Extreme temperature events	-	-
Atmosphere	**CO_2**	-	-
Wind	**Cyclones**	××	××

Strong relationship (or uncertain)	××
Potential relationship	×
No apparent relationship	-

The results of the risk identification were then used to develop the risk scenarios. Risk scenarios were collaboratively developed using a “condition consequence” format. Given a certain condition (typically mediated by a climate driven hazard), a particular consequence could result. The results of this exercise are presented in Section 3.3.3

3.3.3 Risk Analysis

#	Risk Statements	Risk Level	Score	Likelihood	Likelihood Statement	Consequence	Consequence Statement
1	**With sea level rise and changes in tropical cyclone intensity, there is a greater risk of boulders overtopping on the road (Coastal Road)**	**Medium**	8	Likely (4)	The projected increase in sea level rise and tropical cyclone intensity is likely and could reach about 15 cm. This occur about 1 in every 3 years.	Minor (2)	When a storm occurs, a large number of boulders wash onto the road causing disruptions. The villagers have to clear the boulders by hand. If there are very large boulders, the road might be closed for a couple of days. This is a moderate storm.
2	**With sea level rise and changes in tropical cyclone intensity, there is a greater risk of boulders overtopping on the road (Coastal Road)**	**High**	12	Possible (3)	The projected increase in sea level rise and tropical cyclone intensity is likely and could reach about 15 cm. Large storms/cyclones occur about 1 in every 10 years.	Major (4)	When a storm occurs, a large number of boulders wash onto the road causing disruptions. The villagers have to clear the boulders by hand or wait for PWD to come and clear it for them. They could wait up to 1 month during emergency. If there are very large boulders, the road might be closed and they have to use the boat. This is a very large storm with most trees down and significant damage.
3	**With sea level rise and changes in tropical cyclone intensity, there is a greater risk of the road structure being damaged and deteriorated (Coastal Road)**	**Medium**	9	Possible (3)	The projected increase in sea level rise and tropical cyclone intensity is likely and could reach about 15 cm. Large storms/cyclones occur about 1 in every 10 years.	Medium (3)	During large cyclones or large storms, the streams overflow and wash away the pavement and dig out the top layer of the road. Villagers have to either go around if the road surface becomes too deep (>2m) or fill it with boulders, coronus material and sand. The road would be closed up to 1 week, without any requirement for temporary repairs by PWD.
4	**There is a slight increase in mean rainfall which would contribute to the road being slippery and more difficult to climb (Hilly Road)**	**Low**	5	Almost Certain (5)	This is currently occuring several times per year and the likelihood would remain similar with climate change (slight increase in mean rainfall).	Insignificant (1)	Vehicles struggle to get up the road; extra people are required to assist in getting the vehicles through particular trouble spots but access is normally not restricted.

#	Risk Statements	Risk Level	Score	Likelihood	Likelihood Statement	Consequence	Consequence Statement
5	**With a projected increase in extreme rainfall intensity (+15 mm) there is a greater risk of landslides (Hilly Road)**	**High**	12	Possible (3)	Landslides do not occur every year; currently a landslide occurs once every 5-6 years. With a projected increase in both mean rainfall and extreme rainfall there could be a higher likelihood of landslides.	Major (4)	For large landslides covering the whole road (several landslides > 20m), local communities call PWD and assess the damages. If the community can do it by themselves they clear the land (PWD pay the community about 200,000 to 300,000 Vatu). If they cannot fix it themselves, PWD needs to send machinery, pay for fuel and labour (about 2,000,000 Vatu). The road could be closed for one week if the community fixed it or up to 1-3 months if PWD has to fix it.
6	**With a projected increase in extreme rainfall intensity (+15 mm) there is a greater risk of surface water runoff on the road which makes access impracticable or may even even close the road**	**Extreme**	20	Almost Certain (5)	This is currently occurring up to 30 days over the 6 months wet period every year. With a projected increase in extreme rainfall, the likelihood will remain as almost certain.	Major (4)	The traffic is stopped or drops from 10 trucks/day to 1-2 trucks/day for trucks that are more powerful and better equipped.
7	**With a projected increase in cyclone intensity, there is a greater risk of road obstruction with debris, fallen trees and landslide**	**Medium**	9	Possible (3)	The projected increase in sea level rise and tropical cyclone intensity is likely and could reach about 15 cm. Large storms/cyclones occur about 1 in every 10 years.	Medium (3)	During large cyclone events, trees fall on the road and can obstruct the road. Lots of debris blocks the road and needs to be cleared away. Access is compromised. The community is hired to clear the road of debris (300,000 Vatu). The road would be closed for up to one week.
Road closure:		People cannot access the market, hospital and health centre, airport, school, ships and banks. There is major disruption to local livelihoods. People can walk but they are required to carry goods by hand. It takes 3-4 hours to walk from Nuvi to Rovo Bay though the bush. If the road is closed for a few days this is more of a nuisance. If the road is closed for a week, this can become a problem for people in need of medical attention (in one instance one baby was delivered on the side of the road at the bottom of the hill). In a few instances people could not reach the hospital and resulted in casualties. If the road is closed for one month or more, there can be significant implications for the local economy as people cannot send their goods to the market or the boat.					

3.3.4 Risk Evaluation

The risks considered to be the most threatening and requiring some form of treatment include:

- Risks to the Coastal Road (3.2.2) as a result of sea level rise and severe tropical cyclones (risk #2).
- Risks to the Hilly Road (3.2.2) as a result of more intense extreme rainfall and associated landslides and enhanced road degradation (risk #5 and risk #6).

3.4 Solution Analysis - Adaptation options

In response to the identified challenges a series of adaptation measures have been selected for implementation under the PACC project as shown in Table 28, Figure 12 and Figure 13. These activities have been documented in internal project documentation “PACC Implementation Report Cost and Design” provided by PWD through Ian Iercet. Internal documentation includes a description of the activities, concept design, early costing and a short environmental assessment of the proposed activities. This information was used to undertake the detailed CBA for the PACC road activities.

These solutions largely include infrastructure upgrades to the existing unsealed road network. The proposed activities include the construction of concrete slab in steep sections of the Hilly Road and for waterway crossings. The concrete slabs will greatly reduce the degradation of the top layer of the track during heavy rainfall and avoid the problems associated with vehicle getting bogged down in soft soil. The construction of road drains and culverts will improve the drainage of surface water and some debris away from the unsealed road and further reduce the issues associated with surface degradation of the tracks. All these upgrade will contribute to a greater number of all-weather roads in North Epi and allow both light trucks and light vehicles to travel on these roads during and after heavy rainfall events.

These proposed activities directly address risks #5 and #6 listed above. They will also address risk #4.

The construction of a new unsealed road (also with concrete slaps and drainages infrastructure) between Nuvi and Nevin will greatly improve access for communities currently located in the north-east coast of North Epi. This new road will provide alternative access when the Coastal Road is cut off or difficult to negotiate because of large boulders.

This activity will directly address risks #5 and #6 on that section of road but also indirectly address risks #1, #2 and #3 (but noting that some of the communities and households located along the coast between Nuvi and Moriu station might still experience difficulties).

Table 28 List of the proposed PACC road activities (PACC /PWD 2014)

Types of climate proof structures	Location	
Concrete slabs on steep hills including drainages	Mapuna	Wainia
	Foreland	Walafea
	Vaemali	Malvasi
Causeway slab on river crossings including drains.	Lamen Bay	Forland
	Walavea	Moriu
	Rovo Bay	Nikaura
	Malvasi	Nivenue
Culvert crossings including drains/points/outlets	Lamen Bay	Rovo bay
	Wainia	Mapuna
	Walavea	
Road including drains	New road relocation & Lamen Bay to Foreland	
Bridges	Yevali River	

Figure 12 Map of the proposed PACC Road activities (PACC / PWD 2014)

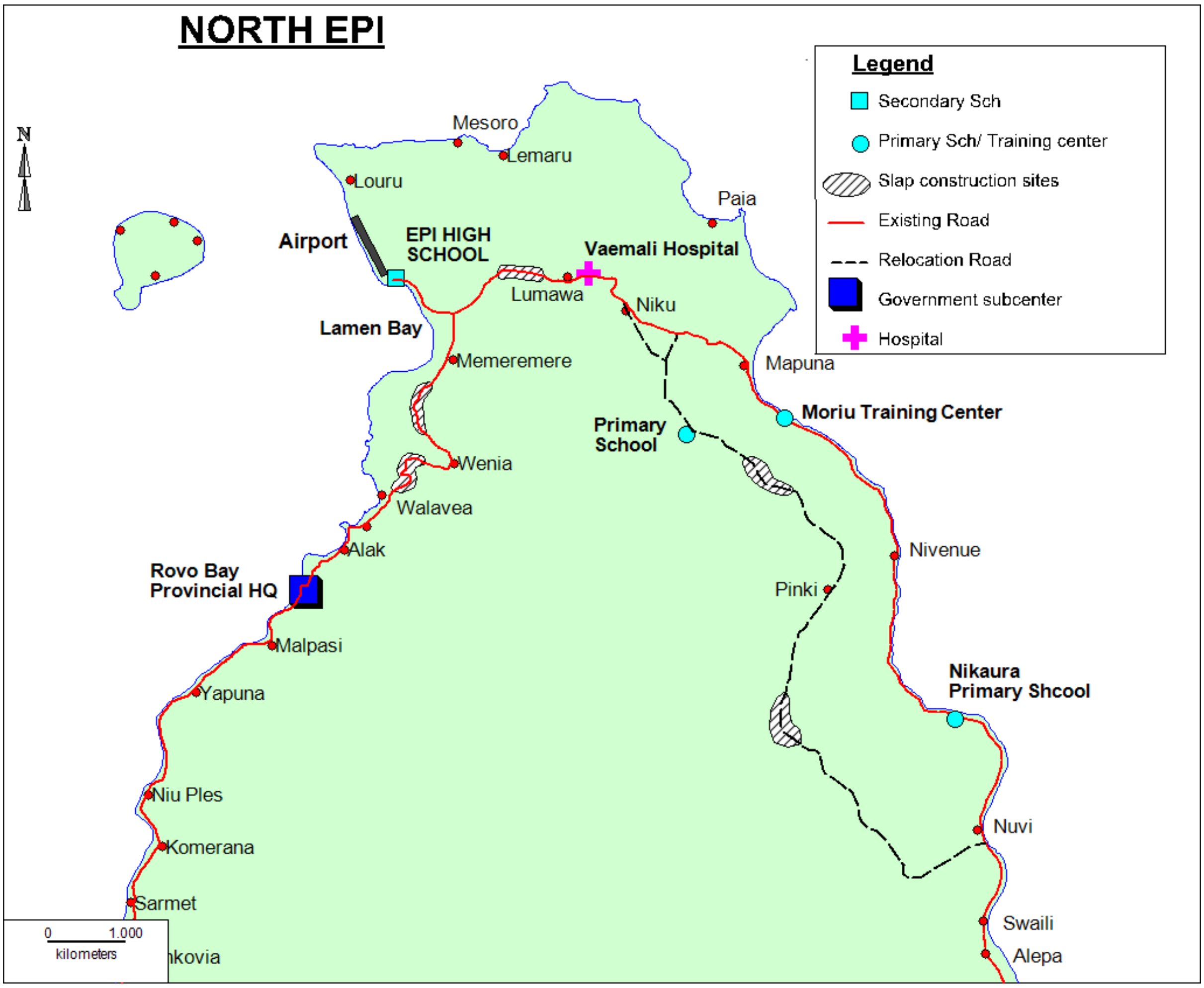
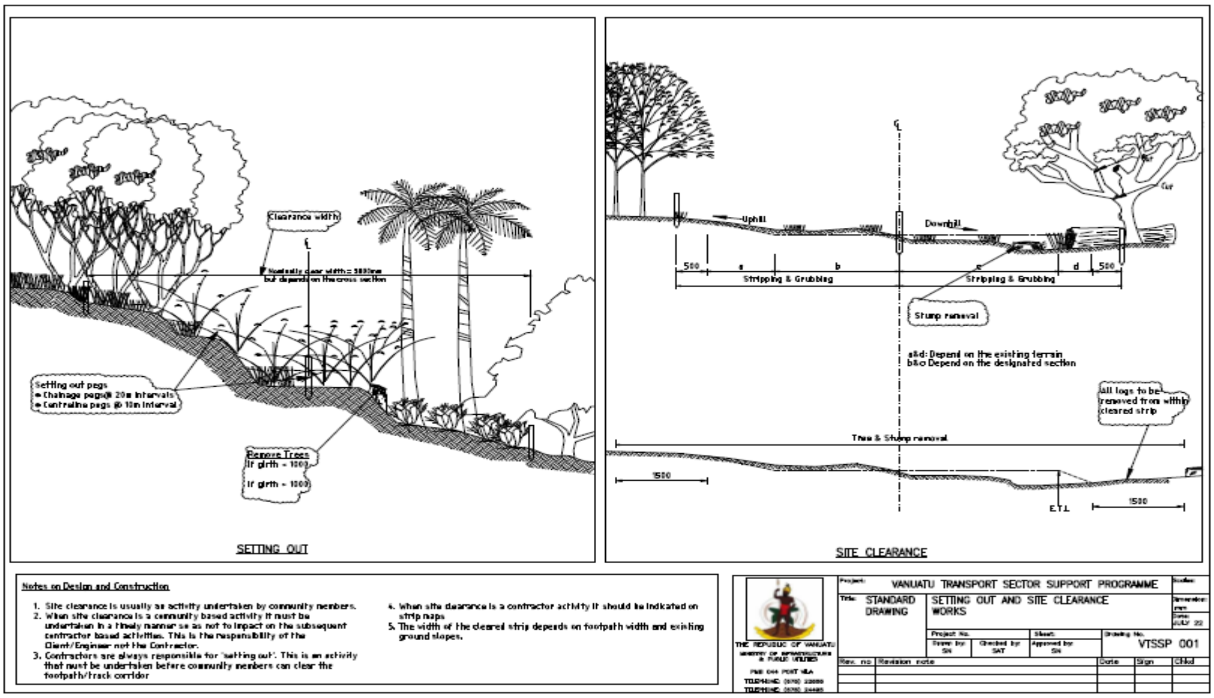
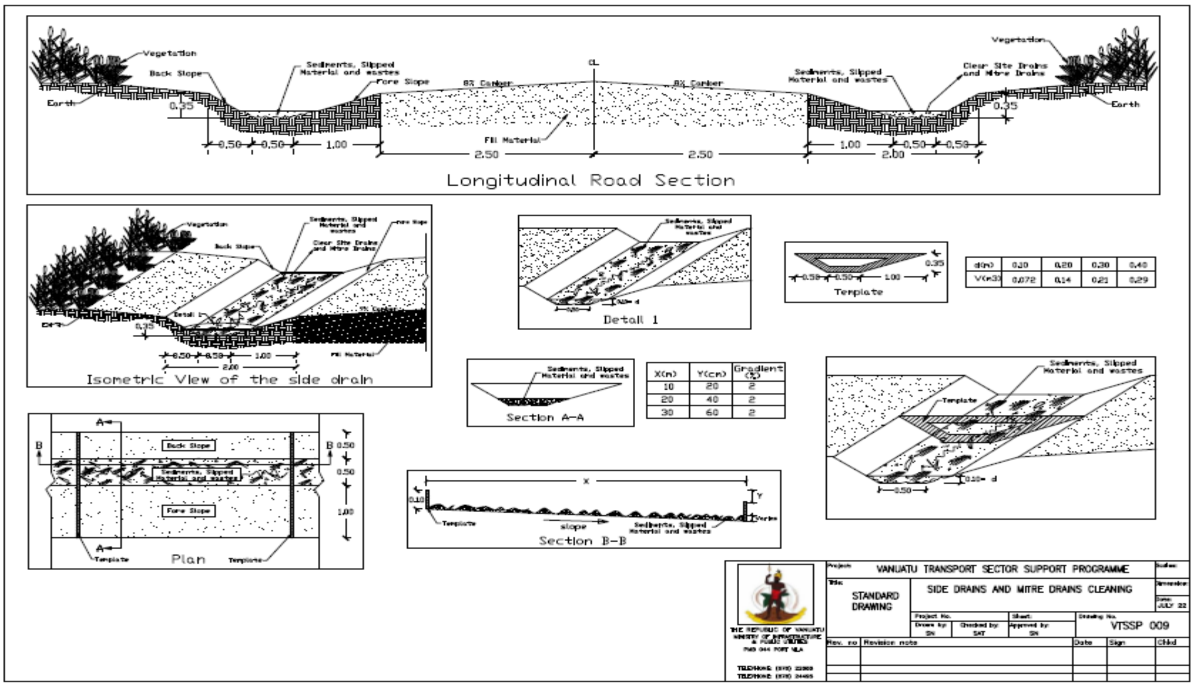


Figure 13 Concept design of the various PACC Road activities (PACC / PWD 2014)

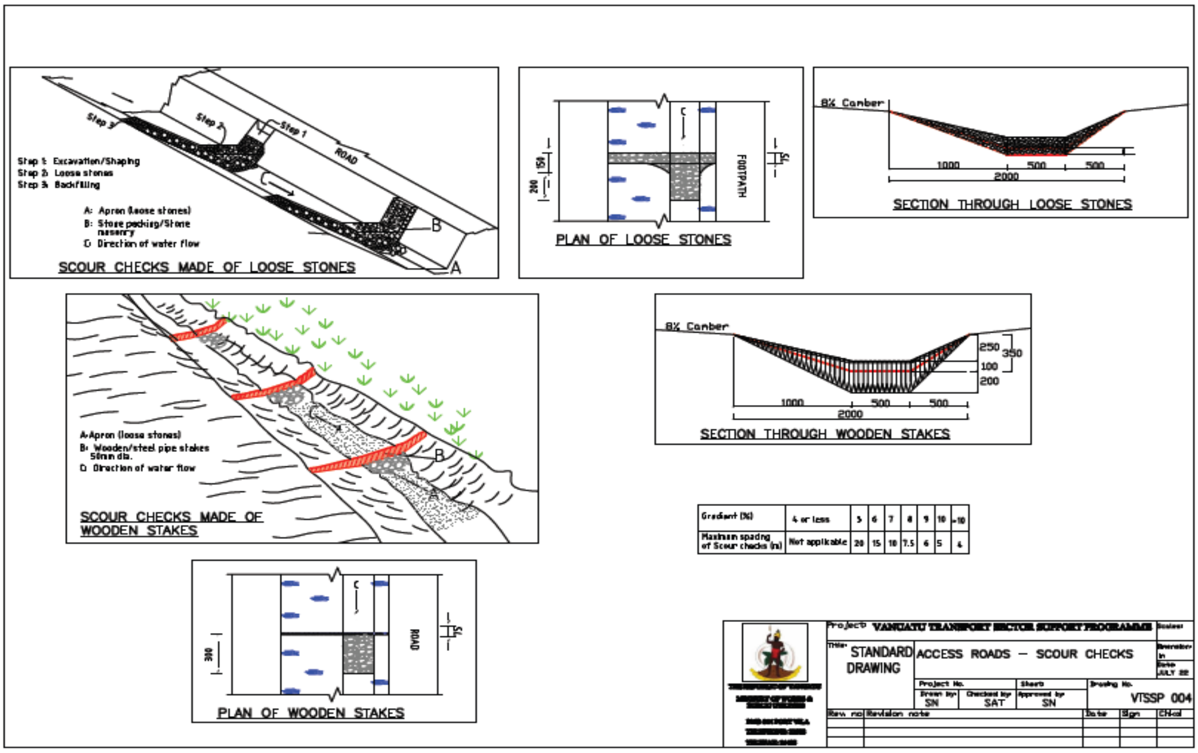
Road Clearance



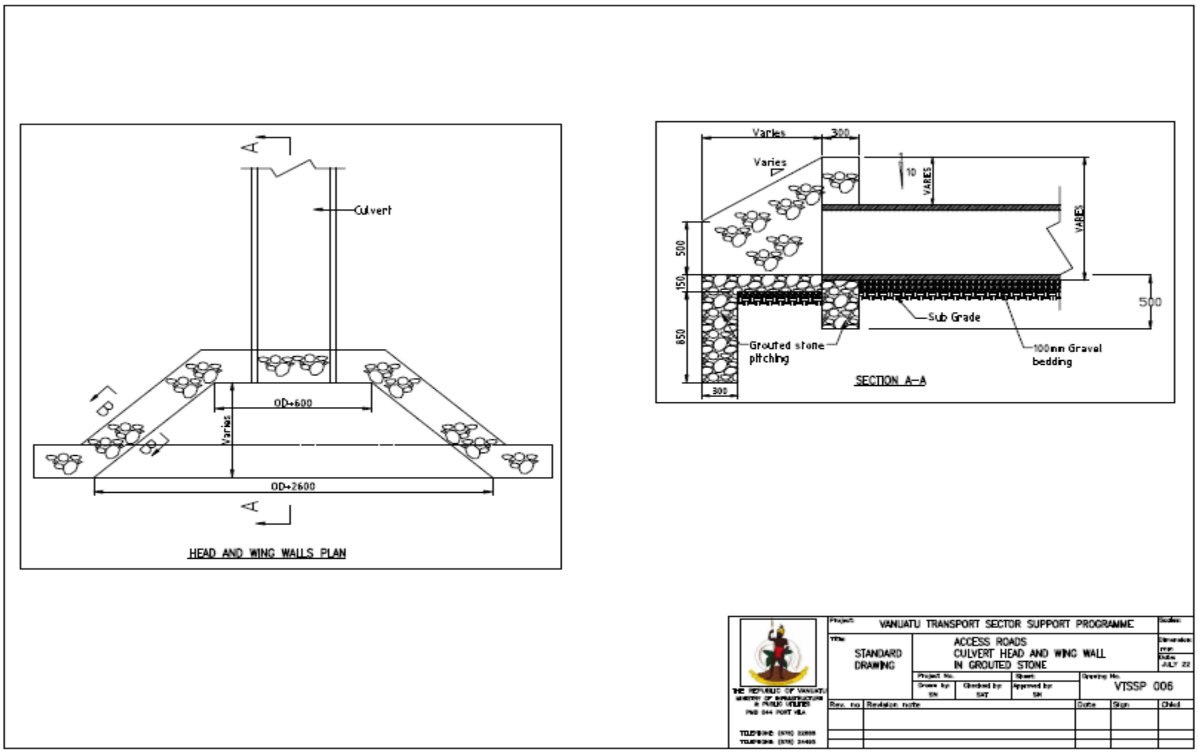
Road Cross Section & Side Drains



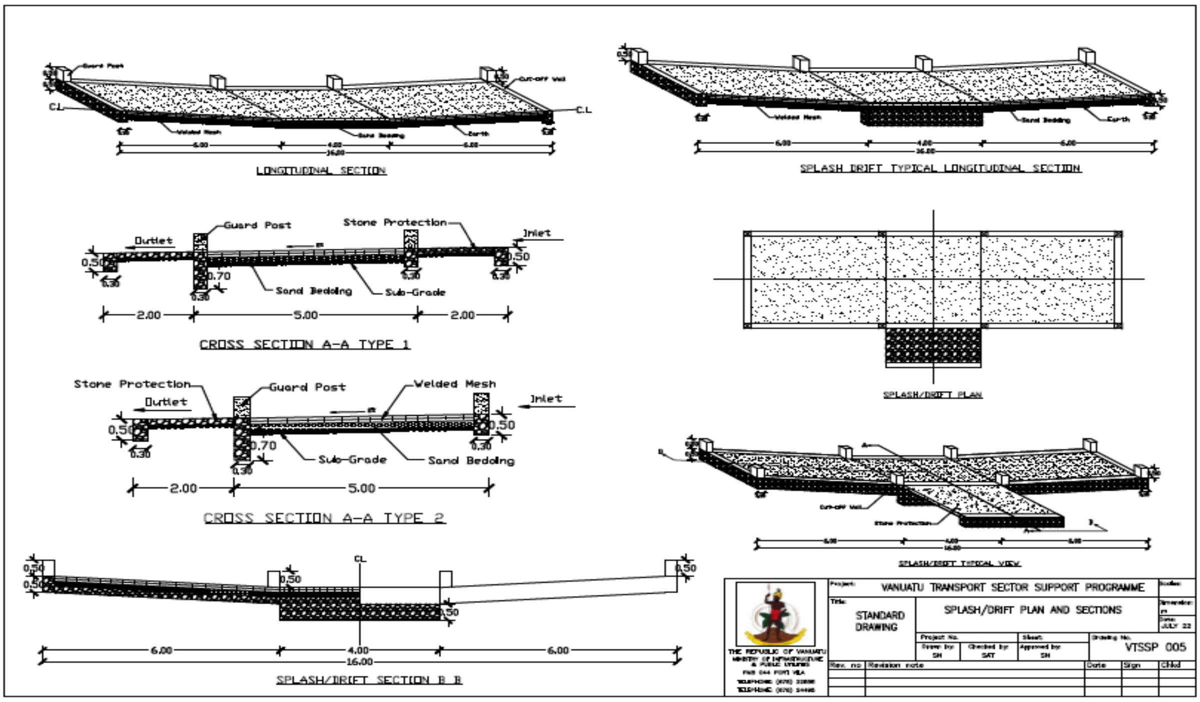
Erosion Control Scour Checks



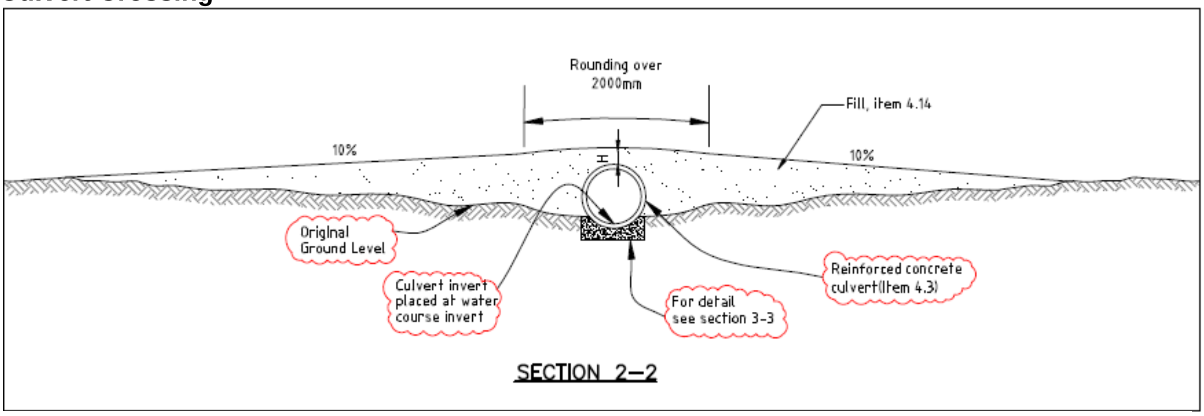
Culvert Headwall & Wing wall



Slash & Drift Crossing



Culvert Crossing



S/N	Culvert Diameter, O.D (mm)	Excavation Width, B (mm)	Excavation Depth, D (mm)	Space between multiple culverts, Min. (mm)	Minimum fill Cover, H (mm)	Bedding Material (mm)
1	450	OD + 600	Varries	150	300	Gravel (item 5.2), Sand (item 4.14) Class lean concrete (item 4.11.1)
2	600	OD + 600	Varries	300	400	Gravel (item 5.2), Sand (item 4.14) Class lean concrete (item 4.11.1)
3	900	OD + 600	Varries	450	500	Gravel (item 5.2), Sand (item 4.14) Class lean concrete (item 4.11.1)
4	1000	OD + 600	Varries	600	600	Gravel (item 5.2), Sand (item 4.14) Class lean concrete (item 4.11.1)
5	1200	OD + 600	Varries	600	700	Gravel (item 5.2), Sand (item 4.14) Class lean concrete (item 4.11.1)
6	1500	OD + 600	Varries	600	800	Gravel (item 5.2), Sand (item 4.14) Class lean concrete (item 4.11.1)

TABLE FOR VARIOUS CULVERT SIZES

3.5 Decision Support - Quantitative CBA of Epi Road Project

Quantitative CBA of PACC Road Activities options involved assessing the benefits derived from implementing the measure, net of its costs, (‘with’ adaptation scenario) and comparing these with the net benefits of ‘business as usual’ with climate change but ‘without adaptation’, including changes in non-climatic risks.

Where short listing resulted in only one desired option, detailed CBA helped assess the economic viability of the selected initiative. The application of CBA to assess economic viability of the improved road network is demonstrated in the following sections, utilising ‘without’ and ‘with’ CBA.

3.5.1 ‘Without’ adaptation scenario – PACC Road Activities

To determine the ‘without adaptation’ costs, the impacts of weather and climatic events were assessed. This included assessing expected costs associated with respective weather and climatic scenarios, together with the likelihood of the respective weather and climatic scenarios occurring.

To determine ‘without adaptation’ impacts the annual loss associated with road closure were characterised and, where possible, quantified (see Table 29). This included quantifying the loss associated with the transport and agriculture sectors. The data gaps for the health, education and employment/services were too significant to be quantified. Targeted surveys and primary data collection would be required to quantify impacts for these sectors (primary data collection was excluded from the scope of this study).

Table 29 Likely consequences for the ‘Without adaptation” scenario

	Unit	Outcome	Valuation method	PACC-EPI CBA
Transport	Number of truck-trips	Reduction of income of truck owners	Production method	Done
Domestic Trade (agriculture, fisheries)	Kava, bananas, yam, sweet potatoes; lobsters, crabs and fish	reduction in HH income	Production method	Done
Export Trade to Port Vila and beyond (agriculture, fisheries, handicraft)	Kava, bananas, yam, sweet potatoes; lobsters, crabs and fish; handicraft	reduction in HH income	Production method	Done
Health	N/A	suffering, death, increase in medical costs	Opportunity Cost	Not done
Education	N/A	missing school classes, affecting education of children; long walks through bush land	? (Non-market valuation)	Not done
Employment/ service	N/A	Loss of service (e.g. bank is closed)	? (Non-market valuation)	Not done

Impacts on Agricultural Production

The impacts on agricultural production were determined on a daily basis and multiplied by the expected number of days during which road is not usable (i.e. when the transport infrastructure cannot perform the desired service). The characterisation of the impacts of road closure was undertaken through engagement with local stakeholders (PWD and representatives from Epi Island) as well as some of the Port Vila companies buying goods from Epi Island. The agricultural products are either sold at the Rovo Bay market (cash crops) or exported to Port Vila (Kava) or Santo (Copra; the product is partially processed on Epi prior to export). The results are shown in Table 30.

Table 30 Likely consequences for the 'Without adaptation" scenario

					Kava	Copra	
Hazard	**Likelihood**	**Annual probability**	**Sectors affected**	**Effect**	**Total Annual cost**	**Value of Copra bought per day**	**Total Annual cost (Copra)**
Coastal-storm surge	1 in 3 year event	33%	Agriculture - domestic sales	Reduced income because of missed market days	VUV 140,000	-	-
			Agriculture - gift	not known	-	-	-
			Agriculture - export	Reduced export income because of missed market days	VUV 637,500	VUV 108,000	VUV 108,000
	1 in 10 year event	10%	Agriculture - domestic sales	Reduced income because of missed market days	VUV 1,400,000	-	-
			Agriculture - gift	not known	-	-	-
			Agriculture - export	Reduced export income because of missed market days	VUV 2,550,000	VUV 108,000	VUV 432,000
Rainfall & hilly roads	2 times a year	200%	Agriculture - domestic sales	Reduced income because of missed market days	VUV 140,000	-	-
			Agriculture - gift	not known	-	-	-
			Agriculture - export	Reduced export income because of missed market days	VUV 637,500	VUV 108,000	VUV 108,000

					Kava	Copra	
Hazard	Likelihood	Annual probability	Sectors affected	Effect	Total Annual cost	Value of Copra bought per day	Total Annual cost (Copra)
Rainfall & mild landslide	1 in 5 year event	50%	Agriculture - domestic sales	Reduced income because of missed market days	VUV 1,120,000	-	-
			Agriculture - gift	not known	-	-	-
			Agriculture - export	Reduced export income because of missed market days	VUV 637,500	VUV 108,000	VUV 108,000
Rainfall and extensive landslide	1 in 5 year event	50%	Agriculture - domestic sales	Reduced income because of missed market days	VUV 140,000	-	-
			Agriculture - gift	not known	-	-	-
			Agriculture - export	Reduced export income because of missed market days	VUV 5,100,000	VUV 108,000	VUV 864,000

3.5.2 'With adaptation' – PACC Road Activities

'With' PACC Road Activities the annual number of days with road closure (or inaccessible roads) would be greatly reduced from the current average of 30 days. It is expected that some of larger events which previously required 'emergency intervention' from PWD and could take up to three months, could now be cleared by the community, e.g. landslides. The damage to the roads is not expected to be significant and the road is not expected to be closed for more than one week. This represents a significant improvement compared to present conditions. It is though still expected that with climate change, PWD inputs may still be required, but less frequently.

Table 31 Likely consequences for the 'With adaptation" scenario

Hazard	Impact location	Scenario	Risk Statement	Likelihood	Assumed Likelihood (2030)	Adaptation	Consequence with adaptation	Risk score	Direct costs to consider	Impact on Livelihood	Impacts duration
Coastal - Storm surges	**Coastal roads**	Moderate storms	Storm surges & overtopping of boulders on coastal roads	1 in 3 year event (Likelihood score= 4)	1 in 3 year event (Likelihood score= 5)	Relocation of the road	Access Disruption Nil	10		Agricultural sales; health effects; work disruption; education disruption; walk through difficult terrain- 2-3 day	Nil
		Heavy storms	High storm surges & overtopping of boulders on coastal roads	1 in 10 year event (Likelihood score= 3)	1 in 10 year event (Likelihood score= 5)	Relocation of the road	No overtopping, etc.	15	Cost of repairs by PWD (from Vila)- 2 million Vatu	Agricultural sales; health effects; work disruption; education disruption; walk through difficult terrain- 4 weeks	Nil

Hazard	Impact location	Scenario	Risk Statement	Likelihood	Assumed Likelihood (2030)	Adaptation	Consequence with adaptation	Risk score	Direct costs to consider	Impact on Livelihood	Impacts duration
		Storm surges + heavy rainfall	Coastal Storm + heavy rain causing stream overflow, flooding and damage to pavement	1 in 10 year event (Likelihood score= 3)	1 in 10 year event (Likelihood score= 4)	Relocation of the road + pavement to cope with 1 in 30 year event	No access disruption	12	Cost of repairs by community - 200000 Vatu	Agricultural sales; health effects; work disruption; education disruption; walk through difficult terrain- 1 week	Nil
Extreme rainfall	**Hilly roads**	Wet and slippery roads	Heavy rain causing damage to roads, causing difficultly for trucks	2-3 times a year (likelihood score = almost certain-5)	2-3 times a year (likelihood score = almost certain-5)	Concrete pavement to cope with 1 in 30 year event	No access disruption.	5	Carry extra passengers to help push; extra fuel, etc.	Delays in travelling on each trip	Nil
		Landslides	Heavy rain causing landslides blocking access	1 in 5-6 years (likelihood - possible 3)	1 in 2-3 years (likelihood - possible 5)	Concrete pavement to cope with 1 in 30 year event	Landslides easy to clear using community labour.	15	Cost of repairs by community - 200000 Vatu	Agricultural sales; health effects; work disruption; education disruption; 3 hr walk through difficult terrain- 1 week	1 week

Hazard	Impact location	Scenario	Risk Statement	Likelihood	Assumed Likelihood (2030)	Adaptation	Consequence with adaptation	Risk score	Direct costs to consider	Impact on Livelihood	Impacts duration
		Landslides	Heavy rain causing landslides blocking access	1 in 5-6 years (likelihood - possible 3)	1 in 5-6 years (likelihood - likely 4)	Concrete pavement to cope with 1 in 30 year event	Landslides in small areas < 20m-use community labour; without access 1 week.	12	Cost of repairs by community - 200000 Vatu	Agricultural sales; health effects; work disruption; education disruption; 3 hr walk through difficult terrain- 1 week	1 week

3.5.3 'With and without adaptation' – PACC Road Activities

In summary, the implementation of upgrade activities to increase the number of all-weather roads will greatly improve access in North Epi all year round. The difficulties and access constraints currently experienced during the wet season will be significantly reduced. These activities will not only address future climate vulnerabilities but also help address current challenges. Specifically, improvements in the current quality of the road will result in better access, directly benefiting the local community via increased income from selling cash crop at the Rovo Bay market during the wet season and exporting copra to Santo and kava to Port Vila. These infrastructure upgrades will also have benefits for the health, education and employment/services sectors although as previously noted it is not possible to quantify these benefits. The following annual 'with and without' baseline profile is used to estimate economic costs and benefits of PACC road activities in relation to the agriculture and transport sectors (see Table 32 and Table 33).

Table 32 'With and without' Agriculture

Kava

	Discount rates		
	3%	5%	10%
Agriculture- Losses without adaptation	VUV 46,532,185	VUV 39,477,843	VUV 27,464,326
Agriculture-Residual losses with adaptation	VUV 6,624,526	VUV 5,587,602	VUV 3,831,014
Losses avoided (with and without adaptation)	VUV 39,907,659	VUV 33,890,241	VUV 23,633,311

Copra

	Discount rates		
	3%	5%	10%
Agriculture- Losses without adaptation	VUV 26,986,728	VUV 22,740,542	VUV 15,513,352
Agriculture-Residual losses with adaptation	VUV 563,706	VUV 471,755	VUV 315,571
Losses avoided (with and without adaptation)	VUV 26,422,021	VUV 22,268,786	VUV 15,197,781

Kava and Copra

	Discount rates		
	3%	5%	10%
Agriculture- Losses without adaptation	VUV 73,518,913	VUV 62,218,385	VUV 42,977,678
Agriculture-Residual losses with adaptation	VUV 7,189,232	VUV 6,059,358	VUV 4,146,856
Losses avoided (with and without adaptation)	VUV 66,329,680	VUV 56,159,027	VUV 38,831,092

Table 33 'With and without' adaptation Transport

	Without adaptation					With adaptation (No of days not accessible = 5)	
	Rovo Bay – Lamen Bay	Lamen Bay - Vaemali	Vaemali - Niku	Niku - Nikaura	Total (Lamen to Niku)	Rovo Bay – Lamen Bay	Niku to Lamen
No of vehicles per day (v)	12 (v)	12 (v)	5 (v)	5 (v)	-	12 (v)	5 (v)
No of days that cannot get through per year	30 (d)	30 (d)	120 (d)	120 (d)	-	5 (d)	5 (d)
No of vehicle-days lost	360 (v/d)	360 (v/d)	600 (v/d)	600 (v/d)	-	60 (v/d)	25 (v/d)
Vehicle hire charge	VUV 4000	-	VUV 6000	-	-	VUV 4000	VUV 6000
Cost of transportation income lost (Without adaptation)	VUV 1,440,000	-	VUV 3,600,000	-	VUV 5,040,000		
Cost of transportation income lost (With adaptation)						VUV 240,000	VUV 150,000

	3%	5%	10%
PV of lost transport earnings without adaptation	VUV 66,357,237	VUV 63,307,954	VUV 60,167,193
PV of lost transport earnings with adaptation	VUV 5,134,786	VUV 4,898,830	VUV 4,655,795
NPV (transport losses avoided)	VUV 61,222,451	VUV 58,409,124	VUV 55,511,398

3.5.4 'With and without' adaptation - Economic benefits and costs

The 'with and without' net benefits of climate change adaptation are assessed in terms of the changes in economic value derived by the community in improving the transport network with all-weather roads and a new road connection.

Economic cost of weather and climatic risks

The economic cost of the impact of extreme weather and climate events on road access are estimated using the expected frequency and intensity of extreme events under current and projected climate conditions. The costs are estimated in terms of the equivalent value of the loss of productivity in the agricultural and transport sectors. The costs of regular (planned) maintenance and the costs of repair following an extreme event are also considered.

Economic costs of non-climatic risks

The economic costs of non-climatic risks on the road network (such as increased road degradation with heavier vehicles and higher traffic volumes) have been considered either non-existent or negligible. Therefore they have not been included in this analysis.

Costs of interventions (improved road infrastructure) PACC Road Activities

The costs of the improved road infrastructure have considered two key scenarios. The first involves a scenario where all works are completed using local labour, and the second involves a scenario where the works are completed by a specialist contractor based in Port Vila. The costs of these two different scenarios are quantifiable, with the scenario involving the specialist contractor typically involving a greater upfront cost. The key economic benefits that flow from the improved road infrastructure in the analysis is characterised by savings in road maintenance costs as a result of the intervention.

Other intangible costs and benefits, for example the long term benefits to the local community from enhanced capacity building and skills in road construction under the local construction scenario, or the greater longevity that could result from an arguably higher standard of construction experience and technique under the Port Villa contractor scenario have not been considered in this analysis.

Table 34 Costs of the proposed activities

Types of climate proof structures	Location	Labour cost	Material cost	Total
Concrete slab on steep hills including drainages	Mapuna hill (400 m)	VUV 2,000,000	VUV 4,000,000	VUV 6,000,000
	Vaemali hill	VUV 700,000	VUV 1,300,000	VUV 2,000,000
	Wainia hill	VUV 500,000	VUV 700,000	VUV 1,200,000
	Walavea hill	VUV 500,000	VUV 700,000	VUV 1,200,000
	Malvasi hill	VUV 700,000	VUV 800,000	VUV 1,500,000
	Foreland	VUV 700,000	VUV 800,000	VUV 1,500,000
	Ngevin	VUV 500,000	VUV 700,000	VUV 1,200,000
	Nuvi nikaura hill	VUV 2,000,000	VUV 4,000,000	VUV 6,000,000
Causeway slab on river crossings including drainages.	Lamen Bay	VUV 100,000	VUV 150,000	VUV 250,000
	Walavea	VUV 100,000	VUV 150,000	VUV 250,000
	Rovo Bay	VUV 100,000	VUV 150,000	VUV 250,000
	Malvasi	VUV 100,000	VUV 150,000	VUV 250,000
	Forland	VUV 100,000	VUV 150,000	VUV 250,000
	Moriu	VUV 100,000	VUV 150,000	VUV 250,000
	Nikaura	VUV 100,000	VUV 150,000	VUV 250,000
	Nivenue	VUV 100,000	VUV 150,000	VUV 250,000
	New road relocation	VUV 600,000	VUV 1,000,000	VUV 1,600,000

Types of climate proof structures	Location	Labour cost	Material cost	Total
Culvert crossings including drains	Mapuna hill x 3	VUV 100,000	VUV 1,200,000	VUV 1,300,000
	New road relocation x 3	VUV 100,000	VUV 1,200,000	VUV 1,300,000
Bush clearing		VUV 7,000,000	VUV 5,000,000	VUV 12,000,000
Road formation including side drains and scour checks	**Relocated road network** Nuvi - Ngevin – Niku (11km)	**VUV 3,500,000**	**VUV 500,000**	**VUV 4,000,000**
Graveling	**Relocated road network** Nuvi - Ngevin – Niku 11km	**VUV 5,000,000**		**VUV 5,000,000**
Bridges	Yevali River	VUV 1,000,000	VUV 1,000,000	VUV 2,000,000
Mitre Drains	Vaemali hill	VUV 70,000		VUV 70,000
	Mapuna hill	VUV 140,000		VUV 140,000
	Wainia hill	VUV 70,000		VUV 70,000
	Walavea hill	VUV 70,000		VUV 70,000
	Forland hill	VUV 100,000		VUV 100,000
	Ngevin hill	VUV 50,000		VUV 50,000
	Nuvi nikaura hill	VUV 140,000		VUV 140,000
	Rovo bay hill	VUV 50,000		VUV 50,000

3.5.5 Quantitative CBA Results

The following tables compare the results of the analysis undertaken in the previous sections, using two key project standards (20 year and 30 year), as specified by the PWD. The tables present some of the key outputs of the CBA, including the Net Present Value (NPV), the Benefit Cost Ratio (BCR) under different scenarios, and applying different discount rates (3%, 5%, and 10%).

Applying a 1-in-30 year Road Standard

Table 35 Cost Benefit analysis of PACC Road Activities / 1-in-30 year Road Standard /Local Labour

NPV adaptation cost (using community labour)	Establishment + Maintenance (without taking into account PV of current maintenance costs without adaptation)	VUV 55,987,977	VUV 54,562,944	VUV 51,330,640
BCR (with community labour) - (real terms)	Without taking into account PV of current maintenance costs without adaptation	2.28	2.10	1.84
With and Without ' Costs of adaptation (NPV)		- VUV 79,571,356	- VUV 73,589,566	- VUV 60,876,648
		3%	**5%**	**10%**
NPV with adaptation, including 'with and without' maintenance costs of adaptation		VUV 207,123,487	VUV 188,157,717	VUV 155,219,139
BCR (taking into account maintenance cost savings from adaptation) (real terms)		**3.70**	**3.45**	**3.02**

Table 36 Cost Benefit analysis of PACC Road Activities / 1-in-30 year Road Standard /Port Vila contractor

		3%	**5%**	**10%**
NPV adaptation cost (Vila contract)	Establishment + Maintenance	VUV 66,020,801	VUV 64,225,368	VUV 60,177,778
With and Without' Costs of adaptation (NPV)	Establishment + Maintenance	- VUV 143,042,832	- VUV 133,415,242	- VUV 112,871,638
		3%	5%	10%
NPV with adaptation, including 'with and without' improvement +maintenance costs of adaptation		VUV 270,594,964	VUV 247,983,393	VUV 207,214,128
BCR (taking into account improvement + maintenance cost savings from adaptation (real terms)		**4.10**	**3.86**	**3.44**

Applying a 1-in-20 year Road Standard

Table 37 Cost Benefit analysis of PACC Road Activities / 1-in-20 year Road Standard/Local Labour

NPV adaptation cost (using community labour)	Establishment + Maintenance (without taking into account PV of current maintenance costs without adaptation)	VUV 43,975,841	VUV 42,779,611	VUV 40,082,913
BCR (with community labour)	without taking into account PV of current maintenance costs without adaptation	2.90	2.68	2.35
With and Without ' Costs of adaptation (NPV)		- VUV 91,583,491	- VUV 85,372,899	- VUV 72,124,376
		3%	5%	10%
NPV with adaptation, including 'with and without' maintenance costs of adaptation		VUV 219,135,623	VUV 199,941,050	VUV 166,466,866
BCR (taking into account maintenance cost savings from adaptation)		**4.98**	**4.67**	**4.15**

Table 38 Cost Benefit analysis of PACC Road Activities / 1-in-20 year Road Standard/Port Vila contractor

NPV adaptation cost (Vila contract)	Establishment + Maintenance	VUV 56,307,208	VUV 54,696,797	VUV 51,082,324
With and Without' Costs of adaptation (NPV)	Establishment + Maintenance	- VUV 152,756,425	- VUV 142,943,813	- VUV 121,967,092
		3%	5%	10%
NPV with adaptation, including 'with and without' improvement +maintenance costs of adaptation		VUV 280,308,556	VUV 257,511,965	VUV 216,309,583
BCR (taking into account improvement + maintenance cost savings from adaptation)		**4.98**	**4.71**	**4.23**

As noted above, other intangible cost and benefits, for example the long term benefits to the local community from enhanced capacity building and skills in road construction under the local construction scenario, or the greater longevity that could result from an arguably higher standard construction experience and technique under the Port Villa contractor scenario have not been considered in this analysis. From an economic analysis perspective while the Port Villa contractor option looks better, having a higher BCR (for both the 1-in-20 and 1-in-30 year road standard), it may not necessarily provide all of the ancillary community benefits, that the option using community labour offers.

Uncertainty analysis

The above CBA analysis is based on many assumptions of key parameter estimates that define the likelihood and consequence of unfavourable climatic and non-climatic events. There are many uncertainties in these parameter estimates because of poor or partial knowledge about the agricultural practices, actual benefits of the interventions on the transport and agriculture sectors and other sectors. Additional primary data collection would assist in removing some of these uncertainties, but were outside the scope of the current project. Sources of uncertainty in this study include:

- Missing time series data about past weather and climate conditions, past flooding, landslides and extreme rainfall. There is no operating weather monitoring station on Epi Island and there is no historical baseline on the various natural hazards, in particular, their location, intensity and frequency.
- Limits with climate models and understanding of hazards patterns, such as parameter values or dynamic and poorly understood systems (e.g. projections of changes and variability in daily/monthly/seasonal rainfall and storm surge incidence and intensity in Vanuatu and Epi Island).
- There is limited information on the existing road network conditions and the actual extent of damage and previous repair and maintenance activities on the island.
- Difficulties in determining the impact of proposed adaptation options on the road network (in terms of actual reduction in road closure) and the corresponding benefits for Epi communities.
- Reliance on specialist knowledge, engagement with local stakeholders and assumptions on the impacts, costs and benefits; this is due to the lack of detailed documentation and previous technical and scientific studies.

Different techniques are available for dealing with uncertainties, depending on the nature of the variables involved and associated uncertainty, and the availability of scientific information required to underpin such parameter estimates.

Ideally, sophisticated techniques, such as Monte Carlo simulation and real options analysis, are used if the probability distribution for values of the uncertain variable can be determined with confidence. In this case study, such approaches are not possible due to the lack of quantitative information. As a minimum, in the presence of uncertainty, sensitivity analysis can provide a more nuanced picture by varying key parameter values, and highlighting any significant aspects of the analysis.

Sensitivity analysis

Because of the nature of the data generated and the lack of empirical data (i.e. the absence of data range) a sensitivity analysis was not possible for this CBA.

Notwithstanding these limitations, both options returned high benefit to cost ratios, suggesting that for every dollar invested in the adaptation, in excess of four dollars would be generated (for the 20 year project), clearly demonstrating the value in undertaking the project.

References (Case Study 2)

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PART IV
LESSONS LEARNT

Australian Aid

4.0 LESSONS LEARNT

The application of a CBA framework in the two case studies has highlighted key challenges associated with applying CBA to climate change adaptation options in the Pacific; the data-poor environment and limited in-country capacity were amongst the greatest obstacles encountered during the analysis.

Climate change adaptation decisions are often made with imperfect information and only partial analysis. For instance, problem analysis does not always build on historical trends and future climate projections; there is often limited description of the analytical framework used to identify, analyse and evaluate risks; the adaptation options are proposed without clear explanation on how they respond to the issues previously identified; and the costs and benefits are partially considered but often not monetised or analysed

These various shortfalls affect the ability to replicate and compare risks and solutions across projects and activities.

The two case studies have also demonstrated that there is a growing awareness of CBA and climate change adaptation although the capacity of practitioners remains low. Key concepts and objectives are relatively well understood but the ability to undertake analysis independently is lacking.

The lessons learnt through this process (presented in summary form below) offer some ideas on how such challenges can be overcome:

1) **Even when quantitative CBA is not feasible (due to a lack of data) or suitable (due to the size of the project), applying CBA principles and a qualitative CBA provides valuable support to decision making.**

2) **Communicating the results of a CBA (quantitative or qualitative) is important for justifying decisions, and for advocacy, continuation and replication activities.**

3) **CBA and the analysis of climate change adaptation options can be complementary. Combining and integrating them in existing project processes, leads to more robust and transparent decisions addressing the most threatening risks (climatic and non-climatic).**

4) **Planning CBA at the early stages of a project is much more resource and time efficient compared with undertaking CBA later in the project when many parts of the project are fixed, and opportunities to obtain information may have passed.**

5) **Empirical data required for CBA and the analysis of climate risks can be gained by drawing on the technical and experiential knowledge of local stakeholders. Stakeholder engagement also helps to test assumptions and remove some subjectivity inherent to the analysis of climate change risks and CBA in an adaptation context.**

6) **Similar to other analytical frameworks, CBA highlights knowledge gaps.**

7) **Building capacity among PIC practitioners in the areas of economic analysis and the formal process of considering risk in a climate change context will improve project outcomes. Current projects suffer from a lack of in-country technical capacity in these areas meaning that in some cases the costs or benefits of particular decisions could be overlooked.**

8) **There is a strong synergy between the results of *expost* CBA and typical M&E (Monitoring and Evaluation) requirements.**

Lesson 1: Even when quantitative CBA is not feasible (due to a lack of data) or suitable (due to the size of the project), applying CBA principles and a qualitative CBA provides valuable support to decision making.

Detailed (quantitative) CBA may not always be feasible (e.g. when data gaps are too significant or there is no capacity) or suitable (when the costs of conducting a detailed assessment are not justified with regards to the project scope, budget and design life of the intervention).

Instead a qualitative CBA can be applied to identify (and describe with a narrative) the costs and benefits associated with climatic and non-climatic risks and adaptation options. Where qualitative assessments are undertaken the comparison will be more subjective. When undertaking a qualitative approach, it is important to clearly document the issues identified and the reasons supporting the decisions made.

For the Solomon Islands Case Study a preferred suite of adaptation options was selected without CBA. The application of a qualitative CBA confirmed that an improved agroforestry-based farming system is a good development strategy for hilly lands. For flat lands, and where households do not have access to hilly lands, conservation agriculture alone can also contribute to improving food security. The qualitative CBA also demonstrated that these interventions are likely to provide a net gain in food security and are economically feasible, with or without climate change.

Lesson 2: Communicating the results of a CBA (quantitative or qualitative) is important for justifying decisions, and for advocacy, continuation and replication activities.

Clearly documenting the process through which a CBA (either quantitative or qualitative) has been completed, is important in justifying the reasons why certain decisions are made. Recording the process is a useful tool to communicate the merits of different adaptation options to decision makers, the broader community and other stakeholders. Good communication about the CBA process and results can support advocacy efforts, continuation and replication of adaptation activities.

For the Solomon Islands Case Study, the results will be communicated to demonstrate the benefits of the SPC-USAID food security project and promote the continuation of the proposed agricultural improvements; this strengthens the case for implementing further activities for other Choiseul communities. A number of other development partners (e.g. the United Nations Development Program) are planning to deliver similar activities in Choiseul and other Provinces. These activities can build on the results of the CBA undertaken for the SPC-USAID food security project. The CBA also brought robustness to the decisions made for that project by demonstrating the net benefits delivered.

The CBA for the Vanuatu PACC+ project focused on infrastructure improvements. The benefits identified and analysed through the CBA have highlighted the relevance of these works. This will support ongoing and future infrastructure improvement projects in Vanuatu (such as the Climate Resilience Road Project) and the other activities delivered under the PACC+ project, by providing a framework for, and a reference of, the analysis of costs and benefits associated with infrastructure projects of this type.

Lesson 3: CBA and the analysis of climate change adaptation options can be complementary. Combining and integrating them in existing project processes, leads to more robust and transparent decisions addressing the most threatening risks (climatic and non-climatic).

The climate change adaptation process (through a structured consideration of and response to climate change risks), provides a solid basis in terms of situation analysis and problem analysis (making sure that the interventions focuses on the most threatening risks). CBA builds on the solution analysis (where a list of adaptation options is shortlisted) and provides a very detailed assessment of the benefits and costs of different adaptation options.

This can help in selecting the option most likely to generate highest returns net of costs (*exante CBA)*. CBA (*expost)* is also used to assess and report on the impact of a climate change adaptation project once it has been implemented.

While the analysis of climate change adaptation options can be undertaken separately to CBA, given that they both have common data requirements, it makes sense to complete them together to achieve the most reliable outcomes. By combining them, an explicit consideration of climatic and non-climatic risks during key stages of the project is also completed. This is particularly critical when the focus of intervention may not be specifically on addressing climate risks but rather on improving economic or social development. The results of which could be influenced by current and projected climatic and non-climatic risks.

The SPC-USAID project has previously included activities to assess key climatic risks but the Vanuatu PACC+ project did not sufficiently build on a comprehensive assessment of climate risks (even though adaptation activities have been implicitly selected to address these risks). For both case studies the PACCSAP project team applied a combined analysis of climate change adaptation options and CBA approach.

For the Solomon Islands Case Study, this combined approach highlighted that the current level of food security risk faced by households is related more strongly to population growth than it is to any climatic risks. This suggests that to achieve and sustain food security in Loimuni and Sepa, priority attention needs to be given to non-climatic risks. The combined approach also confirmed that the interventions being implemented are addressing key climatic risk (for example increased rainfall variability) and non-climatic risks (primarily population growth placing pressure on food security) and would provide net benefits.

For the Vanuatu Case Study, the PACCSAP project team had the opportunity to apply a combined analysis of climate change adaptation options and CBA approach and test its effectiveness due to the absence of previous analysis. The combined approach allowed for a very fast collection and processing of information (a few weeks) and a very logical analysis. Instead of applying climate change adaptation analysis and CBA in a sequential manner both analyses were explained simultaneously to stakeholders and undertaken in parallel; this also facilitated data collection with local stakeholders.

Lesson 4: Planning CBA at the early stages of a project is much more resource and time efficient compared with undertaking CBA later in the project when many parts of the project are fixed, and opportunities to obtain information may have passed.

A decision to use CBA-based ranking and selection of desired options would ideally be made well before the project is implemented, rather than as an afterthought. An early decision to use CBA would help to ensure that appropriate social, economic and environmental information is collected. The activities undertaken during project planning and other analysis (such as those required for the analysis of climate change adaptation options) could also be defined and scoped to provide direct inputs to the CBA, rather than requiring double handling of data and additional information processing.

To address climate change risks to food security in the Choiseul Province, contour-based farming had already been selected as a desired climate change adaptation option. This decision was made by several development partners, such as SPC-GIZ, UNDP and SPC-USAID, and supported by communities and government ministries. Demonstration projects were designed and implemented without necessarily undertaking explicit assessment of costs and benefits (qualitative or quantitative) of the activities under current and future conditions.

Consequently, only limited baseline empirical information about current weather and climate and non-climatic risks was collected. The problem and solution analysis was partially completed but did not provide readily available inputs for the PACCSAP CBA. This affected the ability of the project team to undertake quantitative and qualitative *exante* and *expost* CBAs. The project team needed to revisit the entire process; this included re-processing some of the data for the problem and solution analysis, and engaging with local project staff to 'generate' requisite information and empirical data for the CBA.

For the Vanuatu Case Study, the PACC+ project activities did not include CBA to inform a decision on the most appropriate adaptation options. Similar to the Solomon Islands Case Study, the project team also needed to re-process data and information and engage with local stakeholders to generate inputs for the CBA. The project had several opportunities to generate this information, but only if CBA had been incorporated in project activities.

Lesson 5: Empirical data required for CBA and the analysis of climate risks can be gained by drawing on the technical and experiential knowledge of local stakeholders. Stakeholder engagement also helps to test assumptions and remove some subjectivity inherent to the analysis of climate change risks and CBA in an adaptation context.

Often cost and benefit data/information is identified and discussed in development projects but is not systemically documented. In many cases it is possible to draw on technical and experiential knowledge of local stakeholders and technical staff to generate the empirical data required. The degree of confidence that can be placed on CBA results depends on (i) the available empirical data, (ii) the empirical data generated through further engagement with local specialists and the community, and (iii) the ability to cross-check these various sources of data.

Both the analysis of climate change adaptation options and CBA require a number of assumptions to be made to compensate for data gaps and as such will always contain some limitations and identified uncertainties. For instance, risk assessment is always a subjective exercise and the determination of some of the benefits can also be relatively subjective. Traditional knowledge should be used when seeking to gain an understanding of local conditions, testing assumptions underpinning the CBA and the climate change adaptation process. The engagement should aim to be objective, neutral and collegial to avoid bias in the respondents' inputs.

As information on existing characteristics of the social and economic environment was scarcely available, both case studies relied on extensive engagement with local stakeholders to supplement available information. For both case studies, local stakeholders provided inputs and comments on the assumptions made for the risk assessment (particularly in relation to the consequences) and the CBA (when characterising the costs of the impacts and the benefits of activities). This input was gathered through one-on-one exchanges with local stakeholders but also through group feedback sessions. These sessions highlighted the importance of engaging with multiple stakeholders when testing assumptions.

V&A assessment in the SPC-USAID project and earlier SPC/GIZ, SPREP and Government of Solomon Islands V&A assessment of communities in Choiseul Province generated some useful baseline line information. Quantitative information was compiled about many aspects of the socioeconomic characteristics of the communities (e.g. number of households, household size, current production, consumption of locally produced crops, marine foods and imported foods). Qualitative information about current weather and climatic risks was also documented.

While useful, this information was not sufficient to derive the economic values of 'with' and 'without' adaptation. This issue was overcome by drawing on the expertise of SPC-USAID technical persons (in particular local agricultural officers) with long standing experience in the Solomon Islands and Choiseul Province.

For example, the following information could not be identified in previous projects' documentation or other references and was generated through at least four discussions with local practitioners and stakeholders (two face to face discussions in country and two teleconferences):

- Frequency and intensity of flooding/landslides and droughts, and their subsequent impact on crop output.
- The value of crops produced from mixed gardens under current climatic conditions and current farming practice, and the price data collected from local markets or from the households buying/selling those crops.
- Expected decline in crop yields caused by the effects of non-climatic risk factors (increasing population growth-induced reduced fallow and other poor farming practices).

The PACC+ project documentation provided a reasonable level of information in relation to the proposed infrastructure improvements. Most activities included a simple work breakdown structure, budget estimates to carry out the activities (divided between labour and materials), concept designs and tentative locations. All of this information could be readily used to inform the CBA for the Vanuatu Case Study.

In addition, the following information was sourced through local stakeholders to inform the CBA:

- Frequency, duration and consequences of road disruptions (through heavy rainfall, storms and landslides).
- The monetary value of the transport and agricultural services to the local Epi communities.
- Qualitative information about health, education and employment services.

Lesson 6: Similar to other analytical frameworks, CBA can highlight knowledge gaps

Like other analytical frameworks (such as MCA or risk assessment), CBA can help to identify and characterise key knowledge gaps. With the application of CBA, gaps in knowledge about the extent of climate change impacts and the costs and benefits of adaptation can be better understood. These gaps can be explicitly acknowledged and documented during the CBA process.. If resources are available some of these gaps can also be filled.

The application of CBA in both case studies highlighted a wide range of gaps both in terms of climate change impacts and information on the selected climate change adaptation options. These gaps were addressed through engagement with local stakeholders (such as the costs of agriculture improvement activities in the Solomon Islands or the expected benefits of adaptation options for both case studies). Some of these gaps could not be addressed (such as quantifying the benefits of the road improvement activities on the health and employment sectors in the Vanuatu Case Study) but they were explicitly documented.

Lesson 7: Building capacity among PIC practitioners in the areas of economic analysis and the formal process of considering risk in a climate change context will improve project outcomes. Current projects suffer from a lack of in-country technical capacity in these areas meaning that in some cases the costs or benefits of particular decisions could be overlooked.

For many development and climate change adaptation initiatives interdisciplinary technical expertise is required to undertake analysis and complete the project. Economic analysis is largely delivered by international consultants and there are few local practitioners with the capacity to undertake CBA or other types of economic analysis.

Local project staff are often not familiar with CBA and the concept of climate change adaptation. To encourage systematic planning and adoption of CBA, training and support is needed to build capacity among staff involved in making decisions about future investment (be it in infrastructure, agricultural development, or other social policy areas) to carry out the activities required to complete the analysis of climate change adaptation options and CBA. It is also important for stakeholders to understand the limitations of CBA, particularly where non-market values are involved, and why a systematic application of the CBA framework is preferable to the lack of CBA to inform decisions.

Early engagement with local technical staff, who are often project proponents and designers, is useful when identifying sources of relevant data required for CBA. This understanding will assist the team undertaking CBA to collect appropriate data. The local practitioner can also use this data to inform input/output indicators required for M&E activities.

The four inception and training missions in Solomon Islands and Vanuatu provided the opportunity to better understand the current level of capacity. The vast majority of stakeholders and training participants did not have an economic background; some had a basic understanding of the concepts and objectives but would not have the capacity to undertake CBA autonomously.

Lesson 8: There is a strong synergy between the results of *expost* CBA and typical M&E requirements.

The results of *expost* CBA can provide a comprehensive and detailed reporting on the impact of a climate change adaptation intervention. While it might not always be possible to undertake a quantitative *expost* CBA, even a qualitative assessment will provide a valuable analysis of the effectiveness of the activities implemented. Some of the baseline information on key M&E indicators is most cost effectively collected during the problem analysis and solution analysis phases.

This use of CBA was mentioned by several training attendees as a driver for them to undertake the training and understand better how to apply CBA to projects, both future and already completed. The *expost* CBA conducted for the Solomon Islands Case Study has clearly demonstrated the net benefits of the SPC-USAID food security interventions and could directly inform evaluation of this project's activities.

Appendix A

Templates for Risk Management (Problem and Solution Analysis)

Templates for Risk Management

Problem Analysis - Screening Project Risks

Using the information on the project, the climate scenarios and understanding of the local area (developed in the situation analysis), the aim is to identify which elements of the projects could be sensitive to climate change. Follow these steps:

1) Insert the main project components in the columns
2) Compare these project components with the climate variables and hazards to identify which component would be sensitive. Sensitive means that these project elements could be impacted negatively by climate events.
3) Indicate whether you think that relationship is strong, potential or if there is no apparent relationship
4) Ideally this task should be completed by:
   a) safeguards or environmental staff with an understanding of the local environment, and how climate driven hazards may operate, and
   b) engineering or project staff who understand how the different parts of the project work.
5) See Examples in Sections 2.3.2 and 3.3.2.

Table 39: Risk screening matrix used for the project

		Component			
		E.g. drainage infrastructure			
Sea	Sea level rise				
	Storm surge				
	Surface temperature				
	Ocean Acidity				
	Currents				
Rainfall	Annual average rainfall				
	Extreme rainfall events (flooding)				
	Drought				
Temperature	Annual average temperature				
	Extreme temperature events				
Atmosphere	CO_2				
Wind	Cyclones				

Strong relationship (or uncertain)	××
Potential relationship	×
No apparent relationship	-

Problem Analysis - Developing Risk Scenarios

Based on the risk screening the aim is to define the relationship into a risk scenario. To turn the ticks and crosses into a story follow these steps:

1) For all the relationship considered as strong or potential you need to determine the risk scenario
2) The risk scenario describes in a simple sentence how the climate variable or climate hazard is likely to have negative impacts, and should be written in a condition consequence format, in other words, given a certain condition (e.g. continued sea level rise) a certain condition could result (e.g. increased erosion of coastal roads and loss of access for vehicular traffic).
3) Ideally this task should be completed by:
    a) safeguards or environmental staff with an understanding of the local environment, and how climate driven hazards may operate, and
    b) engineering or project staff who understand how the different parts of the project work.

Problem Analysis - Detailed Risk Assessment

Using the risk scenario undertake the detailed risk assessment

1) Use the risk scenarios developed in the previous template as the base for the risk assessment
2) Use the description of likelihood and consequences below to complete the risk assessment, discussing in groups the consequences if the risks occur, and the likelihood of each risk occurring
3) Try and document the decision making and thinking behind the assigning of consequences and likelihoods, as this will make the risk assessment easier to understand and the results easier to justify.
4) See Examples in Sections 2.3.3 and 3.3.3.

Table 40: Risk matrix

		Consequences				
		Insignificant (1)	Minor (2)	Moderate (3)	Major (4)	Catastrophic (5)
Likelihood	Almost certain (5)	Medium (5)	Medium (10)	High (15)	Extreme (20)	Extreme (25)
	Likely (4)	Low (4)	Medium (8)	High (12)	High (16)	Extreme (20)
	Possible (3)	Low (3)	Medium (6)	Medium (9)	High (12)	High (15)
	Unlikely (2)	Low (2)	Low (4)	Medium (6)	Medium (8)	Medium (10)
	Very Unlikely (1)	Low (1)	Low (2)	Low (3)	Low (4)	Medium (5)

Table 41: Details for different likelihoods used in the risk assessment

Descriptor	Recurrent risks / Single events
Very Unlikely	Recurrent Events: Unlikely during the next 25 years. Single Events: Negligible / Probability very low Probability: < 15%
Unlikely	Recurrent Events: May arise once in 10 years to 25 years. Single Events: Unlikely but not negligible / Probability low but noticeably greater than zero. Probability: 16%−35 %
Possible	Recurrent Events: May arise once in 10 years. Single Events: Less likely than not but still appreciable Probability: 36%−59%
Likely	Recurrent events: May arise about once per year. Single events: More likely than not Probability: 60%−84%
Almost Certain	Recurrent events: Could occur several times per year. Single events: Noticeably more likely than not Probability: > 85%

Table 42: Descriptions of different consequence levels utilised for the risk assessment

Consequence	Description
Insignificant	Infrastructure: No infrastructure damage. Financial Loss: Asset damage < $ 100K. Reputation: Some public awareness. Livelihoods: Negligible or no impact on the livelihood system. Health/Safety: Negligible or no changes to the public health profile or fatalities as a result of extreme events. Industry: Any impacts can be absorbed within existing systems.
Minor	Infrastructure: Localised infrastructure service disruption / No permanent damage / Some minor restoration work required. Financial Loss: Asset damage between $100K and $500K. Reputation: Some adverse news in the local media / Some adverse reactions in the community. Livelihoods: Isolated and temporary disruption to an element of the livelihood system. Health/Safety: Slight changes to the public health profile or isolated increases in fatalities as a result of extreme events. Industry: Isolated and temporary disruption to a key economic element.
Moderate	Infrastructure: Widespread infrastructure damage and loss of service / Damage recoverable by maintenance and minor repair / Partial loss of local infrastructure. Financial Loss: Asset damage between $500K and $2 million. Reputation: Adverse news in media / Significant community reaction. Livelihoods: Localised and temporary disruption to an element of the livelihood system, leading to the requirement of supplemental inputs. Health/Safety: Noticeable changes to the public health profile or localised increases in fatalities as a result of extreme events. Industry: Short-term and localised disruption to a key economic element.
Major	Infrastructure: Extensive infrastructure damage requiring extensive repair / Permanent loss of local infrastructure services. Financial Loss: Asset damage between $2 million and $5 million. Reputation: Damage to reputation at national level; adverse national media coverage; Government agency questions or enquiry; significant decrease in community support. Livelihoods: Widespread and reversible or localised and permanent impacts to core elements of the livelihood system. Health/Safety: Marked changes in the public health profile or widespread increases in fatalities as a result of extreme events. Industry: Widespread and reversible or localised and permanent disruption to a key economic element.
Catastrophic	Infrastructure: Permanent damage and/or loss of infrastructure service / Retreat of infrastructure. Financial Loss: Asset damage > $5 million. Reputation: Irreversible damages to reputation at the national and even international level / Public outrage. Livelihoods: Core elements of the livelihood system are permanently impacted. Health/Safety: Substantial changes to the public health profile or substantial increases in fatalities as a result of extreme events. Industry: Widespread and permanent disruption to a key economic element.

#	Risk Statement	Risk Level	Score	Likelihood	Likelihood Statement	Consequence	Consequence Statement
1	***EXAMPLE: With sea level rise and changes in tropical cyclone intensity, there is a greater risk of the road structure being damaged and deteriorated (coastal road)***	***Medium***	*9*	*Possible (3)*	*EXAMPLE: The projected increase in sea level rise and tropical cyclone intensity is likely and could reach about 15 cm. Large storms/cyclones occur about 1 in every 10 years.*	*Medium (3)*	*EXAMPLE: During large cyclone or large storms, the streams overflow and wash away the pavement and dig out the top layer of the road. Villagers have to either go around if it is too deep (>2m) or fill it with boulders and corals, sands, No need of PWD for temporary fixing of the road. The road would be closed up to 1 week.*
2							
3							

#	Risk Statement	Risk Level	Score	Likelihood	Likelihood Statement	Consequence	Consequence Statement
4							
5							

Problem Analysis - Risk Evaluation

Determine which risks are not acceptable and require treatment

1) Using the risk rating and the table below discuss which risks are acceptable and which risks are unacceptable and require treatment.
2) Prepare a prioritise list of risks from the biggest problem to the smallest problem.
3) See examples in Sections 2.3.4 and 3.3.4.

Table 43: Levels of risk, and required responses

Level of Risk	Required Response
Low	- Low risks should be maintained under review but it is expected that existing controls should generally be sufficient and no further action should be required to treat them unless they become more severe. - These risks can be acceptable without treatment.
Medium	- Medium risks could be expected to form part of routine operations but they should be assigned to relevant managers for action, maintained under review and reported upon at middle management level. - These risks are possibly acceptable without treatment.
High	- High risks are the most severe that can be accepted as a part of routine operations but they should be the responsibility of the senior operational management and reported upon to the Director. - These risks are not acceptable without treatment.
Extreme	- Extreme risks demand urgent attention at the most senior level and cannot be simply accepted as a part of routine operations. - These risks are not acceptable without treatment.

The key issues to emerge from the risk assessment (extreme and high risks) are:

The issues that could be acceptable (low and medium risks) are:

Solution Analysis - Risk Treatment

For the top risks discuss possible solutions

EXAMPLE - Road structure being damaged and deteriorated (coastal road)

#	*Possible Solution*	*Discussion (+) and (-)*	*Timeframe*
1	*Relocation of road away from the coastal area likely to be affected by sea level rise*	*(+) Relocation will avoid the risk and guarantees that the road will not be affected by sea level rise and coastal erosion.* *(-) It is however an expensive option and will require extensive negotiation with affected landowners.*	*Would realistically take 5 years to complete, but will then be effective for a very long time.*
2	*Incorporation of coastal protection measures in priority areas likely to be affected by sea level rise, and coastal erosion*	*(+) Relatively cheap option that can be flexible and respond to priority need areas.* *(-) will not always be effective, requires ongoing maintenance, and eventual replacement. Eventually the road may need to be relocated anyway as a result of sea level rise.*	*Could be completed immediately in priority areas, but will need ongoing maintenance, and eventually replacement after 5-10 years.*

Risk 2

#	Aspect	Discussion	Timeframe

Risk 3

#	Aspect	Discussion	Timeframe

#	Aspect	Discussion	Timeframe

Appendix B

Templates for Cost Benefit Analysis

Template for CBA

Solution Analysis

Of the Top 3 risks that you analysed earlier, select the highest risk(s) that needs urgent attention. For this risk, decide on the key sector (s) to focus in your project (that is define the boundary of the CCA measure).

Risk(s)	Sector (s) to target

Using one sectoral focus identify at least 3 potential adaptation options to be considered for further analysis.

	Option title
#1 Solution	
#2 Solution	
#3 Solution	

'Without adaptation' analysis

This section is largely derived from the 'Risk Analysis' section.

'With adaptation' analysis

For each adaptation option:

1) **Describe key activities/ sub-activites needed**
2) **Identify inputs required, and their likely quantity / costs**
3) **Identify expected impacts (benefits) associated with each option**
4) **Consolidate costs and benefits of each adaptation option**
5) **Compare 'without adaptation intervention' (loss and damages with costs and benefits associated with each adaptation option**

Key adaptation options for the targeted sector

Describe key activity or package of activities involved in each adaptation Option

Adaptation Option	Describe activities involved, including single or package of activities; sequencing & timeframe,

‘With adaptation’ Costs

For each adaptation option

1) Identify inputs required, and their likely quantity/ costs; note when such costs may be incurred - now and later

Adaptation Option	Activities/ sub activities	List Inputs required	Quantities of inputs/ Cost estimate if possible
#1			
#2			
#3			

‘With adaptation’ - Benefits

Identify benefits expected from each adaptation option; note any time delays

Adaptation Option	Expected impact	Describe likely benefits	Benefit in $ or qualitatively
#1			
#2			
#3			

'With adaptation' Costs and Benefits

Consolidate information about costs and benefits of each option

Adaptation Option	Key Costs	Key benefits
#1		
#2		
#3		

‘With and without adaptation’

For each option discuss costs and benefits associated ‘with intervention’ and the ‘without intervention’ damage and loss, compare and assign a ‘net benefit score’ for each adaptation option (5 being the highest, 1 being the lowest).

Comparing, scoring and ranking alternative adaptation options		
Adaptation Option	**NB Scores**	**Key reasons behind the score**
1		
2		
3		

Selection of desired option based on CBA

Identify other factors that would need to be considered when making a final selection. Such factors may include distributional effects; financial constraints and or capacity constraints. Then rescore the desirability of the adaptation options.

Comparing, scoring and ranking alternative adaptation options, taking into account NB and other feasibility factors			
Adaptation Option	**Feasibility issues**	**NB Score**	**Combined Score**
1			
2			
3			

Explain the final choice of desired adaptation option

Appendix C

Summary of Climate Tolerance of Key Crops and Tree Species

Summary of Climate Tolerance of Key Crops and Tree Species

	Optimum climate conditions	Physiological limits					
	Annual Rainfall (mm)	Mean Temp. Range (°C)	Rainfall (mm)	Extreme Temp. (°C)	Elevated CO_2	Salinity	Pests and diseases of concern
Sweet potato	Uniformly distributed with lower limit of 500-1,300 and upper limit of 900-1,300	21 -27	Can be grown <5,000 but with good drainage. Wet conditions, especially in early stages can affect yield	>34	Increase in above and below ground biomass but no information on impact on nutritional quality	Some varieties more tolerant of salinity than others	Sweet potato scab when very wet Drought conditions would affect SP weevil and SP begomovirus
C. esculenta (taro)	Optimum growth when rainfall > 2,500	25-35 with 30°C as optimum temp	Not tolerant to drought – would not survive if monthly rainfall for 4 months was <40 mm	Not known	Preliminary indications suggest increase in yield	Not tolerant	Increasing minimum (night) temperature will increase TLB inoculums pressure. Increased rainfall would also favour taro armyworm, Pythium. Drought likely to encourage CBDV
A.macrorrhizos (giant taro)	1,500-5,000	23-31	Will not tolerate water-logging. Will not survive long period of drought	Not known	Not known – could be like taro	Not known - unlikely	None
C. merkusii (swamp taro)	Continuous water supply needed	23-31	Tolerant of water-logging to some extent, likes swampy conditions	Tolerates 38	Not known – could be like taro	Study in Tuvalu indicated tolerance range as 1,000-3,000µs/cm	None

	Optimum climate conditions	Physiological limits					
	Annual Rainfall (mm)	**Mean Temp. Range (°C)**	**Rainfall (mm)**	**Extreme Temp. (°C)**	**Elevated CO_2**	**Salinity**	**Pests and diseases of concern**
X. sagittifolium (cocoyam)	1,500-3,000	13-29 (24 is optimum)	Will not tolerate water-logging. Rainfall of a maximum 5,000 given as long as good drainage	Not known	Not known – could be like taro	Not known	None – can suffer from dasheen mosaic virus – vector for transmission could be affected by rainfall patterns
Cassava	well-distributed rainfall of 1500 – 2000	25- 29	Will tolerate rainfall as low as 500 but drought will reduce yield, affect starch quality and increase cyanogens content	Will tolerate 40	Increase in tuber yield	Not known	None
Banana	Even distribution of 2000-2500	Foliar development: 26-28; fruit development: 29-30	Low rainfall will affect bunch size; water-logging reduces yield but susceptibility to both varies with variety. >4000 is given as max but banana cultivated where rainfall is 1000-6000	>35 will distort flowering emergence and bunch filling	Can increase total yield and fruit weight	Some varieties more tolerant of salinity than others	Drought and higher temperatures could increase nematode problems; increasing temperatures could reduce BBTV.

	Optimum climate conditions	Physiological limits					
	Annual Rainfall (mm)	Mean Temp. Range (°C)	Rainfall (mm)	Extreme Temp. (°C)	Elevated CO_2	Salinity	Pests and diseases of concern
Yam	High yields require 1500 but will grow with 500-700	25-30	Not very tolerant of water-logging. Yield affected if moisture stress in 1st 2 stages of growth	>35 would affect yield	Not known	D. esculenta grows on atolls but no studies on salinity tolerance	Yam anthracnose problems likely to increase with increased rainfall
Breadfruit	1500-3000 but yields obtainable at 1000	21-32	Tolerant of short, dry periods; some varieties more tolerant of high moisture than others	Not known. If heat stress combined with low rainfall then fruit drop and smaller fruit are likely	Not known	Atoll varieties could have some tolerance	Pest and disease pressure could change
Island spinach, Bele, aibika	Range not known but will grow on wet and dry lowlands	Not known	Susceptible to drought	Not known	Not known	Not known	Increased rainfall will favour a number of rots. Drier weather will increase pest damage.

	Optimum climate conditions	Physiological limits					
	Annual Rainfall (mm)	**Mean Temp. Range (°C)**	**Rainfall (mm)**	**Extreme Temp. (°C)**	**Elevated CO_2**	**Salinity**	**Pests and diseases of concern**
Peanut	500 mm – 1,000 mm.	Vegetative growth: 25–30; Reproductive growth 22–24.	Water-logging tolerance appears to vary with genotype	>37 can slow down crop growth. If the soil is too hot, leaf distortion and thickening occurs as well as pollen sterility during flowering.	Legumes can benefit from eCO_2 because of ability to fix N_2 but only if there are no limitations on productivity such as a lack of nutrients. Some evidence that eCO_2 may offer some protection from drought-induced decreases in N_2 fixation	Not known	Rainfall (over 900) or consistently high humidity - more problems with leaf diseases, such as leaf spot, rust and net blotch.
Teak	Will grow between 500 to 5,000 but optimum for wood quality & growth: 1,200- 2,500 with marked dry season of 3-5 months	14-36	Very moist conditions, wood quality poor in terms of colour, texture and density	39 tolerated	Likely that yields will increase if other factors not limiting	Not known	Bacterial wilt often attacks 6-24 month seedlings if drainage not good.
Sandalwood *S. austrocaledonicum*	800-2,500	23-27	Prefer good drainage - will die or die back with any prolonged period of water-logging (> 1-2 weeks).	33	Likely that yields will increase if other factors not limiting	Not known	

	Optimum climate conditions	Physiological limits					
	Annual Rainfall (mm)	**Mean Temp. Range (°C)**	**Rainfall (mm)**	**Extreme Temp. (°C)**	**Elevated CO_2**	**Salinity**	**Pests and diseases of concern**
Sandalwood *S. yasi*	1,400-2,500	23-29		31			Yasi is susceptible to brown root rot which is likely to be exacerbated by excessive moisture.
Cocoa	1,250-3,000- dry season of not>3 months with < than 100 mm per month	Mean max = 30-32; mean min = 18-21	Drought has been shown to affect yield. Black pod disease main threat from increasing rainfall	Increasing temperature over the long term will have an impact	Not known	Not known	Black pod
Papaya	100 per month minimum	21-33	Very susceptible to water-logging	Increases in temperature will increase female sterility leading to poor fruit set	Not known	Not known	Increase in fungal diseases with increased rainfall
Pineapple	1,140 is optimum but will fruit in range 650-3800	18-32	Susceptible to water logging – increase in rots. Drought likely to increase pineapple wilt disease	High temperatures (>35) will affect fruit development and reduce growth	Not known	Not known	Increase in rots with increased rainfall. Drought likely to increase pineapple wilt disease
Citrus	900-3000	25-30 is optimum but mean max = 31-32	In combination with a wetter climate will increase P&D	Increase in P&D	Not known	Not known	Increase in P&D

	Optimum climate conditions	Physiological limits					
	Annual Rainfall (mm)	Mean Temp. Range (°C)	Rainfall (mm)	Extreme Temp. (°C)	Elevated CO_2	Salinity	Pests and diseases of concern
Beans	No information for indigenous beans	Tolerance to heavy rainfall will depend on drainage and also the stage at which the crop is at. Timing and duration of heavy rainfall important	No information but likely that very high temperatures will have a negative impact on production depending on timing	Legumes can benefit from eCO_2 because of ability to fix N_2 but only if there are no limitations on productivity such as a lack of nutrients. Some evidence that eCO_2 may offer some protection from drought-induced decreases in N_2 fixation	Not known	Likelihood that P&D will be affected by CC. Pod borer will increase if harvesting delayed	

Appendix D

Projected Climate Change Impacts on Crops and Species

Crop/species	Projected impact 2030	Projected impact 2050	Projected impact 2090
Sweet potato	Heavy rainfall events could affect tuberization but could be mitigated by genotype and growing practices	Beyond 2030 impact will depend on emissions scenario and resulting temperature increase – extreme events will increasingly continue to have an impact as for 2030. P&D impact difficult to access though likely to be problems with weevil and begomvirus. Production could be affected by high temperature events	Very difficult to assess – depends on emissions scenario, adaptation practices and impact. Adaptation practices will be influenced by data output from research. Problems as projected for 2050 exacerbated. Temperature could have serious implications on production if >34C (depends on emission scenario)
Cassava	Expected to be minimal	Beyond 2030 impact will depend on emissions scenario and resulting temperature increase – extreme events will increasingly continue to have an impact as for 2030. Drought will have an impact but long-term change unlikely to have any effect. P&D interactions with climate change unknown	Very difficult to assess – depends on emissions scenario, adaptation practices and impact. Adaptation practices will be influenced by data output from research
Taro	Likelihood of increase in TLB. Not tolerant of drought	Beyond 2030 impact will depend on emissions scenario and resulting temperature increase – extreme events will increasingly continue to have an impact as for 2030. Temperature rises >2C could affect production. TLB increase, as could fungal and bacterial pathogens	Very difficult to assess – depends on emissions scenario, adaptation practices and impact. Adaptation practices will be influenced by data output from research. Problems as projected for 2050 exacerbated.
Cocoyam and giant taro	Expected to be minimal though both will not tolerate water-logging – therefore heavy rainfall events a problem	Beyond 2030 impact will depend on emissions scenario and resulting temperature increase – extreme events will increasingly continue to have an impact as for 2030. No direct impact though interactions of P&D with climate change unknown. Cocoyam less likely to tolerate higher temperatures	Very difficult to assess – depends on emissions scenario, adaptation practices and impact. Adaptation practices will be influenced by data output from research. Problems as projected for 2050 exacerbated

Crop/species	Projected impact 2030	Projected impact 2050	Projected impact 2090
Swamp taro	Droughts will exacerbate any salinity problems	Some of the varieties with no tolerance to salinity could be eroded	Very difficult to assess – depends on emissions scenario, adaptation practices and impact. Adaptation practices will be influenced by data output from research. Problems as projected for 2050 exacerbated
Banana	Higher temperatures from extreme events could affect flowering and fruit filling, and increase nematode and weevil damage, and possibly BBTV. Higher rainfall could increase BLSD and Fusarium wilt. Water-logging could affect bunch yield	Increased pest and disease pressure (Fusarium wilt, nematode and weevil) Rainfall impact on BLDS could be lessened by higher temperature. Heat stress effect on flowering and fruit filling. Water-logging could affect bunch yield	Very difficult to assess – depends on emissions scenario, adaptation practices and impact. Adaptation practices will be influenced by data output from research. Problems as projected for 2050 exacerbated. Cavendish types more affected by projected rainfall increases assuming 4000 mm per year is the threshold
Yams	Increased rainfall will not favour productivity and an increase in anthracnose likely - therefore heavy rainfall events a problem	Beyond 2030 impact will depend on emissions scenario and resulting temperature increase – extreme events will increasingly continue to have an impact as for 2030. Increasingly impacted by wetter conditions	Very difficult to assess – depends on emissions scenario, adaptation practices and impact. Adaptation practices will be influenced by data output from research. Problems as projected for 2050 exacerbated. Temperatures >35 would affect yield.
Breadfruit	Expected to be minimal as long as cyclones are not an issue	Beyond 2030 impact will depend on emissions scenario and resulting temperature increase – extreme events will increasingly continue to have an impact as for 2030. High temperatures could reduce fruiting and fruit quality. Possible increase in P&D problems	Very difficult to assess – depends on emissions scenario, adaptation practices and impact. Adaptation practices will be influenced by data output from research. Problems as projected for 2050 exacerbated

Crop/species	Projected impact 2030	Projected impact 2050	Projected impact 2090
Bele, aibika, island cabbage	Changes in rainfall will increase P&D problems. Increase in frequency and intensity of drought will affect growth - therefore extreme weather events a problem	Beyond 2030 impact will depend on emissions scenario and resulting temperature increase – extreme events will increasingly continue to have an impact as for 2030. Increased problems with P&D likely. Also impact of high temperatures not known – could suffer from heat stress if moisture also limited	Very difficult to assess – depends on emissions scenario, adaptation practices and impact. Adaptation practices will be influenced by data output from research. Problems as projected for 2050 exacerbated
Peanut	High rainfall likely to affect productivity and incidence of P&D - therefore extreme rainfall events a problem	Beyond 2030 impact will depend on emissions scenario and resulting temperature increase – extreme events will increasingly continue to have an impact as for 2030. High temperature stress will affect plant growth and productivity. Rainfall will continue to impact as per 2030	Very difficult to assess – depends on emissions scenario, adaptation practices and impact. Adaptation practices will be influenced by data output from research. Problems as projected for 2050 exacerbated
Teak	High rainfall could affect quality of wood- therefore extreme rainfall events a problem	Beyond 2030 impact will depend on emissions scenario and resulting temperature increase – extreme events will increasingly continue to have an impact.	Very difficult to assess – depends on emissions scenario, adaptation practices and impact. Adaptation practices will be influenced by data output from research. Problems as projected for 2050 exacerbated. Temperature increases unlikely to be an issue
Sandalwood	Prolonged periods of water-logging will cause dieback or death of trees - therefore extreme rainfall events a problem	Beyond 2030 impact will depend on emissions scenario and resulting temperature increase – extreme events will increasingly continue to have an impact.	Very difficult to assess – depends on emissions scenario, adaptation practices and impact. Adaptation practices will be influenced by data output from research. Problems as projected for 2050 exacerbated. Temperature increases likely to be an issue

Crop/species	Projected impact 2030	Projected impact 2050	Projected impact 2090
Cocoa	Increasing incidence of black pod with increased rainfall and drought will affect yield - therefore extreme weather events a problem	Beyond 2030 impact will depend on emissions scenario and resulting temperature increase – extreme events will increasingly continue to have an impact. Cocoa production could be significantly affected with increasing temperature and rainfall	Very difficult to assess – depends on emissions scenario, adaptation practices and impact. Adaptation practices will be influenced by data output from research. Problems as projected for 2050 exacerbated. Highly likely that with areas such as S Islands where temperature and rainfall are already high will be unable to grow cocoa.
Papaya	Increasing problems with high rainfall and temperature therefore extreme weather events an issue	Beyond 2030 impact will depend on emissions scenario and resulting temperature increase – extreme events will increasingly continue to have an impact. Papaya production could be significantly affected with increasing temperature and rainfall	Very difficult to assess – depends on emissions scenario, adaptation practices and impact. Adaptation practices will be influenced by data output from research. Problems as projected for 2050 exacerbated. Highly likely that with areas such as S Islands where temperature and rainfall are already high will be unable to grow papaya
Pineapple	Expected to be minimal though extreme weather events could impact production through P&D problems events	Beyond 2030 impact will depend on emissions scenario and resulting temperature increase – extreme events will increasingly continue to have an impact.	Very difficult to assess – depends on emissions scenario, adaptation practices and impact. Adaptation practices will be influenced by data output from research. Problems as projected for 2050 exacerbated. Temperature increases unlikely to be an issue
Citrus	Expected to be minimal though extreme weather events could impact production through P&D problems events	Beyond 2030 impact will depend on emissions scenario and resulting temperature increase – extreme events will increasingly continue to have an impact.	Very difficult to assess – depends on emissions scenario, adaptation practices and impact. Adaptation practices will be influenced by data output from research. Problems as projected for 2050 exacerbated. Temperature increases could be an issue

Crop/species	Projected impact 2030	Projected impact 2050	Projected impact 2090
Beans	Likely to be minimal but timing and duration of extreme events could be critical	Beyond 2030 impact will depend on emissions scenario and resulting temperature increase – extreme events will increasingly continue to have an impact.	Very difficult to assess – depends on emissions scenario, adaptation practices and impact. Adaptation practices will be influenced by data output from research. Problems as projected for 2050 exacerbated. Temperature increases could be an issue

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