Climate change adaptation in the Pacific: Making informed choices

A report prepared for the Australian Department of Climate Change and Energy Efficiency




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Acronyms

ACIAR	Australian Centre for International Agricultural Research
ADB	Asian Development Bank
ARI	annual recurrence interval
AusAID	Australian Agency for International Development
BCR	benefit–cost ratio
BOM	Australian Bureau of Meteorology
CBA	cost–benefit analysis
CCA	climate change adaptation
CePaCT	Centre for Pacific Crops and Trees
CBDAMPIC	Capacity Building for Development of Adaptation Measures in the Pacific Island Countries
CIDA	Canadian International Development Agency
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CV&A	community-based vulnerability and adaptation assessment
DCCEE	Department of Climate Change and Energy Efficiency
DM	disaster management
DRM	disaster risk management
DRR	disaster risk reduction
EIRR	economic internal rate of return
ENSO	El Niño Southern Oscillation
EU	European Union
FOB	Free On Board
FSM	Federated States of Micronesia
GCM	global climate models
GDP	gross domestic product
GEF	Global Environment Facility
GIS	geographic information system
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
IISD	International Institute for Sustainable Development
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for the Conservation of Nature
IUCN-ORO	International Union for the Conservation of Nature, Oceania Regional Office
IWP	International Water Program

IWRM	Integrated Water Resource Management
MEA	Multilateral Environmental Agreements
NAPA	National Adaptation Plan of Action
NB	net benefit
NGO	non-government organisation
NPV	net present value
NSDS	National Sustainable Development Strategy
NZAID	New Zealand Agency for International Development
PAA	Priorities and Action Agenda
PACC	Pacific Adaptation to Climate Change
PASAP	Pacific Adaptation Strategy Assistance Program
PIC	Pacific island country
PIFACC	Pacific Islands Framework for Action on Climate Change
PNG	Papua New Guinea
SIRIP	Solomon Islands Road Improvement Project
SLA	sustainable livelihood assessment
SOPAC	Pacific Island Applied Geoscience Commission
SPC	Secretariat of the Pacific Community
SPCZ	South Pacific Convergence Zone
SPREP	Secretariat of the Pacific Regional Environment Programme
TaroGen	Taro Genetic Resources: Conservation and Utilisation
TIP	Taro Improvement Project
TLB	Taro leaf blight (*Phytophthora colocasiae)*
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework of Climate Change Convention
UNISDR	United Nations International Strategy for Disaster Reduction
USP	University of the South Pacific
VARTC	Vanuatu Agricultural and Technical Centre
V&A	vulnerability and adaptation assessment

Climate change adaptation in the Pacific: making informed choices

This summary for decision-makers accompanies the overview report, Climate change adaptation in the Pacific: making informed choices, a project supported by the Australian Government under their Pacific Adaptation Strategy Assistance Program (PASAP). The specific objectives of this project are to provide:

- an analytical framework(s) suitable for assessing economic and social costs and benefits of climate change adaptation (CCA) projects in the Pacific
- an overview of key constraints in undertaking economic and social assessment-based informed choices about the CCA projects in the Pacific
- suggestions for overcoming key institutional and other constraints in the use of economic and social assessment in making informed choices about CCA in the Pacific.

This document provides user-friendly and easy-to-access information about key concepts, issues and challenges that decision-makers face in identifying, assessing and selecting adaptation measures. It examines policy/project cycle-based risk management, supported by robust analysis based on analytical frameworks such as sustainable livelihood analysis, environment impact assessment, and cost–benefit analysis (CBA). It also identifies key constraints in the Pacific for making informed decisions using such analytical frameworks, and makes specific recommendations for strengthening, drawing on risk management, knowledge-based CCA decisions in the Pacific island countries (PICs).

Using this document

The numbers in square brackets, for example [3.1], refer to the section in the overview report where that topic is discussed. Similarly, [case study 4.1] refers to the specific case study—in this case the food security case study—where the specific issue is illustrated.

Adaptation to climate change

Climate change is, as defined by the Intergovernmental Panel on Climate Change (IPCC) (2011), a change in the mean and/or the variability of a climate property (such as precipitation, temperature and wind force) that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forces, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. For climate change, disaster risks are changing in terms of scale, scope, frequency and intensity, calling for major shifts in the way society adapts to current disaster risks and future climate risks [2.2, 2.3].Disaster risk is the likelihood of severe alterations in the normal functioning of community or society to weather or climate events interacting with vulnerable social conditions (IPCC, 2011).

Climate change directly or indirectly affects all sectors and communities and requires measures to reduce and manage residual risks in a changing environment. The economic and social impact of disasters in the Pacific are already significant and risks of disasters and their costs are increasing with climate change [2.2, 2.3], so there is a need for disaster risk management (DRM) not only to address current risks, but also risks heightened through climate change.

DRM is defined as the implementation of strategies to avoid or minimise risks and unacceptable consequences by avoiding exposure to hazards as well as reducing vulnerability and managing residual risks [3.4]. Disaster risk is a result of the interaction between hazard and vulnerability of people, communities, environment and economy, and disaster outcome is a product of the risks and capacity to prepare for, respond to and recover from a disaster event. Adaptation 'in the human systems is the process of adjustment to actual or expected climate and its effects to moderate harm or exploits beneficial opportunities' (IPCC, 2011). IPCC SREX report also notes that adaptation actions may range from incremental steps taken to improve things such as existing governance and technologies to reduce exposure and vulnerabilities to transformational changes in fundamental attributes of a society (IPCC, 2011).

Climate change adaptation exhibits key elements of DRM, but with two key differences. DRM deals with known disaster risks. It comprises disaster risk reduction (DRR) and disaster management (DM). These in turn include disaster preparedness and post-disaster response and rehabilitation. Climate risk management, however, is about dealing with future climate risk. DRM strategies are based on historic data and current experiences with a hydro-meteorological event as a guide to the future disaster risks (without climate change). On the other hand, CCA decisions may be based on past disaster experiences. CCA must also take account of changing risks associated with projected changes in the average and variability in climate conditions and sea-level rise, and changes in the frequency and intensity of extreme events, such as precipitation, cyclones and storm surges [3.3]. Climate adaptation must also include uncertainty, a key feature of climate change.

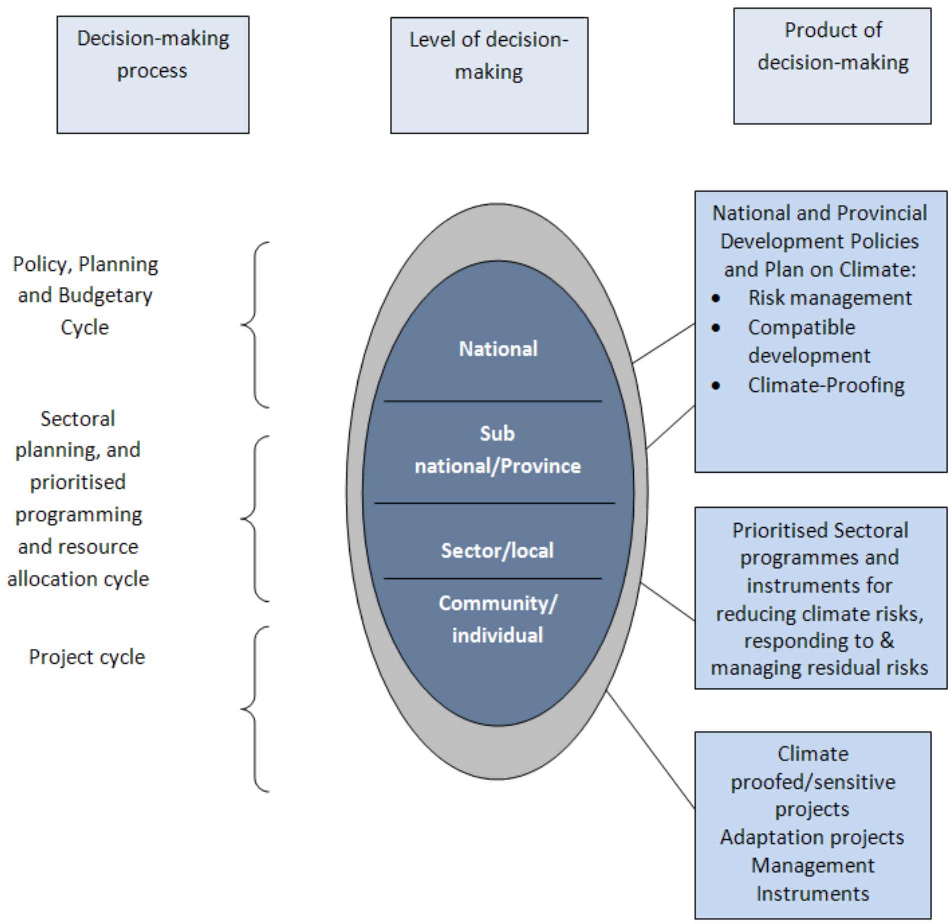
The dynamics of the climate system are not well understood, and there are many uncertainties associated with the available projections of future climate scenarios. For the Pacific, the uncertainty is particularly acute, as baseline time-series meteorological and sea-level data are limited, sub-regional and national level climate models do not exist, and global climate modelling results are not always consistent. Furthermore, there is uncertainty about the scale, scope and magnitude of climate change impacts across sectors. This is due to limited scientific information available in-country, recognising that impacts associated with climate change, variability and extremes are a result of a complex web of interactions involving socioeconomic as well as environmental and meteorological factors [2.1, 3.3].

Adaptation decisions and measures

The adaptation decision-making process would include systematic consideration of climate risk when designing and implementing practical risk reduction and management activities. Adaptation may be implemented in reaction to recent weather and climatic events, and current disaster risks; or proactively planned for using projected climate change, variability and extremes. Adaptation decisions will reflect integrating DRM and CCA principles and would be underpinned by scientific knowledge (technical risk and risk-reduction analysis-based information) and traditional and experiential knowledge [3.2].

Given the cross-cutting and all-pervasiveness of climate change, in practice, all stakeholders in society ultimately face climate change. Adaptation decisions are consequently made across all levels of society. Figure 1 illustrates different levels of government and community decision-making in the Pacific and their effects. In an ideal world, national-level policies translate to sectoral priorities and programs and these in turn determine the portfolio of sectoral activities. Similarly, effects and experiences gained on the ground inform decision-making to higher levels of government. This then leads to a situation where national decision-making and grass-roots decision-making are harmonised and mutually reinforcing [3.2].

Figure 1 Targeting decision-making processes across different levels of government and communities for mainstreaming of climate change risk considerations in the Pacific



Adaptation measures, decided upon by government, communities and private citizens thus may include policies, plans, strategies, programs and projects. At the national level, it may also include allocation of corresponding financial resources to the sectoral-level authorities responsible for translating national priorities into action on the ground. Given the relationship between economic and social status of communities and their vulnerability to disasters, adaptation measures may be implemented in reaction to recent weather and climate events or proactively planned for projected climate change, variability and extremes, as well as address other national development goals. A range of adaptation measures could be used to address current disaster risks and projected climate change challenges and a portfolio of adaptation measures may be required across levels of government, across sectors and by communities. Such measures may be incremental, where countries take steps to reduce current risks, and may also be addressing projected changes in climate risks. Such measures may also be foundational in that the government creates an enabling environment that allows the society to be flexible and built on as the climate changes. In the medium to longer term, a more transformational approach is selected where countries change their values and development approach such that a different path of development may be followed [3.1].

Climate change adaptation decisions

While there are many dimensions to supporting effective CCA decisions in the Pacific, the report has highlighted two in particular, namely: risk-based policy/project decision-making process and the underlying knowledge to make informed decisions.

Policy/project cycle-based adaptation decisions

These climate risk considerations at the national and sectoral policy level would normally follow the policy cycle process, which is similar to the project cycle-based risk management decisions followed at the individual activity/project level. A risk management based-policy/project cycle usually follows key steps that integrate risk considerations: situation context analysis, identification of problems and solutions; appraisal—assessment of the options from relevant perspectives (e.g. technical, economic, environmental); design, implementation and monitoring—implementation of project activities with ongoing checks on progress and feedback; and evaluation—periodic review of the project with feedback for the next project cycle. Institutionally, one would expect a direct relationship between adaptation decisions made at the national level (national priorities), sectoral level (sector policies, objectives and priority programs), and community-based and other projects will put into effect sector policies and strategies [3.4].

Making informed decisions about CCA ideally requires assessing the risks without taking on adaptation initiatives and then comparing the benefits and costs of risk reduction expected with the adaptation measure, together with other development considerations. In DRM, the benefits of CCA are essentially the social and economic costs of damages, losses of disaster avoided, and the costs are those associated with the particular adaptation measure.

Risk analysis, that is, analysis of risks of potential impacts of climate change without risk management involves:

- determining hazards exposure and vulnerability
- identification of management/adaptation measures and associated costs, based on potential adaptation activities and alternatives and their respective costs
- analysis of risk reduction, that is, estimated benefits of reducing risks [3.4.1; 3.5.1].

Making informed choices at the project level

Economic CBA is an established tool for making choices after identifying impacts and assessing economic costs and benefits of an activity and comparing that to the 'without' activity. Economic efficiency measures, such as net present value (NPV), benefit–cost ratio (BCR) and economic internal rates of return (EIRR) are used to compare and select a preferred initiative, particularly when there is pressure to achieve the highest benefits with minimal investment. If the probability of events and impacts can be quantitatively determined, the benefits of adaptation can then be worked out by comparing expected economic present values 'with' and 'without' adaptation [3.5.2]. If detailed probabilities for events and impacts are not known, then sensitivity analysis can reveal possible trade-offs that may be necessary, as is used in the infrastructure [4.4] and water security case studies [4.2] and the food security case study [4.1].

There are though, several challenges to using CBA to identify economically efficient adaptation measures, including:

- not all benefits and costs of risk reduction are identifiable, quantifiable and quantified in monetary terms, due to limited baseline data
- disagreement over an appropriate discount rate to use when addressing long-term benefits and costs, particularly in situations of irreversible decisions
- economic efficiency-based decisions do not typically reflect consideration of who bears the cost of a measure and who enjoys its benefits
- in the face of uncertainties, probabilistic CBA is difficult. Instead, deterministic CBA, together with sensitivity analysis around key uncertain parameters can help provide additional information to make informed decisions.

CBA is best suited for deciding about individual activities. In the case of CAA, instead of a single adaptation activity, a portfolio of interventions is often required within a complex development context. Governments often have to decide between investments to address current development issues, including disaster risks, while also preparing for uncertain longer term climate scenarios. However, there is no single approach or criteria that countries can use in assessing and prioritising adaptation measures.

In many instances, in trying to balance the immediate development needs, disaster risks as well as plans for climate futures, adaptation measures adopted would also make sense from a development perspective, whatever the future climate. Such an approach to CCA is often referred to as 'no regrets' or 'low regrets' strategy.

This produces not only risk-reduction benefits but also other development benefits, such as:

- the protection of coastal mangroves ecosystems
- providing a cost-effective buffer against current and future storm surges
- supporting biodiversity conservation
- enabling improvements in economic livelihoods and human wellbeing, particularly to the poor and vulnerable.

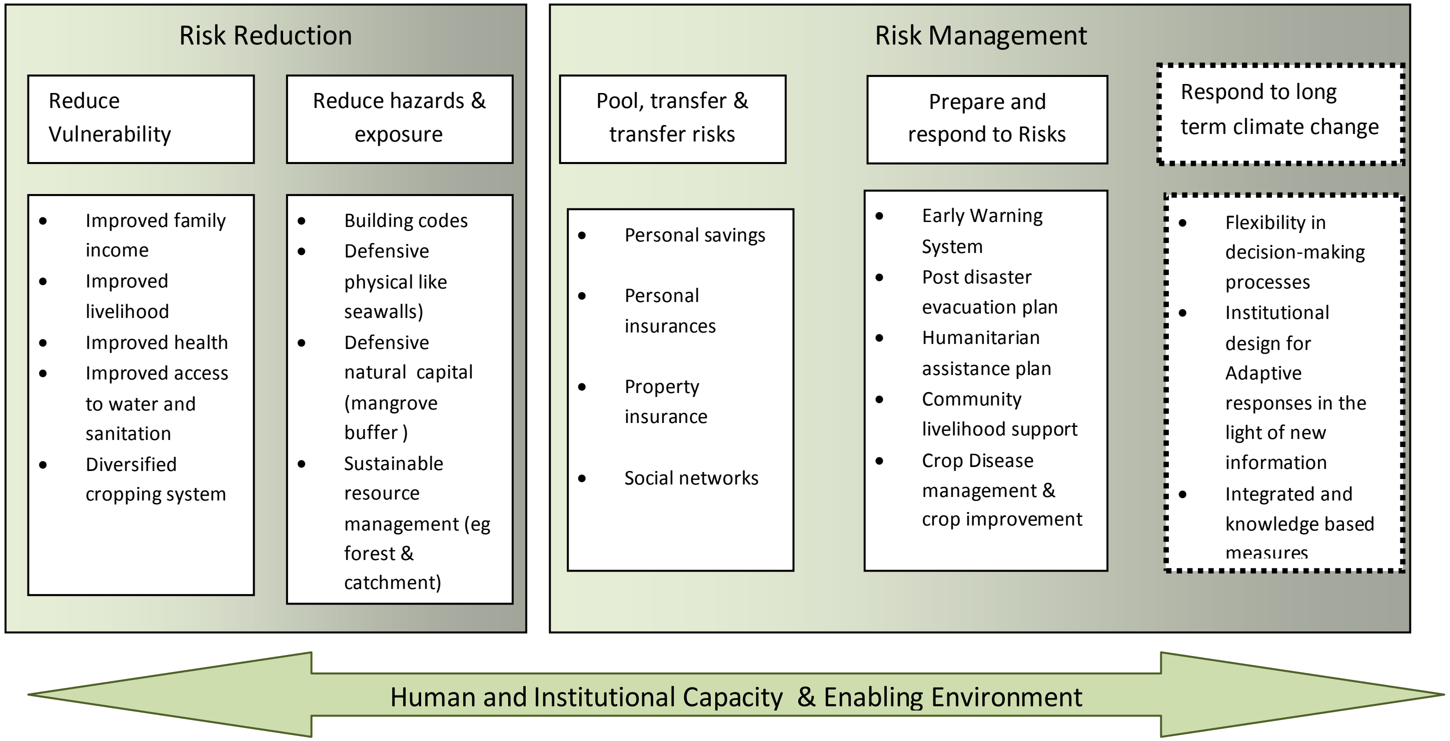
Such ‘low regrets solutions that produce win–win outcomes may though, not always be feasible [3.3]. In situations where investments need to be made that have a long life, explicit considerations of climate projections also become critical, such as in the case of roads, bridges, and other similar infrastructure developments. In extreme situations, countries with limited resources may have to choose to postpone making decisions about future climate risks. This better enables them to address their immediate development needs but also avoid maladaptation [3.3].

On the other hand, countries may need to choose those development and current DRM options that could also be adjusted over time when new information becomes available. Planned adaptation strategies may also be aimed at building individual and institutional capacity and laying necessary foundations, such as in the form of an early warning system, or crop germplasm banks and institutional technical capacity to plan for, respond to, and cost effectively recover. At the individual and or private sector level, adaptation measures may include specific individual interventions or packages of related actions that they can adopt to reduce and manage their risks. These include risk transfer and sharing measures (such as disaster insurances, e.g. social insurance), which can help people access financial and other resources in times of disaster [3.3].

Proactive and reactive adaptation measures could therefore include a single measure or a portfolio of activities. A portfolio could range from ‘pure’ development activities (e.g. from addressing drivers of vulnerability to targeting risk reduction measures), as well as dealing with residual risks by pooling, transferring and sharing risks and preparing for, confronting and reactively adapting to climate change (Figure 2).

When considering a portfolio of adaptation measures, the geographic scale of influence of possible measures may be large, and benefits may accrue across hard-to-identify groups of people. Therefore, CBA as an assessment tool may not be totally appropriate for making detailed choices [3.5.2, see case study 4.3, case study 4.4].The choice of priority strategies would also be informed by other criteria for national development needs, including for example, technical and economic feasibility and the effectiveness of a measure in the light of uncertainties (US National Research Council) Committee on America's Climate Choices (2011). **Despite such limitations, the CBA framework is still useful in helping to systematically identify, evaluate and consider all impacts and their costs and benefits, rather than it providing an exact economic value of an adaptation measure** [relocation case study 4.3]. The CBA process can also help identify critical parameters to measure project impacts, and facilitate iterative learning and adaptation from the new information.

Figure 2 Climate change adaptation measures: building on disaster risk reduction and disaster risk management measures considering projected climate



Source: Based on McGray, Hammill, et al (2007).

Decision-making criteria

Adaptation choices should be made based on not only quantified economic efficiency measures, but also on qualitative and quantitative assessments of other social and economic impacts of CCA. Other criteria relating to national development needs, including for example, urgency of addressing immediate development needs; require institutional foundations to support future decisions, technical and economic feasibility and the effectiveness of a measure in the light of uncertainties [3.5.2; case study 4.1].

Criteria informing adaptation choices would depend on the priorities placed by the government and communities on the balance between meeting current development and risk management needs and addressing future climate. Thus, selection of decision-making criteria needs to be an explicit step in the climate risk management decision, as is the consideration of the local level of risk perception and risk tolerance threshold. The selection of the relevant decision-making criteria would need to be an explicit step in the climate risk management decision, and informed by development needs, local level of risk perception and risk tolerance threshold [3.5.2; case studies 4.3 and 4.4].

The iterative decision-making process, called adaptive management, is also relevant when uncertainties exist, and there is a need to periodically review and adjust adaptation strategies as new information is gained and lessons are learnt from past initiatives [3.3].

Adaptive management involves regular changes in management policies, strategies and practices that are implemented based on lessons learnt from initiatives and by taking into account changes in other drivers in society. Adaptive management is also about bringing together interdisciplinary science, experience and traditional knowledge into decision-making through 'learning by doing' by individual agencies. The adoption of an adaptive management approach would also require cross- sectoral engagement and use of the decision-making process that allows for change. That is, decision-makers would need to be flexible in their decisions allowing different stakeholders to share their experiences and knowledge, develop a shared understanding of complex problems, accept new information as it becomes available, and make collective decisions [3.3].

Adaptation decision: technical aspects

From a technical perspective, the CCA decision-making process would involve many factors. These include the following:

- applying a robust knowledge to identify potential hazards, vulnerable areas, local sectors, and people to target
- developing risk-reduction measures and climate-sensitive or climate-compatible development measures (including policies, strategies, programs, on-the-ground activities and appropriate budgets) [3.4].

Two alternative knowledge-based adaptation planning approaches are generally advocated for responding to climate change: 'science- or impact-first' and 'vulnerability-first' assessments. The impact-first approach involves identifying climate change scenarios using scientific climate models; assessing impacts based on projected climate change scenarios derived from the modelling exercises; identifying, assessing and selecting relevant adaptation measures; recognising underlying uncertainties; implementing the adaptation measure; and then assessing the outcomes and learnings. The starting point of the planning exercise is the climate change modelling and the impact of future extreme climate conditions. The impact-first' approach although used in many research projects, including in the Pacific and being globally advocated, has usually not been used to inform adaptation decisions even in developed countries.

The vulnerability-first approach starts by examining vulnerability and sensitivity conditions that the communities currently face, identifying local sensitivities and resilience of the natural and human systems to climatic hazards, identifying local priorities to climatic variability and then identifying viable adaptation strategies and actions required to improve their resilience. Projected climate conditions are also considered at this stage.

The vulnerability-first approach presupposes that adaptation to short-term climate variability and extreme events will reduce vulnerability to longer term climate change. Adaptation policies and measures are assessed in a development context with some reference to future climatic conditions and for which the adaptation strategy is equally important as the process by which it is implemented. It also emphasises stakeholder engagement and capacity enhancement as cross-cutting components [3.4.1].

Different types of technical analysis supported by good baseline data are required to inform CCA decisions. Risk and risk-reduction analysis will ideally draw on many different disciplines and traditional knowledge, and would involve backward assessment of past disasters to inform the forward-looking responses in the face of projected climate change, or forward-looking assessments based on scientific modelling. A holistic systems approach would need to be adopted to identify the effects of projected climate change across ecological scales, economic activities and communities and to identify appropriate risk-reduction measures necessary to address those risks. Without such an approach, adaptation measures may not fully address the goals of risk reduction and resilience [3.4.1; case study 4.4].

The technical analysis will vary according to the type of hazard of concern and the priority sector(s) being affected, as well as the pathway through which the impacts are realised. Interdisciplinary vulnerability assessment helps in understanding current and projected hazards, exposure and vulnerability under project climate changes. Ecosystem-based assessments can help identify the pathway through which the impacts are realised, and the impacts on human livelihoods. Vulnerability assessment tools based on rapid rural assessment and sustainable livelihood assessment (SLA) framework are used to identify and assess people's sensitivity to hazards of a specific intensity and scale, and to understand the local-level risks, risk management and resilience at the household and community level. Such V&A would require knowledge drawn from different disciplines as well as local experiential knowledge. This is used to understand past disasters and their determinants, as well as drivers of change to inform the forward-looking responses in the face of projected climate change, or forward-looking assessments based on scientific modelling [3.4.1, 3.5.1].

For example, to understand projected increases in risks posed by climate change on food security concerns from increased TLB, several key technical assessments are required:

- the effect of increased precipitation and more warmer nights on the establishment and spread of TLB
- taro crop varieties available in the Asia–Pacific region that exhibit resistance to TLB [case study 4.1].

A different analysis would be required for water security in Tuvalu (Table 17) [case study 4.2]. Such information, including empirical data, is drawn from published and grey literature as well as from different government sources, and community knowledge as well as specifically designed data collections [case studies 4.1, 4.2, 4.3, 4.4; tables 13, 17, 20, 24]. Such detailed technical and scientific information would be used to inform ex-ante or ex-post CBA of adaptation measures [case studies 4.1, 4.2, 4.4].

Observations from the Pacific

PICs continue to face serious challenges to strengthening their DRM, while also responding to projected climate change for their national development goals. Some progress has been made in integrating climate change into national and sectoral level policies, plans and strategies into on-the-ground projects. The range of work implemented also includes a number of climate- and weather- related DRM initiatives and projects that may not have explicitly been categorised as CCA. Many of these projects were implemented with the financial and technical support of development partners on a bilateral or multilateral basis.

National and sectoral policy level climate change adaptation

Many countries have explicitly recognised DRM and climate risk management in their national sustainable development strategy plans although, institutionally, the adoption of risk-based planning is not integral to their day-to-day decision-making process [3.3, 5.1]. Many countries have also attempted to mainstream DRM management and climate change mitigation and adaptation measures in the National Disaster Risk Management Action Plan and National Adaptation Plan of Action (NAPA) for climate change. Some countries, such as Tonga and Republic of the Marshall Islands (RMI), have developed joint national action plans for DRM and CCA. However, a common challenge in many countries is the systematic implementation of such policies and plans [4.2, 4.3,4.4,5].

Elements of ’vulnerability-first’ policy and planning approach have informed development of National Disaster Risk Management Action Plans and NAPAs in the PICs even if this approach was not explicitly identified at the time. National Disaster Risk Management Action Plan and NAPA processes relied on national and sectoral review documents, National First Communication and other

Multilateral Environmental Agreements (MEA)-related reports. Such stakeholder-based action plans also reflected the multiple goals of reducing exposure and vulnerability, preparing for and responding to residual risks, and coping with and recovering from disaster events. Limited information together with expert judgements and local knowledge informed the design of the adaptation and risk management measures, which also reflected an all-hazards consideration.

However, the two streams of disaster and climate risk management have generally been pursued in parallel in the region. This is despite the two streams being guided by two regional instruments based on essentially the same risk management framework and guided by similar risk management principles. At the country level, there is arguably little coordination or integration of the two approaches, neither between institutions supporting DRM and CCA, nor during the implementation of policies, plans, programs and activities. Co-ordination is even less likely in the approaches and tools used in respective decision-making processes [5].

Although most countries have national plans of action for DRM and CCA in place, this has not been translated into the sub-national and sectoral levels. Where they have been undertaken, the relationship between goals, sector objective and activities is not always clear in most countries. Where some linkages can be found, for example in Nauru, a direct line of sight can be seen between national development goal and the sector objectives, but not necessarily between the sector priorities and on-the-ground projects implemented under some regional projects (such as the Pacific Adaptation to Climate Change project). Similarly, the National Transport Plan in the Solomon Islands clearly outlines the need for climate proofing infrastructure as highlighted in its NAPA. But there are no specific strategies aimed at operationalising this. In some cases, pilot project activities are underway to inform the development of the national sector policy and framework, however, the relationship between the overall sector goal, objectives and the actual design of the various projects is difficult to identify [5].

The link between national, sector, program and project-level adaptation measures could be strengthened by adopting a linked set of cascading processes used in climate risk identification and risk management across the decision-making levels, informed by more specific and explicit relational information.

Project level climate change adaptation

Institutionally, risk considerations are often not integral to government decisions. Projects implemented to address recent disasters and current disaster risks are often stand-alone projects focusing on targeted community/area-based concerns [3.3; case studies 4.1, 4.2, 4.3, 4.4]. They focus on a single hazard and exclude other hazards and drivers of vulnerability considerations (case studies 4.3, 4.4). Government-led and community-based projects are also often implemented ad hoc and in a policy vacuum. Such projects often limit scope for sustainability once the project funds are exhausted [3.3].

The vulnerability-first planning approach has been the norm, and in some cases a hybrid of 'impacts first' and 'vulnerability first' has been used along with CBA to inform CCA decisions [3.4.1]. Many externally funded community-based adaptation projects, implemented by community-based organisations and local non-government organisations (NGOs) have adopted some elements of the vulnerability-first assessment approach, starting with community-based vulnerability assessments. These use variations of community-based vulnerability and adaptation assessment (CV&A) tools. However, it is difficult to see in the cases examined to what extent project teams actually followed the vulnerability-first process, as steps followed are often not documented. Personal observations of recent CCA projects in the region suggest that specific project activities were not selected on the basis of V&A assessments (i.e. risk analysis, or risk management assessment and prioritisation). This is confirmed by the detailed case studies examined here [3.4.1; case studies 4.2, 4.3].

Data limitations, capacity constraints and uncertainty have also been the main constraints in the use of 'impact-first', and to a lesser extent in the vulnerability-first planning approach at the project level. Where the impact-first approach has been attempted, researchers are forced to adopt different degrees of quantitative assessments based on assumptions about climate change scenarios, impact scenarios as well as broad generalisations about the adaptation measures and the potential benefits of adaptation assumptions. The impact-first approach is also difficult to use regularly in most countries as climate change modelling expertise is limited but, more importantly, not even suitable climate change models for the region are available, let alone for countries. Nor is there baseline data to inform such modelling exercises with a degree of confidence. Furthermore, for sectoral-level social and economic impacts, better technical information and country/context-specific data are needed and are generally limited at best and in most cases not available [3.4.1, 3.5.2; case studies 4.1, 4.2, 4.3, 4.4].

Systematic social and economic assessment of projects is not common in the region. Even less common are risk-management projects, and economic CBA of projects and policies is almost non-existent, except for large-scale externally funded projects such as infrastructure projects. Many DRM and CCA project documents make reference to their economic and social benefits, but empirical information to support such statements is often limited. A detailed ex-ante or ex-post probabilistic CBA is even less likely to have been undertaken. Detailed CBA in the Pacific is often difficult because of factors such as limited empirical baseline data and a high degree of uncertainty concerning future climate scenarios and impacts. In some adaptation projects, CBA could only be done using a deterministic CBA together with a series of sensitivity analysis [3.5.2; case studies 4.1, 4.2, 4.4].

The CBA framework is useful to structure and systematically identify risk-reduction impacts and costs and benefits of adaptation measures, even if detailed CBA may not be critical to making an informed choice [3.4.2, 3.5.2; case study 4.3].

Where detailed CBA of risks and risk reduction measures are warranted, robust scientific information about climate change, its impacts on natural systems and its impact on economic activities and societies is critical.

As a start, a holistic systems perspective that provides a context-specific all-hazards understanding of risks would help identify appropriate, hard and soft adaptation measures for consideration and further assessment. Without such a systems-based approach, adaptation measures identified and implemented may not be effective, and in some cases may even be a maladaptation [case study 4.3, 5].

Economic efficiency measures of climate adaptation projects may not always be sufficient for prioritising and choosing between adaptation measures, and particularly when a decision is required to inform a portfolio of adaptation measures. The choice of adaptation measures for national development will also be guided by the explicit acknowledgement of the multifaceted nature of climate risks and the interaction between development and disaster outcomes. Multiple criteria that would guide the selection may include, not only the usual economic efficiency criteria, but also others that recognise current development needs, current disaster risk as well as increasing risks under climate change and associated uncertainties, particularly when resources are limited [3.5.2; case studies 4.1, 4.4].

Where multiple objectives, and or data and capacity constraints are found, decision-makers could progressively move from qualitative to semi-qualitative to quantitative assessment (if adaptation and management responses warranted the detailed assessment). As a minimum, experiences in the Pacific suggest that broadbrush, largely qualitative, risk assessment is likely to be more suitable at the national planning level, where key policy decisions need to be made for national development [5]. A more detailed level of assessment would generally be required at the sector level, when identifying specific sectors to target, as well as when developing detailed sectoral level strategies and programs for action. A detailed quantitative CBA of adaptation options is generally useful where decision making between adaptation options will be improved by detailed quantitative assessment of risks and uncertainties, particularly where the adaptation has a long shelf life. The level of empirical data used in such assessments would depend on the availability of such information [3.5.2, 3.6.2, 3.2, 5, and case studies 4.3, 4.4].

The selection of adaptation projects, as well as the quality of project designs has often been challenged by capacity constraints to assess projects and/or in the use of robust technical assessments. In-country capacity in technical assessment-based decision-making processes is often limited, even in terms of adequately reviewing assessment reports prepared by external consultants.

Key recommendations

To strengthen knowledge-based adaptation decisions, several areas need particular attention across all PICs. Country-specific priority and entry points for such strengthening may though depend on current status of baseline data, past research, and institutional capacity to make informed decisions. Other factors may also be important such as the urgency in addressing current development and disaster risk management needs, and addressing the challenges of climate change and the relevance of strengthening a foundational enabling environment.

To strengthen a cascading and explicitly linked set of adaptive decision-making processes across all levels of national policy, from planning levels to community/project levels that recognise current development and DRM needs and changing risks under projected climate condition and the associated uncertainty.

At each level of adaptation, there is a seven-step risk management cycle-based process, established on a stakeholder-based hybrid impact-first and vulnerability-first technical planning approach. This is a systems view of drivers of vulnerability and exposure, and incorporates context-specific integrated analysis of climate risks and climate adaptation measures.

Determining specific adaptation criteria to guide the choice of adaptation measures is an integral step in this process, together with the recognition that decision-makers may use iterative process, moving from qualitative to semi-qualitative to quantitative assessment as warranted.

Strengthening of technical and institutional capacity to make knowledge-based decisions is required at all levels across the region, recognising uncertainties associated with climate change, risks and risk-reduction potentials. Such capacity development programs need to address a wide spectrum of institutional and technical capacity needs, including:

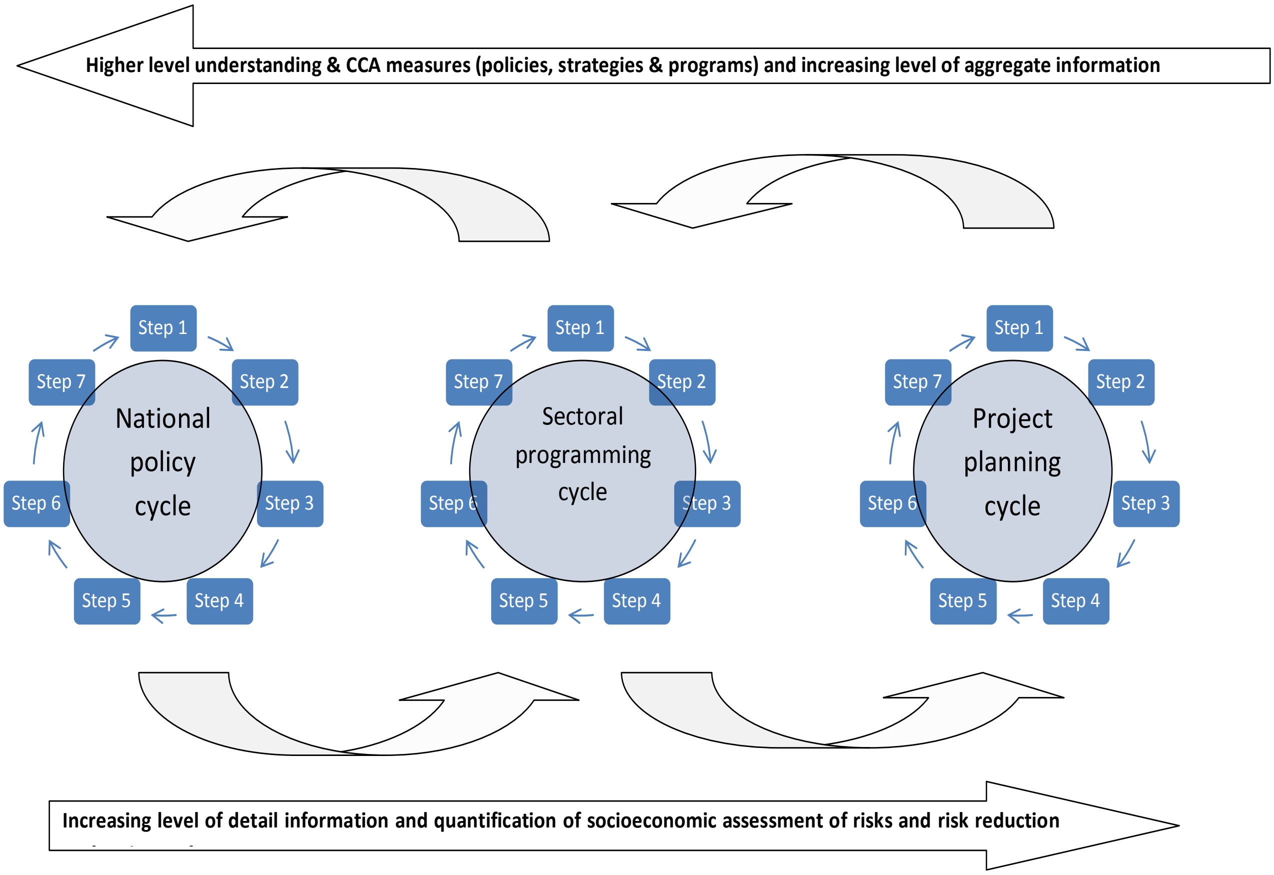
- harmonisation of DRR and CCA plans and policies in the short term and integration of the DRR and CCA decision-making process in the medium to longer term
- integration of climate risks in policy and project cycle-based decision-making process
- systems understanding of the ramifications of climate change and the interactions with drivers of vulnerability and exposure and spectrum of hard and soft adaptation options available to address those climate risks
- decision-making capacity to choose adaptation measures, including a portfolio of adaptation measures for national development, considering multiple criteria such as economic efficiency, other social and economic benefits and costs, and other development criteria
- economic CBA of risks and risk-reduction and adaptation measures
- a sustainable livelihood analytical framework and associated vulnerability assessment tools.

Knowledge-based adaptation decisions need robust data, information and knowledge drawn from across several disciplines that help in the understanding of climate science and climate change, vulnerability, social and economic impacts, and risk-reduction and management measures suitable to the local ecological, social, economic and political environment.

Geo-referenced baseline information and other foundational enabling environments need urgent strengthening across all PICs. Robust information about economic, environment and social systems and their vulnerability and exposure to climate extremes is critical for context-specific integrated assessment of risk and risk reduction-based decisions. Foundational enabling environments that also need urgent attention include inter-agency institutional arrangements to sharing of data maintained across agencies, as well as to facilitate coordination of initiatives across scales and between DRM and CCA activities.

A linked regional–national climate service could be useful in providing a rigorous scientific basis to key in-country decisions. Such a climate service would cover climate science research, vulnerability analysis, decision support, and communication. It would provide timely delivery of relevant information and assessments, that could be used for ongoing evaluation of climate change and climate decisions, and have an easily accessible information portal that facilitates coordination of data among agencies and dialogue between information users and providers. Such a service would also include 'hands-on' strengthening of a national level decision-making process and other enabling environments, that promote knowledge-based decision-making and actions, as well as technical capacity to make informed decisions.

Figure 3 Cascading and explicitly linked CCA decision-making processes, involving national policy and planning across to community/project level risk management decisions, and information and knowledge needs



Legend: Step 1: understand social, environmental and economic context of hazards & vulnerability; Step 2: establish development goals & decision-making criteria; Step 3: identify and assess current risks; Step 4: identify CCA measures; Step 5: Assess CCA options and choose preferred option; Step 6: Project design& implement; Step 7: Monitor, lessons learnt & modify action

Table 1 A seven-stage 'vulnerability-first'-based decision-making process for the Pacific

Stage 1	Understand the social, economic and environmental context of communities, broad drivers of change, including climate and other risks—situation analysis	Baseline data to identify parameters for adaptation monitoring. Baseline data to assess success/progress of adaptation measure
Stage 2	Establish development goals and specific decision-making criteria, including economic, social and other considerations	Clarity in how the adaptation measure directly contributes to national priorities for economic, social and environmental goals
Stage 3	Assess current risks the context of climate change (and other drivers)—assessment of hazards and vulnerability	Qualitative and or quantitative assessment of risk to enable estimation of the benefits of the adaptation measure
Stage 4	Identify different risk-reduction and climate adaptation measures, taking into account the urgency of their implementation, depending on the dynamics of the natural environment, economic and social sectors and the dynamic of the climate change impacts	Identify alternative adaptation measures that address current risks and projected risks, considering the dynamics of the underlying economic systems and the dynamics of climate change impacts
Stage 5	Evaluate alternative adaptation options using cost–benefit analytical framework (process), recognising context-specific relevance and/or usefulness of qualitative, semi-qualitative and/or quantitative information	Stepwise assessment of each adaptation option against the pre-identified criteria (from Step 2)
		Identification of baseline needs, data gaps, before undertaking detailed CBA where appropriate
		Selection of a preferred adaptation option
Stage 6	Conduct a detailed design and implementation plan, including identification of indicators of the effectiveness of the measure, time horizon; and implement	A feasible and cost-effective design
Stage 7	Monitor and evaluate the adaptation measure, and adjust throughout implementation in light of changes in socioeconomic, technological conditions as well as new scientific information	Learning by doing
		Adjustments over time as new information becomes available
		Adaptive management

1. Introduction

In response to the increasing impact of climate change, countries in the Pacific have implemented a number of CCA measures over the last two decades. These range from activities that focus on mainstreaming climate change into national and sectoral level policies, plans and strategies to actual on-the-ground projects. This range of work implemented also includes a number of climate and weather-related DRM initiatives and projects that may not have been explicitly categorised as CCA. Many of these projects were implemented with financial and technical support of development partners on a bilateral or multilateral basis, with approximately 500 projects, costing US$1860 million and supported between199 and 2009 (Hay, 2009a). These projects covered a variety of themes such as climate risk management, mainstreaming, land use and sectoral adaptation activities.

Most regional CCA projects implemented in the Pacific in recent years have focused on capacity building in one way or the other; for example:

- institutional strengthening for improved decision-making[1];
- policy development and planning (based on various regional projects funded by AusAID (Australian Agency for International Development), European Commission, United Nations Development Programme, Asian Development Bank, and the World Bank)[2];
- mainstreaming DRM into national planning and budgetary process, together with the identification of priority adaptation needs, and the development of NAPA (and National Action Plans for DRM);
- development of national and/or sectoral policies on climate change and DRM
- Australian Pacific Climate Change Science Program for improving climate change scenario projections for the Pacific island countries (www.pacificcliamtechangescience.org).

The few on-the-ground projects have mainly targeted community-based activities, such as water storage facilities, shoreline protection through mangrove replanting and trialling of versatile crop varieties, which mainly focused on addressing current disaster risk deficits. PICs have increasingly been requesting that the focus be shifted to more tangible and practical on-the-ground adaptation projects, undertaken and targeted at local-level vulnerabilities rather than just developing policies and plans (Morrell, 2009).The call for institutional and technical capacity development is also a consistent theme under climate change (Wickham, Kinch et al., 2009).

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[1]See e.g. GIZ project on *Coping with climate change in the Pacific Island Region (CCCPIR);* http://www.spc.int/lrd/index.php?option=com_content&view=article&id=478&Itemid=44

[2]See e.g. (www.bom.gov.au/climate/pi-cpp; www.ausiad.gov.au/country/pacific; www.csiro.au/parntership/Pacific-Cliamte-Change-Science-Program.htm; www.adaptationlearning.net/program/programmes-water-safety-plans-pdms), ADB (www.adb.org/projects/project.asp?id=41187); www.thegef/sites/thegef.org/files/documents/document/09-16-08-SCCF.pdf)

In response, there has been an increase in the number of projects targeting climate change risks, including projects currently underway such as:

- the first regional United Nations Development Programme Global– Environment Facility (UNDP–GEF) funded Pacific Adaptation to Climate Change (PACC) project in 14 countries executed by the Secretariat of the Pacific Regional Environment Programme (SPREP) across 14 countries and covering core sectors such as coastal zone/infrastructure, water security and food security
- climate proofing of the Western Guadalcanal Road in the Solomon Islands
- construction of reservoirs and water tanks across eight PICs to increase water security funded by the European Commission and executed by Pacific Island Applied Geoscience Commission (SOPAC)
- introduction of climate-resistant crops, breeding extreme weather-adapted livestock, developing community land-use plans, trialling new agroforestry and soil stabilisation methods, and undertaking innovative climate adaptation education programs in Vanuatu executed by Secretariat of the Pacific Community-Deutsche Gesellschaft für Internationale Zusammenarbeit (SPC-GIZ) with funding from the German Government.

There are also other food security-related projects, implemented by the Centre for Pacific Crop and Trees (CePaCT), that focused on producing salt-, pest- and drought- resistant crops and help address current development needs but which could also serve to reduce future climate risks (http://www.spc.int/lrd/index.php?option=com_content&view =article&id=630:climate-ready-collection&catid=66:centre-for-pacific-crops-and-trees&Itemid=26). A list of key current and planned adaptation projects implemented by country is summarised in a recent International Institute for Sustainable Development (IISD) report (Dohan, Hove et al., 2011).

Although some of these projects have produced, or promise to produce good localised benefits, some countries and donors have found it difficult to sustain such benefits, and/or to scale up the activities to generate country-wide benefits. It is unclear if recent and current progress in DRR will be sufficient to protect people and properties from future increases in the number of potentially disastrous events brought about by a combination of climate variability and change (Hay and Mimura, 2010).

The success of adaptation options does not solely rely on understanding climate change, exposure and vulnerability. It also requires an understanding of other drivers of vulnerability. A robust and practical analytical framework that recognises current data and capacity constraints in the PICs is required to support countries in their adaptation decisions. It is essential that such an analytical framework is supported by the best available scientific and traditional knowledge, as well as experiential knowledge of dealing with climatic disasters.

In this context, the Australian Government is implementing PASAP under its International Climate Change Adaptation Initiative program in the Asia–Pacific. PASAP is intended to strengthen partner country capacity for assessing vulnerability to climate change and develop evidence-based adaptation strategies. A key element of PASAP is a regional overview that describes regional trends and variability in climate change impacts, vulnerability and adaptive capacity, and identifies common needs. The overview is also expected to synthesise existing knowledge about adaptation in the region, identify both lessons learned and relevant good practice measures and significant knowledge/research gaps.

As part of this regional overview, the Australian Government commissioned the International Union of Nature Conservation, Oceania Regional Office (IUCN-ORO) to research how the economic and social costs and benefits of adapting to climate change are currently considered in decision-making at the national, sub-national and/or community levels in the Pacific. The research is implemented in partnership with SOPAC (now Applied Geosciences and Technology Division of SPC/SOPAC).

1.1 DCCEE–IUCN project objectives

The basis of the specific objectives of this Department of Climate Change and Energy Efficiency-International Union for the Conservation of Nature (DCCEE-IUCN) project is a review of international and regional literature and a selected number of case studies. The project's objectives are to provide:

- analytical framework(s) suitable for assessing economic and social costs and benefits of CCA projects in the Pacific
- an overview of key constraints in undertaking economic and social assessments-based informed choices about CCA projects in the Pacific
- suggestions for overcoming key institutional and other constraints when using economic and social assessment for making informed choices about CCA in the Pacific.

Four case studies (Table 2) were selected to reflect priority climate change-related sectoral adaptation issues in the Pacific:

- food security and crop improvement
- water security
- relocation
- infrastructure.

Table 2 Case studies selected for detailed assessment

Climate change adaptation issue	Title of case study	Country
Food security and climate resistant crops	Assessing the social and economic value of germplasm and crop improvement as a CCA strategy: Samoa and Vanuatu case studies	Samoa and Vanuatu
Water security	Assessing the social and economic value of CCA in the Pacific region: A case study of water quality, quantity and sanitation improvements as an adaptation to climate change, Tuvalu	Tuvalu

Relocation/resettlement/migration	Social and economic assessment-based climate risk management: a case study of sea-level rise and relocation of Lateu community, Vanuatu	Vanuatu
Climate proofing of infrastructure projects	Making informed adaptation choices: A case study of climate proofing of road infrastructure in the Solomon Islands	Solomon Islands

The project was originally to provide case study-based economic and social assessments to inform analytical framework for informed CCA decisions. This was subsequently revised to provide a generic CCA framework, commonly used globally, and then to assess a limited number of case studies using this framework to highlight the kinds of constraints faced in adoption of knowledge-based adaptation decisions in the Pacific.

This study provides a preliminary analysis of issues and constraints facing the PICs and suggests some key areas that could be strengthened to assist them make knowledge-based adaptation decisions. It is noted that a critical review of a wider set of DRM and CCA projects in the Pacific and a larger number of detailed case studies would ideally be required to inform the Pacific in their efforts to strengthen their decision-making process for knowledge-based climate risk management.

The report is structured as follows.

To provide a context for the analytical framework, Chapter 2 provides a brief overview of climate-related disasters and climate change risks in the Pacific, and summarises current knowledge about Pacific-specific climate change scenarios, and outlines expected changes in climatic and vulnerabilities in the PICs.

Chapter 3 describes a conceptual framework for making informed CCA decisions. The framework covers two dimensions in recognising uncertainties associated with climate change: the decision-making context and linkages between levels of adaptation measures; and technical risk and risk reduction analysis informed by robust baseline data and other knowledge. In the Pacific, there is the added challenge of the availability of limited robust baseline technical information about climate science, environmental and socioeconomic impacts of climate change, and limited capacity.

Chapter 4 discusses the four illustrative case studies from the Pacific region to highlight the key issues and challenges faced by PICs, and identifies areas for strengthening knowledge-based climate adaptation decisions. This chapter is drawn from a compendium volume that contains the detailed case studies. Chapter 5 provides some observations on mainstreaming efforts at national/ sectoral planning levels. Chapter 6 then draws on chapters 3, 4 and 5 to provide a synthesis of finding and providing practical steps towards strengthening economic and social knowledge-based CCA choices.

2. Climate change risks in the Pacific

PICs are among the most vulnerable countries in the world to climate change, and are already facing regular climate-related disaster risks. Disaster risk is defined by the interaction between hazard, exposure of social, economic and environmental elements and the properties of the exposed systems, that is, their sensitivity to social, economic and environmental systems. United Nations International Strategy for Disaster Reduction (UNISDR) notes that disasters, development and environment are inextricably linked (ISDR, 2004). Hazard is defined as 'a potentially damaging physical event, phenomenon or human activity, which may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation' (p. 16, ISDR, 2004).

The 'big ocean, small islands' context of the Pacific islands contributes to the environmental and economic exposure and risks of these nations and communities to natural disasters. PICs, many of which are located along the equatorial belt, are regularly exposed to and experience climate and hydro-meteorological hazard conditions, including cyclones, high winds, flooding and storms (Table 3).

Table 3 Some example of the risks to climate-related disasters faced in the Pacific region

Country	Cyclone flood	Coastal flood	River flooding	Drought	Storms	Landslide
Fiji	H	H	H	M	H	H
Federated States of Micronesia	M	H	L	H		L
Kiribati	L	H	n/a	H	M	L
Marshall Islands	n/a	M	H	n/a		L
Solomon Islands	H	H	H	L	H	H
Tonga	H	H	M	H	M	L
Tuvalu	L	H	n/a	M	L	L
Vanuatu	H	H	H	L	H	H

H – high; M – medium; L – low; n/a – not applicable

Source: Adapted from United Nations Department of Humanitarian Affairs (1994).

Global warming is recognised as the major factor accentuating climate regimes and normal variations due to El Niño Southern Oscillation (ENSO). ENSO is a natural cycle of the climatic system, characterised by distinct patterns of change in features such as wind, surface pressure, air and sea temperature and precipitation. Historically, El Niño events have been correlated with moderate to extreme drought conditions, whereas La Niña events are associated with wetter springs and summers. It is however, difficult to distinguish between the effects of ENSO, the longer term interdecadal change, and those associated with anthropological climate changes. Nonetheless, it is certain that natural variability in climatic conditions and extreme events will be compounded by climate change and sea-level rise over time (BOM and CSIRO, 2011), increasing vulnerability of the Pacific countries.

The relationship between development and disasters is well known (UNDP, 2004) and PICs are particularly vulnerable to the effects of climatic conditions because of their limited development and weakening traditional lifestyle (Wickham et al., 2009). Their vulnerability is heightened by a reliance on the climate-sensitive primary sectors, such as agriculture for basic livelihood and income, limited alternative sources of income, low human development conditions (such as household income, access to water and sanitation), and limited financial and human capital. Climate change is projected to exacerbate these disaster risks.

Climate change, as defined by IPCC (2011), is a change in the mean and/or the variability of a climate property (such as precipitation, temperature, and wind force) and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forces, or to persistent anthropogenic changes in the composition of the atmosphere or in-land use. Under climate change, disaster risks are changing in terms of scale, scope, frequency and intensity, calling for major shifts in the way society adapts to current disaster risks and future climate risks. Disaster risk is the likelihood of severe alterations in the normal functioning of community or society to weather or climate events, interacting with vulnerable social conditions (IPCC, 2011).

2.1 Climate change projections

Weather, climate and ocean current patterns in the Pacific are a product of both natural and human-induced climate change. Natural factors include trade wind regimes, South Pacific Convergence Zone (SPCZ), with ENSO as the dominant force affecting annual variability. The Working Group II report to the Fourth Annual Assessment Report (AR4) of the IPCC (Mimura, Nurse et al., 2007) noted the following climate changes for the Pacific region, based on global climate modelling:

- annual and seasonal ocean surface and island air temperature have increased by 0.6–1.0°C since 1910 throughout a large part of the region south-west of the SPCZ and projected to further increase over time
- more hot days and warm nights, and significantly fewer cool days and cold nights, particularly in years after the onset of El Niño events
- analysis of satellite and tide gauge data show a maximum rate of sea-level rise in the central and eastern Pacific, spreading north and south around the subtropical gyres of the Pacific Ocean near 90°E, mostly between 2 and 2.5 mm/year, peaking at over 3 mm/year for the period 1950–2000
- differential changes in average precipitation are also expected—some islands show drier conditions and other areas are projected to experience increased average rainfall as well as extremes.

Under the Pacific Climate Change Science Program, the Australian Bureau of Meteorology (BOM) and the Commonwealth Scientific and Industrial Research

Organisation (CSIRO) have identified 24 global climate models (GCM) (BOM and CSIRO 2011). BOM and CSIRO acknowledge that these models do not explicitly represent the situation faced in the Pacific islands, noting that that while they can simulate broadscale Pacific climate conditions, they cannot account for local climate effects, resulting from island shapes and topography. Given constraints in computational resources and lack of available data, only 6 of the 24 GCMs could be relied on for use in the Pacific region with any degree of confidence (BOM and CSIRO 2011). Using available GCMs, BOM and CSIRO's latest results suggest that projected changes in mean climate conditions are projected to remain small in the short term (Figure 4), while a significant shift is expected in the extreme events, including:

- the number of days of heavy rain is projected to increase in all locations, except for those areas where annual mean rainfall is projected to decrease
- the proportion of cyclones with higher intensities is expected to increase, although overall the Pacific region is expected to see a decrease in the number of cyclones (10–50% decrease).

Countries in the region are also projected to experience differential changes in climate conditions (Table 4), suggesting a need to consider local climatic scenarios when assessing local disaster risks.

Taking natural- and human-induced climatic forces and dynamics into account, BOM and CSIRO provide likelihood estimates associated with different climatic futures, recognising inherent uncertainties (Figure 4). For example, 14 out of 18 GCMs suggest that the Solomon Islands can expect to see little change in its average rainfall pattern, but a worst case scenario projects warmer and wetter condition (Figure 4b). In comparison, 50 per cent of the GCMs predict that Tuvalu can expect to experience wetter conditions, with a most likely future of little rainfall change (Figure 4c). Such likely and worst case projections of climate futures, as discussed in Chapter 3 and illustrated in the 'climate proofing' case study from the Solomon Islands are required to identify appropriate adaptation measures and design and choose specific adaptation options.

Table 4 Illustration of indicative types of observed current and projected future climate variation in the Pacific: Solomon Islands, Vanuatu, Tuvalu and Samoa

	Recent observed changed	Future climate
Solomon Islands	• Temperatures have increased • No clear trend in rainfall • 41 cyclones passed within 400 km of Honiara between 1969 and 2010 • Sea level has risen 8 mm per year since 1993 (larger than global average of 2.8–3.6 mm/yr)	• Temperatures will continue to increase and more hot days and warm nights • Annual and seasonal rainfall projected to increase and increased number of extreme rainfall days • Less frequent but more intense tropical cyclones • Sea-level rise expected to continue and projected to be 4 to 15 cm by 2030 under a high emissions scenario

Vanuatu	• Annual maximum and minimum temperatures have increased • Decreasing trend in wet season rainfall, but no clear trend in annual and dry rainfall, with significant variation • 41 cyclones between 1969 and 2010; number of cyclones per year varying, ranging from 0–6 in a season • Sea level has risen 6 mm/yr since 1993	• Average air and sea temperatures will increase; by 2030 worst case scenario increases projected to be 0.4–1.0°C; and more hot days and warm nights and decline in cooler weather • Uncertainty in rainfall changes; decrease in dry season and increase in wet season projected over 21st century • Less frequent but more intense tropical cyclones • Sea-level rise expected to continue and projected to be 3–117 cm by 2030 with expected increases in storm surges and cyclones
Samoa	• Temperatures have increased since 1950 • Rainfall remains unchanged (Apia) • 52 tropical cyclones passed within 400 km of Apia; number of cyclones per year varying from 0–5 in one season; cyclones occurred more frequently in El Niño years • Sea level has risen	• Average air and sea temperatures will continue to increase; by 2030, worst case scenario increases projected to be 0.4–1.0°C; and more hot days and warm nights and decline in cooler weather • Uncertainty in rainfall changes with decreases in dry season and increases in wet season projected over 21st century; drought projections inconsistent for Samoa; more extreme rainfall days projected • Less frequent but more intense tropical cyclones • Sea-level rise expected to continue and projected to be 5–15 cm by 2030, with expected increases in storm surges and coastal flooding
Tuvalu	• Annual seasonal maximum and minimum temperatures have increased since 1950 • No rainfall change in Funafuti since 1950, but with substantial variation between years • 33 cyclones between 1969 and 2010, number of cyclones per year varying and ranging from 0–3 in a season, cyclone occurred more frequently in El Niño years • Sea level has risen 5 mm/yr since 1993 (a total of 9 cm over this period), variation from year to year or decades caused by ENSO	• Average air and sea temperatures will continue to increase; by 2030, worst case scenario increases projected to be 0.4–1.0°C; and more hot days and warm nights and decline in cooler weather • Increase in average annual and seasonal rainfall Increase in wet season and dry season projected; but uncertainty in rainfall projections; drought projections inconsistent for Tuvalu; more frequent extreme rainfall days projected • Less frequent but more intense tropical cyclones • Sea-level rise expected to continue and projected to be 4–14 cm by 2030 and 19–58 cm by 2090, with expected increases in storm surges and coastal flooding
Source: BOM and CSIRO (2011a); BOM and CSIRO (2011b); BOM and CSIRO (2011c); BOM and CSIRO (2011d).		

Figure 4 Climate future projection for annual rainfall and annual surface water for 2030, using A2 emission scenario, including uncertainties associated with climate scenario projections

a. Samoa

Climate future for 2030 using the A2 emission scenario

		Annual Surface Temperature (C)			
		Slightly Warmer < 0.50	Warmer 0.50 to 1.50	Hotter 1.50 to 3.00	Much Hotter > 3.00
Annual Rainfall (%)	Much Drier < -15.00				
	Drier -15.00 to -5.00		**Likelihood: 2 of 18 models** (11%)		
	Little Change -5.00 to 5.00		**Likelihood: 13 of 18 models** (72%)		
	Wetter 5.00 to 15.00		**Likelihood: 3 of 18 models** (16%)		
	Much Wetter > 15.00				

- Most likely future: warmer with little annual rainfall change (CSIROMk3.5 model)
- Largest change future: warmer and wetter (HADGEM model)

b. Solomon Islands

Climate future for 2030 using the A2 emission scenario

		Annual Surface Temperature (C)			
		Slightly Warmer < 0.50	Warmer 0.50 to 1.50	Hotter 1.50 to 3.00	Much Hotter > 3.00
Annual Rainfall (%)	Much Drier < -15.00				
	Drier -15.00 to -5.00				
	Little Change -5.00 to 5.00		**Likelihood: 14 of 18 models** (77%)		
	Wetter 5.00 to 15.00		**Likelihood: 4 of 18 models** (22%)		
	Much Wetter > 15.00				

- Most likely future: warmer with little annual rainfall change (CSIROMk3.5 model)
- Largest change future: warmer and wetter (HADGEM model)

c. Tuvalu

Climate future for 2030 using the A2 emission scenario

		Annual Surface Temperature (C)			
		Slightly Warmer < 0.50	Warmer 0.50 to 1.50	Hotter 1.50 to 3.00	Much Hotter > 3.00
Annual Rainfall (%)	Much Drier < -15.00				
	Drier -15.00 to -5.00				
	Little Change -5.00 to 5.00		**Likelihood: 9 of 18 models** (50%)		
	Wetter 5.00 to 15.00		**Likelihood: 9 of 18 models** (50%)		
	Much Wetter > 15.00				

- Most likely future: warmer with little annual rainfall change (GFDL2.1 model)
- Largest change future: warmer and wetter (ECHAM5 model)

d. Vanuatu

Climate future for 2030 using the A2 emission scenario

		Annual Surface Temperature (C)			
		Slightly Warmer < 0.50	Warmer 0.50 to 1.50	Hotter 1.50 to 3.00	Much Hotter > 3.00
Annual Rainfall (%)	Much Drier < -15.00				
	Drier -15.00 to -5.00		**Likelihood: 4 of 18 models** (22%)		
	Little Change -5.00 to 5.00	**Likelihood: 1 of 18 models** (5%)	**Likelihood: 11 of 18 models** (61%)		
	Wetter 5.00 to 15.00		**Likelihood: 2 of 18 models** (11%)		
	Much Wetter > 15.00				

- Most likely future: warmer with little annual rainfall change (CSIROMk3.5 model)
- Largest change future: warmer and drier (GFDL2.0 model)

(Source: BOM and CSIRO 2011)

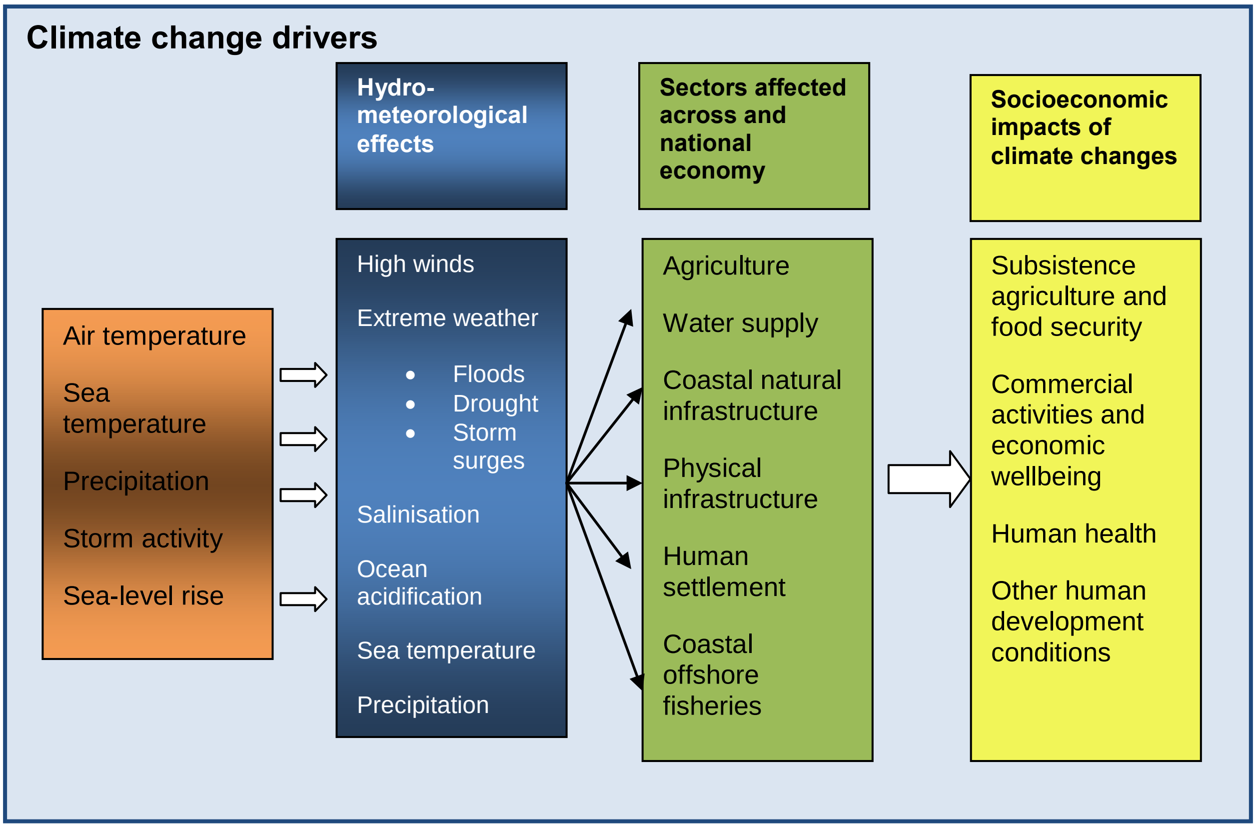
2.2 Impacts

Under global warming, countries and communities are projected to experience changes in their hazard and risk profiles. These may include (Prabhakar, Srinivasan et al. 2009):

- changes in the kind of disasters that are experienced (from no disasters in the past to more disaster events)
- changes in types of hazards (from floods to more droughts); and/or
- change in hazard intensities and magnitude.

Such changes in disaster risks may arise from changes in one or more climatic conditions and may manifest themselves through multiple pathways, ultimately affecting human wellbeing (Figure 5). For example, a decreased in precipitation lasting for extended periods of time could result in drought conditions. Whether these are due to long-term, human-induced climate changes of climatic variability from ENSO events, or events compounded by climate change, they both have direct and indirect impacts on human wellbeing. The ENSO associated droughts in 1998–2000 for example, resulted in serious water shortages across much of the region, including Papua New Guinea (PNG), RMI, Federated States of Micronesia (FSM) and Samoa. A national emergency was declared in FSM in 1998 when 40 atolls ran out of water, while RMI imposed severe water rationing and constructed desalination plants to provide some much needed access to drinking water.

Figure 5 Selected climate changes, their hydro-meteorological effects, sectors that may be affected and the social and economic impacts on people



Water availability affects human hygiene levels, although the interaction can be complex. Singh et al. (2004) found that in low-atoll islands, such as Tuvalu and Kiribati, there is a strong correlation between climate variability and rates of diarrhoea. In Tuvalu for example, after heavy rains the economic cost on the island can be as high as A$500 000 because of flooding-induced pollution from septic tanks and its effects on water-borne illness and drinking water (Lal, Saloa et al. 2006). By comparison, in Vanuatu increased incidence of diarrhoea, skin diseases and malaria was directly associated with high rainfall and/or storm surges (Nakalevu and Phillips, 2007). After five cyclonic events in 2002–2003, Vanuatu reported a 50 per cent increase in malarial incidence and an almost 100 per cent increase in water-borne diseases when compared to the same period in 2001–2002 (Lal, Wickham et al. 2009).

Some climate factors can affect multiple sectors and the effects of climate change can be further magnified. For example, increased precipitation can affect productivity and have both a positive and negative effect on agricultural production, but through its effects on human health can lead to human suffering (Table 4). Changed climatic conditions can result in the increased spread of pests and diseases, such as taro leaf blight experienced in PNG and Samoa. Other changes in climatic conditions, such as flooding and cyclones, can drastically reduce agricultural output, with major economic costs to society (summarised in Figure 6).

The underlying cause of such observed sector level impacts, that is, whether they are due to observed changes in climate in recent times (Table 4) or by ENSO events (see water, infrastructure and food security case studies for further discussion), or any other drivers (see the relocation case study) remains unclear. Whatever the underlying causes, projected climate changes would exacerbate such disaster events, possibly increasing the frequency, intensity, spatial extent, duration and timing of extreme weather and climate events. The climate change risks are not always easy to predict with certainty because the effects of climate change manifest themselves through multiple pathways, and there is a complex web of interactions between meteorological conditions, environmental changes and socioeconomic vulnerability (Pielke (Jr), Rubiera et al., 2003), as Figure 6 illustrates using crop examples from the Pacific.

Figure 6 Selected climate change effects and pathways of impacts on agricultural production and food security

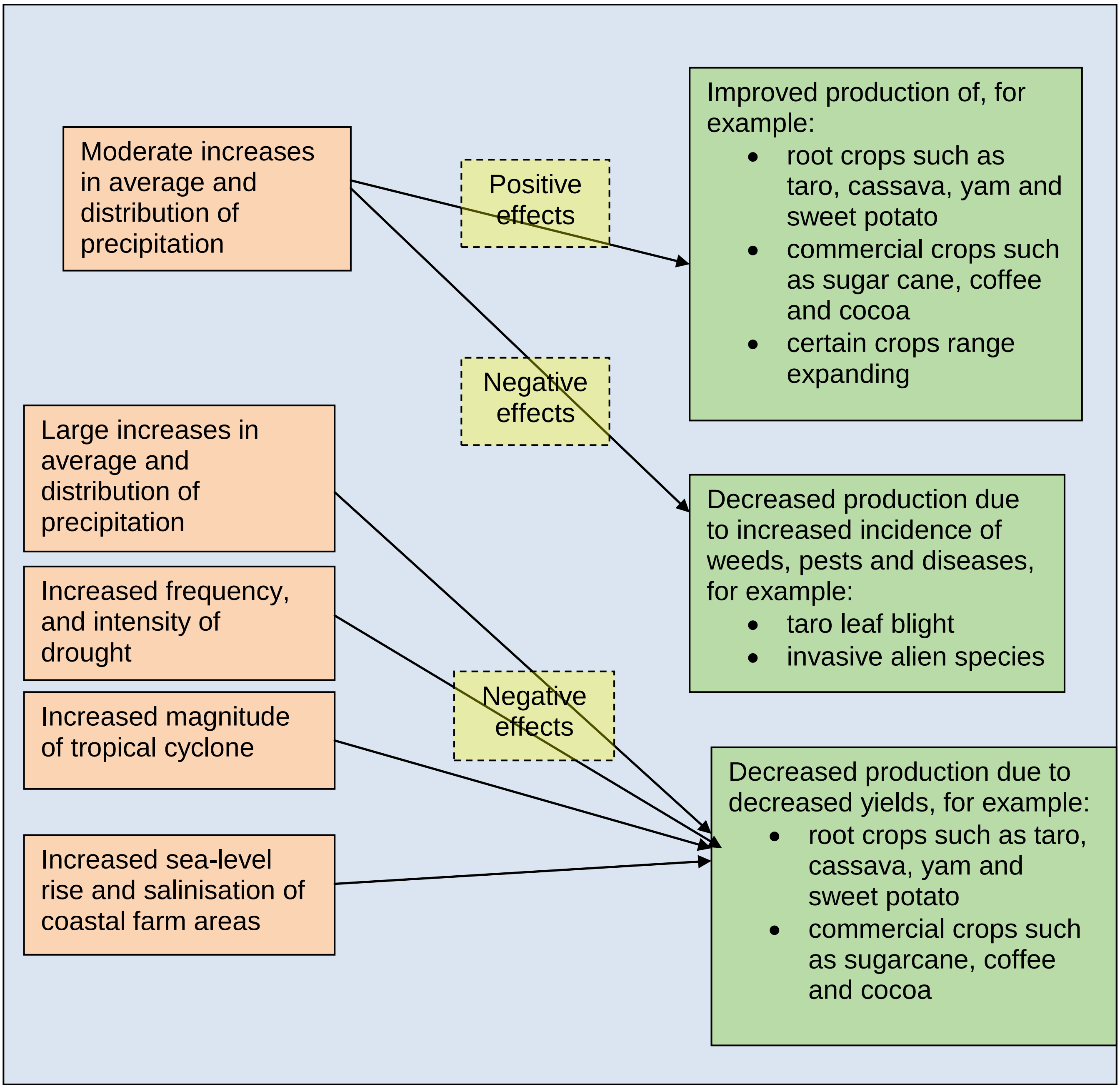


Table 5 Selected climate change and expected impacts on agriculture, water, coastal zone and infrastructure sectors

	Agriculture and food security	**Water (quantity and quality)**	**Coastal zone and human habitation**	**Infrastructure**
Increased precipitation	• Flooding of agricultural lands and crop damage • Create favourable conditions for growth of less invasive species • Create conditions favourable for spread of pest and diseases	• Alleviate water shortage, especially on small islands • Flooding and pollution of underground water sources and coastal areas • Flooding and causing water and insect-borne disease	• Coastal flooding	• Flooding damage to roads, bridges
Decreased precipitation (and increased temperature) —drought conditions	Decrease in crop yield and production: • plant and animal stress • water shortages for agriculture • affect health, production and reproductive capacity of animals • slow growth and low yields from food crops	• Increased water shortage especially on small islands • Water shortage and associated sanitation issues, causing water-borne diseases		
Cyclones	• Wind damage to agricultural crops and forest trees • Erosion of coastal areas due to wave surges and flooding • Damage to crops from salt spray and rising sea levels • Loss of animals due to falling coconut trees • Outbreaks of invasive species	• Inundation of groundwater sources by salt water • Destruction of farm rainwater storage facilities • Flooding and pollution of underground water sources and coastal areas • Flooding and causing water- and insect-borne disease	• Coastal flooding, damage to homes and property	• Flooding damage to roads, bridges

Sea-level rise	• Salt water inundation and flooding of coastal agricultural lands • Erosion of soil and coastal areas, increase salinity of agricultural lands	• Inundation of coastal springs and underground water sources	• Coastal flooding and damage to homes and property • Coastal inundation and forced relocation	• Coastal inundation and damage to roads, ports and other infrastructure
Temperature	• Extreme night-time temperatures: mixed crop yields, with temperature-tolerant crops showing increases but with night-time lows causing decreased yield	• Increased evaporation and decreased water storage		• Roads and bridges warping with high temperatures
Source: Based on World Bank (2000), FAO (2008), and ADB (2011)				

2.3 Climate-related disaster impacts in the Pacific and vulnerability

PICs regularly experience significant disaster events, including climate-related disasters that impact on the local people and across the economy. Between 1950 and 2009, PICs experienced over 200 declared climate disaster events, causing damage of approximately US$6.5 billion (Hay and Mimura, 2010). Most of the damage was caused by cyclones (storms), which caused almost 95 per cent of all climate-related damage in the region (Table 5). However, such disaster statistics do not include estimates of crop losses due to pest and disease outbreaks, many of which are also climate dependent. In terms of national gross domestic product (GDP), such costs on average were equivalent to two to seven per cent of a country's GDP (Word Bank, 2000). Individual disasters caused a damage equivalent of 200 per cent of annual GDP in Niue following cyclone Heta in 2004 (McKenzie et al., 2004).

Table 6 Frequency and reported economic and social impacts of natural disasters in the Pacific

Type	Number	Killed	Total affected	Total victims	Economic damage	Number of events with reported economic damage
Drought	8	60	947,635	947,635	66,666,667	1
Epidemic	12	306	10,662	10,968	-	0
Flood	28	132	451,073	451,205	264,339,362	11
Landslide	16	544	2,563	3,107	-	0
Storm	134	1573	1,937,467	1,939,040	6,128,846,865	57
Surge	4	2534	11,574	14,108	-	0
Wildfire	2	0	9,000	9,000	67,340,426	1
Climate-related total	204	5149	3,369,974	3,375,063	6,527,193,320	70
Total (all disasters)	250	8297	3,611,773	3,620,070	6,892,230,514	78
%	82%	62%	93%	93%	95%	90%
Source: Hay and Mimura (2010).						

After Cyclone Ivy in 2004, Vanuatu reported damages of about US$12 million. This affected 50 000 people, 90 per cent of water resources, 70 per cent of roads, and 60 per cent of all health infrastructure, together with damage to about 80 per cent of their food resources. In Fiji, Cyclone Amy is reported to have caused a direct agricultural loss of about FJ$66 million (approximately US$29 million) (McKenzie, Prasad et al., 2005). Most PICs rely on locally grown rain-fed crops for their energy and protein, so current disaster risks also have significant effects on household livelihoods. Cyclones in 1985 and 1986 in the Solomon Islands are reported to have caused significant food shortages in the ‘weathercoast’ communities of Makira. Such events have been regular enough to affect the society and culture, with locals talking about ‘time blong hungry’(Jackson, Tutua et al., 2006), which increases their vulnerability to projected changes in climate.

Vulnerability has three dimensions which would require assessments at different levels of decision-making to inform appropriate scale and scope of response—national, community or household level:

- the sensitivity of households, communities, economies and environment to hazards
- their ability to respond to extreme events
- the ability to cope with the immediate effects of an event.

‘Sensitivity’ is used in this report to refer to those conditions with the greatest potential to magnify the effect of disaster on individuals and communities. At the national level, vulnerability is generally high as a result of poor infrastructure, which is often perceived as a key component of a country’s economic status. Freeman (1999) demonstrated a direct link between vulnerability to natural disasters and poor infrastructure. Poor infrastructure affects people’s ability to engage in income-generating activities as well as their ability to respond to disasters. Poor infrastructure standards, weak government regulations (such as the absence of building codes) and weak regulatory enforcement also increase disaster risks.

Countries that heavily rely on the primary sector are also generally found to be more sensitive to the effects of natural disasters (Benson, 1997; Benson and Clay, 2004), particularly disasters of hydro-meteorological origin. At the same time, the process of development adopted and the development choices made in many countries affect those countries’ vulnerability to disasters—for example, environmentally unsustainable development practices, such as logging in areas prone to landslides, increases disaster risks. Human vulnerability is exacerbated by weak end-to-end disaster warning systems and the ability of people to manage disaster.

People’s sensitivity also depends on their development condition. The poorer the economic and social wellbeing at the household level, the more sensitive the household is to the impact of hazards (primarily because it has a low threshold for withstanding external shocks). They are also less able to respond to, cope with and adapt to disasters because they would not have much, if any, financial and social capital on which to draw on (IISD, IUCN et al., 2003; Elasha, Elhassan et al., 2005). Such conditions are also reflected at the human development index which has been adopted globally. This index reflects national conditions such as household income, access to water and sanitation, maternal and child mortality, and education (UNDP, 2010).

International literature (Benson and Clay, 2004; Benson and Twigg, 2004) suggests that factors that drive vulnerability of local communities are linked to the structure and the status of the national economy, the condition of physical infrastructure (including access to water and sanitation) and the socioeconomic characteristics of households (including income, health and education). PICs still struggling to meet their Millennium Development Goal targets across all goals are highly vulnerable to the effects of weather, climate and other disaster events. Environmental degradation too, is a major driver of disaster risks as it aggravates the impact of hazards, for example by altering ecological processes that affect the magnitude and frequency and timing of hazards (ISDR, 2009). However, as the effects of climate risks manifest themselves through multiple pathways, the impacts are not always easy to predict with certainty without sound scientific and/or experiential knowledge.

What is known about the impacts of climate change in the Pacific is largely based on local observations and experiences; generally these have not been validated by robust technical assessments. Pacific communities have been observing significant patterns in rainfall, droughts, storm surges and changes in their crops, with much change believed to have occurred in the last several decades. Community perception of climate change (BOM and CSIRO, 2011) include:

- more frequent and extreme rainfall causing flooding and mudslides
- more drought and fires
- more hot days
- shifts in seasonal patterns of rainfall and tropical cyclone
- an increased incidence of certain weeds, pests and diseases outbreaks (such as taro leaf blight)
- increased storm surge, causing coastal erosion, salt water contamination of freshwater springs and taro swamps.

Table 4 above had summarised the latest observations and projections about climate change, based on rigorous analysis of available empirical data and global modelling exercises (BOM and CSIRO, 2011).

Based on their past experiences and recent observations, PICs acknowledge their vulnerability and have identified key sectors of particular concern, including agriculture (food security), water (water security and human heath, particularly from waterborne and insect-borne diseases), infrastructure (flooding and sea-level rise), and the coastal zone (sea-level rise and human settlement) (Table 7). Such assessments were carried out as part of the National Communication reports to United Nations Framework of Climate Change Convention (UNFCCC) and assessments done for NAPA in the least developed countries, and other national assessments.

Table 7 Priority sectors of concern in Pacific island countries

Country	Agriculture	Water (water security)	Water (flooding)	Health (water and insect-borne diseases)	Fisheries	Road and ports infrastructure	Coastal zone sea-level rise, and human settlement	Biodiversity
Cook Islands	✓	✓				✓	✓	✓
Federated States of Micronesia		✓					✓	
Fiji		✓	✓	✓		✓	✓	
Kiribati		✓		✓			✓	✓
Marshall Islands		✓					✓	✓
Nauru		✓		✓			✓	
Niue	✓	✓		✓			✓	✓
Palau	✓	✓		✓			✓	
PNG	✓	✓		✓			✓	
Samoa	✓	✓		✓			✓	✓
Solomon Islands	✓	✓	✓	✓		✓	✓	
Tonga	✓	✓		✓			✓	
Tuvalu	✓	✓	✓	✓			✓	
Vanuatu	✓	✓		✓		✓	✓	

Source: Cook Islands Government (1999); FSM National Government (1997); Fiji Government (2005); Kiribati Government (1999); (RMREPA 2000) Nauru Department of Commerce Industry and Environment (2010 (draft));Niue Government (2000); Papua New Guinea Government (Papua New Guinea Government 2000); RMREPA (2000); Samoa (1999); Solomon Islands Government (Solomon Islands Government 1999);Tonga (Tonga 1999); Tuvalu Ministry of Natural Resources (2007); Vanuatu National Advisory Committee on Climate Change (2007).

With such projected impacts across the economy, countries also recognise that adaptation to increasing and changing risks would need to be tackled across sectors, and the CCA measures would need to be multidimensional and multifaceted and implemented across all levels of decision-making.

Although the specific combination of measures varies across countries, they have identified in their national communications, NAPAs, and other reports noted in Table 7; adaptation measures such as early warning systems and communication, research and development, improved policies, plans and governance, as well as sector-focused measures including:

- agriculture – pest and disease management; crop diversification; salt-resistant crops and heat-tolerant species; land use planning, soil conservation; and agroforestry techniques
- water security and flooding – integrated water resource management, rainwater harvest and storage, and desalinisation; demand management; flood control
- human health – improved water and sanitation; improvements in the prevention of insect-borne diseases, such as malaria and dengue; education and public awareness
- biodiversity – enhanced research into the possible impacts of climate change on flora and fauna as well as ecosystem rejuvenation, reforestation and conservation programs, promotion of agroforestry, changes in land use policies, and education
- coastal zone and infrastructure – climate proofing and relocation
- coastal (marine and fisheries) – mangrove and coral reef conservation, protected area management, marine breeding and restocking programs, fisheries conservation and management.

3. Making informed climate change adaptation decisions: an analytical framework

Climate change is a multifaceted national concern directly or indirectly affecting all sectors and communities. The economic and social impact of disasters in the Pacific are already significant, and risks of disasters and their costs are increasing with climate change (as discussed earlier). Therefore a need exists for DRM to not only address current risks, but also risks heightened through climate change.

The focus of this report is on direct adaptation measures that governments can target to reduce risks due to climate change. It recognises that mitigation over the long term is also a form of adaptation intervention that directly targets root cause of climate change greenhouse gas emissions. Strategies for achieving this include reduction in greenhouse gas emissions, increased carbon-sequestration and low-carbon economic development.

The following terminology is applied in this report. Disaster risk is the likelihood of severe alterations in the normal functioning of community or society to weather or climate events interacting with vulnerable social conditions (IPCC, 2011). Disaster outcome is a product of the risks and capacity to prepare for, respond and recover from disaster events, and is influenced by the underlying development conditions. Risk management is the implementation of strategies to avoid or minimise risks and unacceptable consequences by avoiding exposure to hazards as well as reducing vulnerability. Risk management strategies for climate change comprise CCA and mitigation (Pittock, 2003).

3.1 Adaptation and adaptation measures

Adaptation to climate change has been variously defined (Box 1) with reference to 'adjustments', a process, a set of 'practical steps' to achieve some predetermined goal, or even an 'outcome'. Essentially though it is about managing climate change-related risks. This may include the adaptation of natural and social and economic systems, and emphasise institutional/policy dimensions (Levenia and Tirpak, 2006). In the Pacific, all of these dimensions of 'adaptation' are relevant. In this report, 'adaptation' is used as defined by the IPCC SREX, which refers to changes in human systems: 'the process of adjustment to actual or expected climate and its effects in order to moderate harm or exploit beneficial opportunities' (IPCC, 2011). The term, 'adaptation measures' is used to refer to policies, strategies, programs and/or projects (OECD, 2009).

Box 1 Definitions of 'climate change adaptation'

Adaptation – Adjustment in natural and human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2007).

Adaptation – Practical steps to protect countries and communities from the likely disruption and damage that will result from effects of climate change. For example, flood walls should be built and, in numerous cases, it is probably advisable to move human settlements out of floodplains and other low-lying areas… (http://unfccc.int/essential_background/feeling_the_heat/items/2911.php).

Adaptation – A process by which strategies to moderate, cope with and take advantage of the consequences of climatic events are enhanced, developed, and implemented (UNDP, 2005).

Adaptation – The process or outcome of a process that leads to a reduction in harm or risk of harm or realisation of benefits associated with climate variability and climate change (UK Climate Impact Programme, Willows and Connell 2003).

Adaptation – In human systems is the process of adjustment to actual or expected climate and its effects to moderate harm or exploit beneficial opportunities (IPCC, 2011).

Source: Levinia and Tirpak *(2006) and (IPCC, 2011).*

Adaptation measures may be implemented in reaction to recent climatic events or proactively planned for projected climate change, variability and extremes, as well as address other national development goals. For example, individuals may decide to construct stronger homes to better withstand a higher cyclone category, knowing that their families will be better protected. Autonomous adaptation actions could also include the adoption of private insurance against future disaster events. By comparison, governments may identify risks, implement planned initiatives for adaptation to climate change and proactively invest in risk reduction. Governments' actions are generally required when the benefits of specific activities will accrue to everyone and where individuals do not have incentives to meet the costs of doing so (IPCC, 2007). Given that vulnerability to current and projected climate change is increasing and the public good nature of many planned adaptation benefits, there is a growing need for greater attention on planned and publicly funded adaptation to climate change risks (ISDR, 2011).

Current development and disaster risk management needs and climate change challenge is multifaceted, therefore a portfolio of adaptation measures may be required across levels of government, across sectors and by communities. In the Pacific, there is again limited robust technical information available on the impacts of climate change, although communities have experienced some changes.

To strengthen knowledge-based adaptation decisions in the Pacific, two aspects of DRM need particular attention: adaptation decision-making process, and technical risk and risk-reduction analysis (and other knowledge) to inform adaptation measures.

3.2 Adaptation decision-making processes

Adaptation decisions are made across all levels of society. The levels of government make decisions relevant to their respective roles, responsibilities and functions and generate different adaptation measures. Adaptation decision-making processes include systematic consideration of climate risk across national and sectoral planning and programming stages when designing and implementing practical risk-reduction and management activities (OECD 2009). Figure 7 summarises different levels of government and community decision-making and the outputs they usually produce in the Pacific.

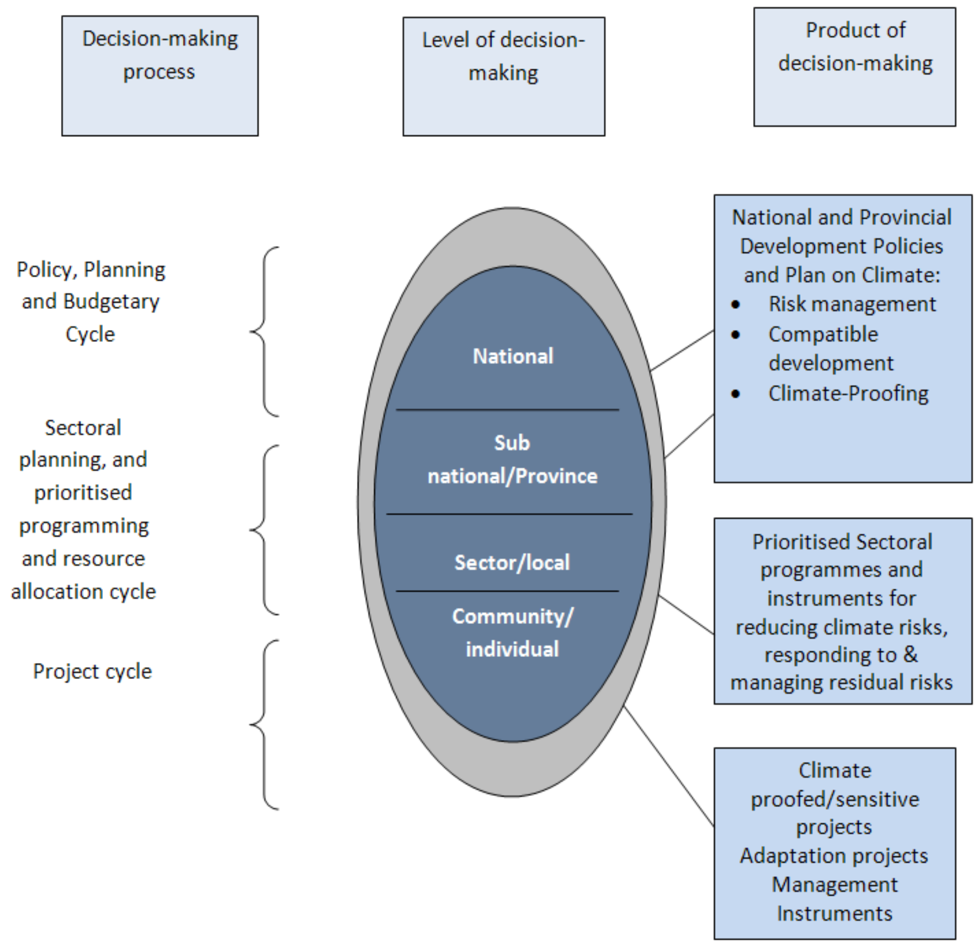
Ideally, there would be a direct relationship between adaptation decisions about national priorities, sector level objectives and activities. Once the government has identified its vision, goals and policies in its national development plans, national-level policies should be translated into sectoral priorities. This is followed by sectoral programs and portfolios of sectoral activities that operationalise the sectoral priorities and strategies. This includes the allocation of corresponding financial resources to the sectoral-level authorities responsible for translating national priorities into action on the ground (Handmer and Dover, 2007; ISDR, 2008c; OECD, 2009). One would also expect the effects and experiences gained on the ground to be aggregated upwards and for decision-making institutions to be scaled-up appropriately, including effective top-down and bottom-up interaction.

Adaptation policies may either be directly incorporated into national goals, or they may be drawn from the overall national development goals by acknowledging changing climate (Levina and Tirpak, 2006). National development goals may include CCA policy objectives about improved efficiency in water use and consumption (water sector), conservation of mangrove wetlands (forestry), enhanced food security (agriculture), improved public health (health and sanitation sector) or improved livelihoods and human wellbeing (cross-sectoral). For example, National Development Goal 6 for the Cook Islands calls for a ‘safe and resilient community’, and identifies priority actions related to climate change that are relevant to land, coastal zone, freshwater and marine resources.

At the sector level, adaptation measures may include strategies and actions that operationalise national policies that maximise positive and minimise negative outcomes for communities and societies in climate-sensitive sectors such as water, agriculture and food security, and coastal infrastructure — 'climate-proofing' sectoral plans and programs (OECD, 2009). Palau's National Sustainable Development Strategy (NSDS) goal on water and sanitation states 'to provide a reliable, safe, affordable, secure and sustainable water supply to meet socioeconomic development needs', and in its National Water Policy identifies a priority action to establish 'a secondary desalination plant'.

Planned on-the-ground practical adaptation projects, promoted and implemented by governments would progress those sectoral development and management objectives into actions that integrate or reflect climatic risks. On-the-ground projects may be developed and implemented by communities or individual households to address disaster risk and climate change challenges. Examples of on-the-ground activities include: planting of mangroves to rehabilitate degraded coastline as a storm buffer; water harvest and storage at the household level; or planting crops resistant or tolerant to the effects of climate change, such as pest- and disease-resistant taro and salt-tolerant crops to cope with salinisation of coastal farming areas due to storm surges.

Figure 7 Targeting decision-making processes for mainstreaming of climate change risk considerations



3.3 CCA: challenges for decision-makers

CCA exhibits key elements of DRM (ISDR, 2009; ISDR, 2011), but with two key differences. DRM comprises DRR and post-disaster management dealing with current disasters; whereas climate risk management is about dealing with future climate risk. DRM strategies are based on historic data and experiences with hydro-meteorological events as a guide to the future disaster risks. On the other hand CCA decisions, although possibly based on past experiences, must also take account risks associated with projected changes in the average and variability in climate conditions and sea-level rise and changes in the frequency and intensity of the extreme events, such as precipitation, cyclones and storm surges. Given there are countries already facing significant challenges in addressing current weather and climate variability and extremes and associated disaster risks, addressing the drivers of vulnerability and exposure, such as poverty and human wellbeing, and environmental degradation is a critical aspect of their response to projected climate change (Yodmani, 2001; IFRC, 2004; Venton and Trobe, 2008).

Furthermore, uncertainty is a key feature of climate change. Climate futures are highly dependent on both past increases in greenhouse gas emissions and their effects on global climate, as well as on mitigation measures adopted and rate of greenhouse gas emission reductions achieved over time and their effects on global warming and climate systems. For the Pacific, the uncertainty is particularly acute, as the baseline time-series meteorological and sea-level data are limited, sub-regional and national level climate models do not exist, and GCM results are not always consistent (Figure 4 and Table 3). There is also uncertainty about the scale, scope and magnitude of climate change impacts across sectors due to limited information. Disaster impacts associated with climate change, variability and extremes are a result of a complex web of interactions, involving socioeconomic as well as environmental and meteorological factors (Pielke(Jr), Rubiera et al., 2003; Hallegatte, Hourcade et al., 2007).

In the face of uncertainties, complexity and diversity, current disasters and projected climate futures; CCA decisions become even more challenging when countries have to decide between investments that address current development issues, including current disaster risks, while also preparing for uncertain longer term climate scenarios. There is no single approach or criteria to use in assessing and prioritising adaptation measures (Hamill and Tanner, 2010; Füssel, 2007). To some extent, current decisions can be made, particularly in response to the dual challenge of meeting current needs and DRM solutions in the short–medium terms, and which may be also suitable under alterative climate scenarios.

In trying to balance the immediate development needs, disaster risks as well as plan for climate futures, adaptation measures are often prioritised to focus on current development imperatives, whatever the future climate (Hellmuth, Moorhead et al., 2007). Such an approach to CCA is often referred to as ‘no regrets’ or ‘low regrets’ strategy, which produces not only risk-reduction benefits but also other development benefits. For example, a ‘low regret’ strategy could be aimed at the protection of coastal mangrove ecosystem. This can provide a cost-effective buffer against current and future storm surges, as well as support biodiversity conservation and enable improvements in economic livelihoods and human wellbeing, particularly to the poor and vulnerable (Figure 8). Such decisions may be based on recent climatic variability and observed trends in disaster risks and development needs though, such ‘low regrets’ solutions that produce win–win outcomes may not be always feasible.

In long-term situations where investments need to be made, explicit considerations of climate projections also become critical, as in the case of roads, bridges, and other similar infrastructure developments, such as the Solomon Islands Road Improvement Project (SIRIP) 2 sub-project. In extreme situations, countries with limited resources may choose to postpone making decisions about future climate risks while they address their immediate development needs, but while also avoiding maladaptation. On the other hand in some cases, countries may need to choose development and current DRM options that could also be adjusted over time when new information becomes available (Ranger, Milner et al., 2010).

Planned adaptation strategy may also be aimed at building individual and institutional capacity, such as in the form of an early warning system, to plan for, respond to and cost effectively recover. At the individual and/or private sector level, adaptation measures may include specific individual interventions or packages of related actions that they can adopt to reduce and manage their own risks. These include risk transfer and sharing measures, such as disaster insurances and social insurance, which can help people to have access to financial and other resources in times of disaster (IPCC, 2011).

Proactive and reactive adaptation measures could therefore, range from ‘pure’ development activities at one end of the spectrum, to specific response measures at the other (McGray, Hammill et al., 2007; ISDR, 2009; ISDR, 2011). The spectrum of adaptation measures is summarised in Figure 8 including those that target:

- addressing the drivers of vulnerability
- reducing hazards and exposure
- pooling, transferring and sharing risks
- preparing for, confronting and reactively adapting to climate change.

Climate adaptation can require enhancing current sustainable development efforts, including current DRM. In other circumstances, it may require a total transformation in a society, or the postponement of a decision when better information becomes available (IPCC 2011) (Table 8).

GIven uncertainty and limited information, international literature suggests that effective adaptation measures should also be robust and flexible. An adaptation is considered to be robust when the adaptation option has the ability to perform adequately across a wide variety of possible futures. It is flexible when it has the ‘ability to be adjusted to new information or circumstances in the future’ (Ranger, Milner et al., 2010).

Ultimately, transformational changes may be required in societies, not only in the way economies are organised, but also the manner decisions are made in conditions of uncertainty, and fundamental value systems (IPCC, 2011). The term ‘climate-compatible development’ is often used when the focus is on reducing climate impacts through development efforts that also target low-carbon initiatives (Mitchell and Maxwell, 2010). In the presence of uncertainties, the decision-making process would need to recognise the need to periodically review and adjust adaptation strategies, as new information is gained and lessons learnt from past initiatives, essentially adopting adaptive management (Walters, 1986; Sayer and Campbell, 2004) and making transformation changes.

Adaptive management involves regular changes in management policies, strategies and practices are implemented based on lessons learnt from the outcomes of initiatives, and by taking into account changes in other drivers in society (Walters, 1986; Holling, Berkes et al.,1998; Sayer and Campbell, 2004). Adaptive management is also about bringing together interdisciplinary science, experience and traditional knowledge into decision-making through 'learning by doing' by individual agencies (e.g. Walters, 1986; Sayer and Campbell, 2004). There are many examples of adaptive management in the area of natural resource management, but adaptive management has also been applied (Sayer and Campbell, 2004) to DRM (e.g. Thomson and Gaviria, 2004; Thompson and Mackey et al., 2009). It may also be relevant in CCA decision-making processes, where the manner in which agencies are organised and the process they use to make decisions would need to change. Decision-makers need to be flexible, accept new information as it becomes available, share their experiences and knowledge with stakeholders and develop a shared understanding of complex problems and make collective decisions (Lee, 1993; Sayer and Campbell, 2004).

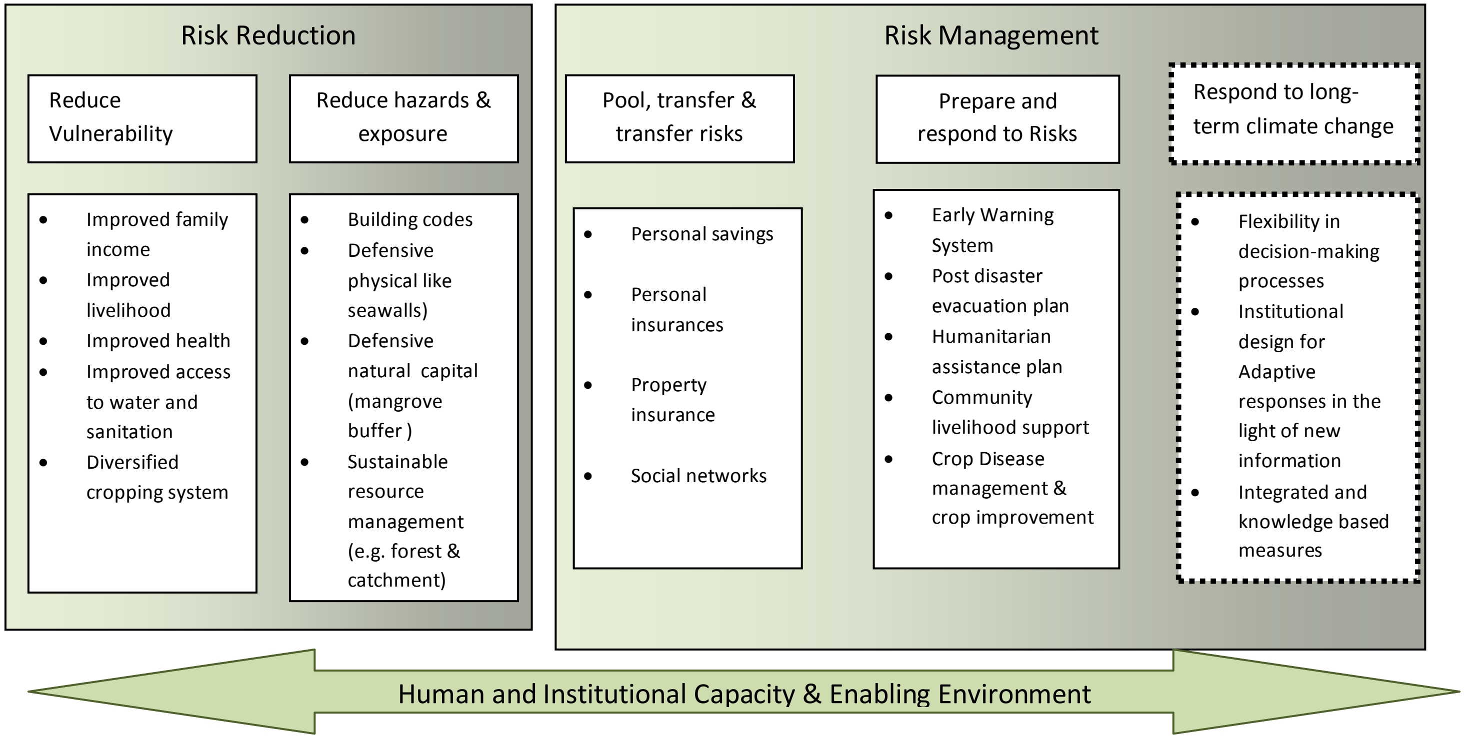
To strengthen knowledge-based adaptation decisions, two aspects need attention: the context and the decision-making process, and technical risk and risk-reduction analysis (and other knowledge) to inform adaptation measures.

Table 8 Some examples of the relationship between current disaster risk and development efforts and adaptation efforts required in response to climate change

Sector	**DRM addressing current hazards and vulnerability (risks)** including traditional 'no regrets' and 'low regrets' actions	**Changes to DRM practices to reflect changing climate and CCA needs, including uncertainty**	**Changes in institutional decision-making processes** to ensure responsive, proactive, flexible and robust decisions in the context of uncertainties, new information and lessons learnt
Agricultural and food security	Improved and sustainable farm management, reducing soil erosion and increasing yields Crop improvement for increased yield, current pest and disease resistance	Increased investment in crop diversity in regional and national germplasm conservation, including in farmers' fields, to meet changed requirements under changed climate conditions (e.g. more frequent and different pests and diseases) and alternative crops suitable for the agro-climatic conditions	Sectoral planning and programming process that requires explicit consideration of new information and lessons learnt to inform CCA responses under changing climate conditions (e.g. more frequent and different pests and diseases) and need to access alternative crops suitable for different agro-climatic conditions
Water security	Water catchment and storage to meet current water needs	Increased capacity of water storage and delivery to meet projected increases due to extreme events Increased government budgeting for emergency response supply of water	Water Sector Policy that recognises changing challenges of water security under changing climate conditions Regular sectoral planning and programming process that requires explicit consideration of new information and lessons learnt to inform CCA responses under changing climate conditions
	Irrigated water resource management	Increased access and storage of irrigated water supply to meet extended periods of drought conditions	Climate risks explicitly considered in the design of irrigation facilities and water supply
Infrastructure	Road and river crossing infrastructures built, reflecting current disaster risks and acceptable thresholds	Road and river-crossing infrastructure built to higher standards to cope with increased extreme conditions, and same or higher tolerance thresholds Use of non-engineering options to reduce vulnerability such as integrated catchment	Regular sectoral planning and programming process that requires explicit consideration of new information and lessons learnt to inform CCA responses under changing climate conditions Adopting policies of building back better

		management, sustainable forest management and integrated coastal zone management	(with higher tolerance thresholds) for infrastructure with long shelf life Knowledge-based, decision-making processes that explicitly consider the option of incremental changes to infrastructure designs in response to projected climate conditions Sustainable development, including Integrated catchment management, sustainable forest management and integrated coastal zone management to reduce drivers of risks
Built environment	Houses and buildings built or retrofitted to reflect current disaster risks and acceptable thresholds Hazard zoning and enforcement	Revised building codes reflected with updated climate risks Revised hazard zoning, including possible relocation	Regular institutional process for adapting CCA policy to reflect new information and lessons learnt about changing climate conditions for example: • land-use plans • building and constructions standards and building codes
Coastal zone (sea-level rise and storm surges)	Integrated coastal zone management Ecosystem-based management and protection of coastal habitats	Incorporate CCA, sea-level rise into integrated coastal zone management Use of a combined hard and soft engineering options for CCA Relocation to reduce exposure and vulnerability	Regular institutional process for adapting CCA policy to reflect new information and lessons learnt about changing climate conditions, for example: • to design coastal setbacks • choose the mix of combined hard and soft engineering options for local CCA

Figure 8 Spectrum of climate change adaptation measures (policies, strategies, projects) mirrors disaster risk reduction and disaster risk management

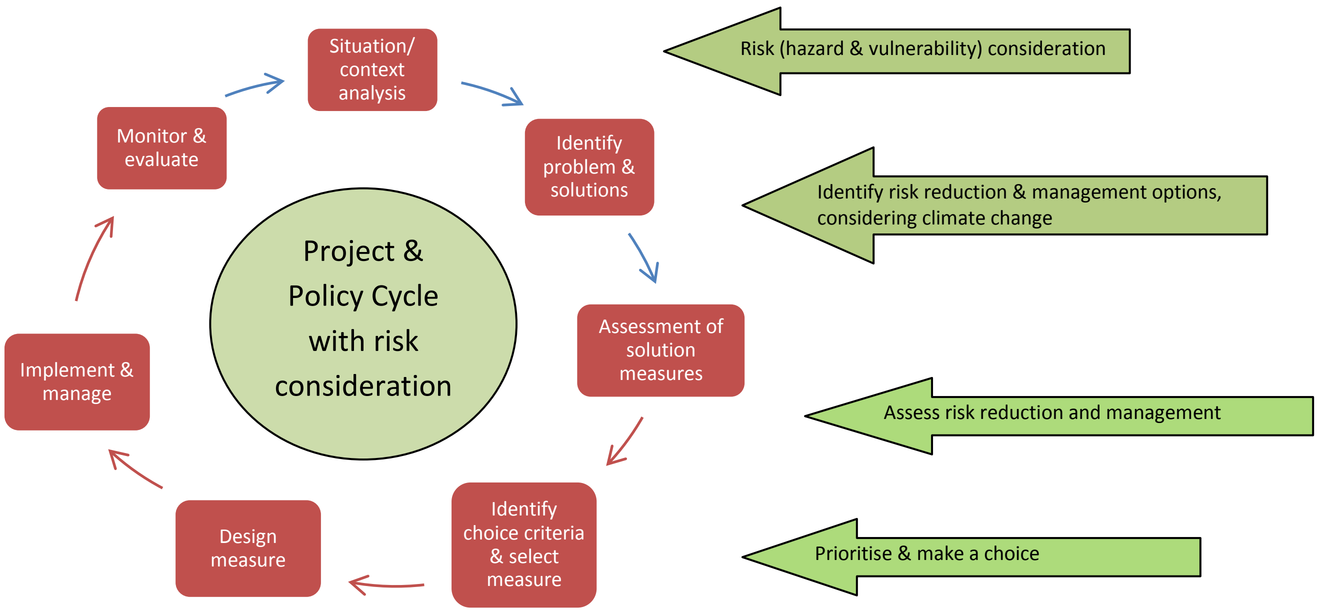


Source: Based on McGray, Hammill, et al (2007).

3.4 Adaptation decision-making processes

Integration of climate change considerations at the policy level would normally follow the policy cycle process; whereas, at an individual activity level, project cycle-based iterative risk management is appropriate (Willows and Connell, 2003; Olhoff and Schaer, 2010; US National Academy of Sciences - Panel on Informing Effective Decision and Actions Related to Climate Change, 2010). A policy/project cycle usually follows the key steps, some of which may be combined during implementation (Gittinger, 1978; European Commission, 2004; Lal and Holland, 2010), integrating risk consideration at key stages (Willows and Connell, 2003; Olhoff and Schaer, 2010), as summarised in Figure 9.

Figure 9 Risk management cycle relevant at the policy or project levels



Source: Adapted from Olhoff and Schaer (2010)

Applying a climate change risk lens during policy or project cycle-based decision-making processes can enable decision-makers to identify potential hazards, vulnerable areas, local sectors, and people to target. It also allows for the development of climate-proofing measures and climate-sensitive or climate-compatible measures, including policies, strategies, programs, on-the-ground activities and appropriate budgets. Examples of the explicit use of policy/planning cycles to develop national sustainable development strategies, national action plans for DRM and the NAPA can be seen throughout the region. However, countries have historically pursued DRM and climate change planning processes as two parallel streams, and face many challenges in operationalising these policies and plans in a coordinated and systematic manner, particularly due to financial and capacity constraints, but also due to the ad hoc nature in which projects are implemented (Wickham, Kinch et al., 2009; Hay, 2009a; Hay, 2009b; King, 2010 – draft; Gero, Méheux et al., 2011).

Ideally, the selection of adaptation policies and projects would be guided by their economic, social and environmental assessments of climate-related risks and risk-reduction and management objectives. Decisions may also be made using other considerations, such as livelihood benefits, future option values and urgency of meeting current needs, as discussed above. Criteria to inform adaptation choices would depend on the level at which the decision is being made and could vary from context to context as the combination of vulnerability, development needs and projected impacts may be different. Countries have only recently begun to consider the relevance of mainstreaming climate and other disaster risk at the sectoral levels, with several activities currently underway under the UNDP GEF funding (SPREP, 2011). The decision-making process for policy/project cycle-based risk management has parallels with the impact-first and vulnerability-first approaches that emphasise both the risk-management process as well as the technical and analytical dimensions of climate risk management. However, as discussed below and illustrated in the case studies, there are many challenges that countries face as they attempt to identify, develop and implement specific adaptation projects. Many of these challenges relate to the decision-making processes and technical issues related to identifying, developing and implementing climate adaptation initiatives.

3.4.1 Adaptation planning approach

Several different planning approaches have been suggested, emphasising different degrees of reliance on climate change scenario information, and stakeholder involvement: IPCC approach, risk approach, human development approach and the Adaptation Planning Framework of UNDP (Dessai, Lu et al., 2005). Essentially, two alternative adaptation planning approaches are generally advocated and used in the Pacific: science or impacts-first and vulnerability-first assessments (Dessai, Lu et al., 2005; Ranger, Milner et al. 2010). Both these process are informed by a combination of scientific and local knowledge, acknowledging the dynamic nature of risk and uncertainties in future climatic scenarios. The difference between the two processes is the stage at which climate change scenarios are considered, and the degree of reliance on climate science.

'Impacts first'

The impacts-first approach involves identifying climate change scenarios using scientific climate models; assessing impacts based on projected climate change scenarios derived from the modelling exercises; identifying, assessing and selecting relevant adaptation measures; recognising underlying uncertainties; implementing the adaptation measure and then assessing the outcomes and learnings (Figure 10). The impacts-first approach, although advocated by IPCC, has usually not been used to inform adaptation decisions even in developed countries (Willows and Connell, 2003).

Experiences across the globe and those in the Pacific are no different, suggesting that modelling-based, impacts-first assessment approaches have not always yielded useful results for the purpose of informing adaptation decisions. This may be due to constraints associated with uncertainties of climate and socioeconomic scenarios, mismatch between the scales at which scenarios are readily available and that at which adaptation policy is formulated (see various references in Burton, Huq et al., 2002). Very few impact-first assessments have been carried out in the Pacific and they have been more for advocacy purposes, providing an insight into orders of magnitude of costs and benefits associated with CCA (Box 1). Uncertainty and data limitations have been the main constraints, forcing researchers to adopt different degrees of quantitative assessments (Table 9) based on assumptions about climate change scenarios, impact scenarios, as well as broad generalisations about adaptation measures as well as the potential benefits of adaptation assumptions (Lal, et al., 2009).

For the Pacific, the impacts-first approach is also difficult to use regularly in most countries at this stage as climate change modelling expertise is limited. But more importantly, suitable climate change models are not available for the region, let alone the countries. Nor is there baseline data to inform such modelling exercises with an acceptable degree of confidence. Furthermore, for sectoral-level social and economic impacts, better technical information and country/context-specific data is needed (Lal et al., 2009; World Bank, 2010).

For the impact-first approach to climate adaptation planning, not only is there a need to improve climate science and climate projections, but also a need to strengthen the geospatially disaggregated baseline information required for risk and risk-reduction assessments, informing adaptation choices. Targeted in-country and regional-level capacity in technical risk and risk-reduction assessment are also required across sectors to support context-specific informed decision-making across levels.

Table 9 Examples of categories of economic assessments in the Pacific

	Examples
Quantitative economic estimates based on empirical climate change scenarios and projected sectoral/economy-wide impacts	(World Bank, 2000; Shorten, Goosby et al., 2003; ADB, 2005; World Bank, 2010); Fiji's First Communication Report
Qualitative economic impact assessment based on context-specific climate change scenarios and limited sectoral impact assessment	(Nunn, Ravuvu et al. 1994; Koshy 2007)
Qualitative comments on climate change impacts on economic activity (community vulnerability assessments), using projected IPCC climate change scenarios, and general country-specific environmental, social and economic characteristics	(Hay and Mcgregor, 1994; Sem and Underhill, 1994; Carruthers and Bishop, 2003; Hay, Mimura et al., 2003; Vanuatu National Advisory Committee on Climate Change, 2007; Reti, 2008)
Source: Adapted from Lal, Wickham et al. (2009).	

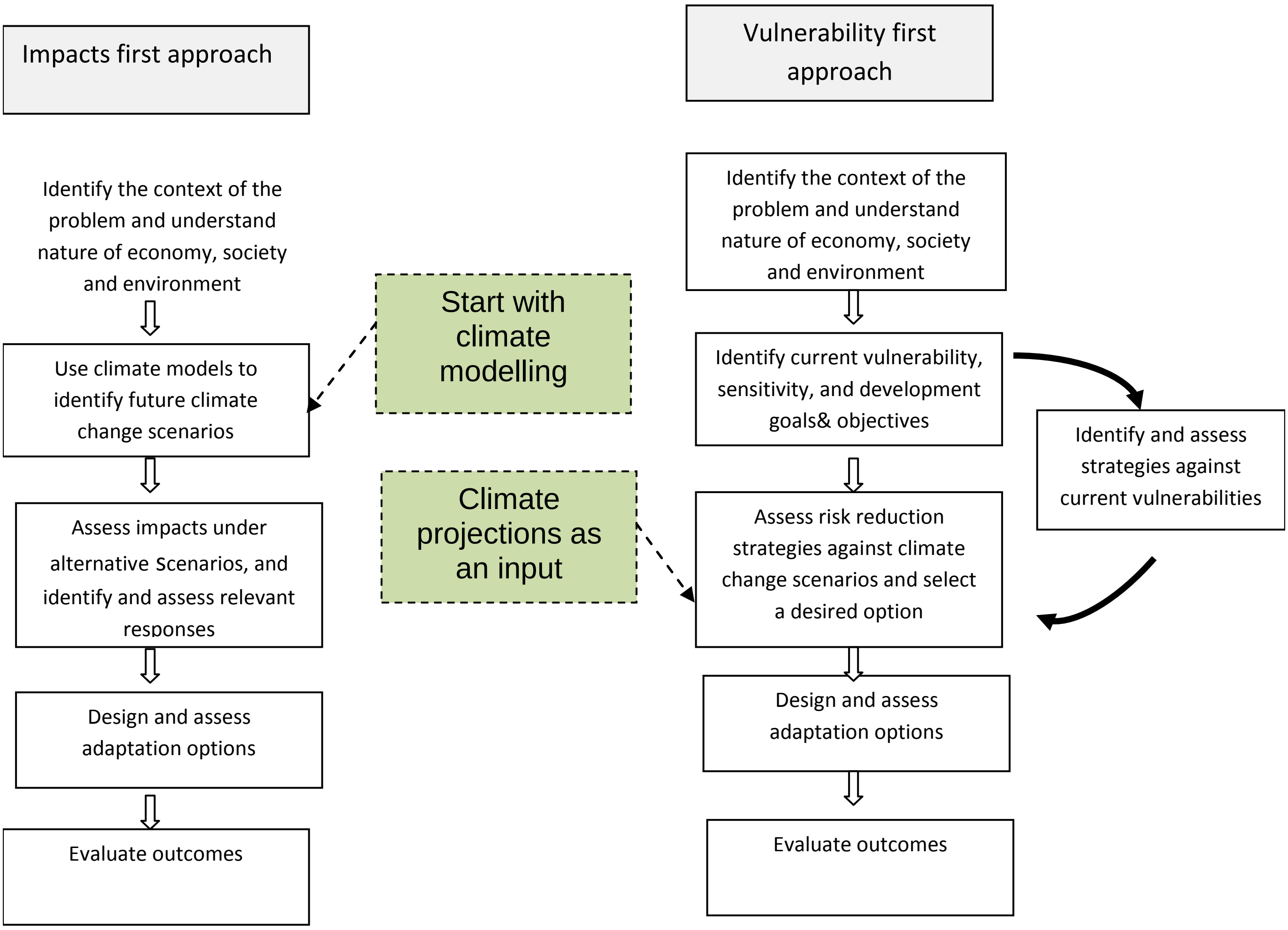
Box 2 Pacific examples, of impacts-first approach to adaptation for advocacy purposes

The World Bank reviewed the macroeconomic costs of climate change (i.e. without adaptation) and benefits of adaptation in Samoa (World Bank, 2010a). They used available climate change scenarios information from IPCC AR 4 and assumed changes in the storm intensity and frequency, expected impacts of the different sectors, such as coastal zone, water, tourism and agriculture, giving an economic cost of about $104–$212 million by 2050; or an equivalent of 0.6–1.3per cent of the present value of GDP over the same period. Using various adaptation measures outlined in Samoa's NAPA, the World Bank also emphasised the economy-wide economic benefits of CCA. Similarly, ADB used a 'with and without' CBA analysis (discussed below) to determine the NPVs associated with proactive climate proofing of roads as compared with retrofitting to reflect projected climate change conditions in Kosrae (ADB, 2005). However, such impact-first-based assessments were not integral to any policy decisions in-country. This though, is not unique to the Pacific.

'Vulnerability first'

The vulnerability-first approach starts by examining current vulnerability and sensitivity conditions that the communities currently face, identifying local sensitivities and resilience of the natural and human systems to climatic hazards. It then identifies local priorities to climatic variability and then viable adaptation strategies and actions required to improve their resilience. The considerations of projected climate conditions are also considered at this stage. The vulnerability-first approach also includes the adaptation policy framework, which presupposes that adaptation to short-term climate variability and extreme events will reduce vulnerability to longer-term climate change. Adaptation policies and measures are assessed in a development context with some reference to future climatic conditions and for which the adaptation strategy is as important as the process by which it is implemented (UNDP, 2004).

Figure 10 Impacts-first approach (left) and bottom-up vulnerability-first approach to adaptation planning (right)



Source: Adapted from Willows and Connell (2003); UNDP (2004); Ranger, Millner et al., (2010).

The ‘impacts first’ and ‘vulnerability first’ planning approaches have parallels with policy/project cycle-based risk management decision-making process. They both emphasise the risk management process but approach this from different perspectives (Dessai, Lu et al., 2005). As discussed earlier, the development context is an important determinant of the adaptation approach adopted.

Combining adaptation planning approaches and the climate risk management framework of UNDP (2004), and identifying relevant decision-making criteria in each adaptation context, a seven-staged decision-making process is suggested, supported by robust technical and local knowledge (Table 10). Such a decision-making process recognises the importance of engaging with a diverse set of stakeholders playing complementary roles (spanning all levels of government, sectors and scales as well as the community and private sector), and the relevance of interdisciplinary technical and traditional knowledge. Given the multidimensional effects of climate change, the process emphasises adopting a holistic view of risks and risk management when identifying adaptation measures.

As discussed in Chapter 4, countries in the region have generally adopted this holistic approach when identifying national level responses, but consider climate risks and other disaster risks separately. Climate risk management decisions in the Pacific are usually considered separately in current DRM and future CCA, focusing on the aggregate level issues and supported by broad considerations of hazards and vulnerability across the country. In some countries' national sustainable development plans, climate and disaster risk management goals feature, such as the Cook Islands and Nauru.

Table 10 A seven-stage vulnerability-first based decision-making process for the Pacific

Stage 1	Understand the social, economic and environmental context of communities, broad drivers of change, including climate and other risks—situation analysis	Baseline data to identify parameters for adaptation monitoring Baseline data to assess success/progress of adaptation measure
Stage 2	Establish development goals and specific decision-making criteria, including economic, social and other considerations	Clarity in how the adaptation measure directly contributes to national priorities for economic, social and environmental goals
Stage 3	Assess current risks in the context of climate change (and other drivers)—assessment of hazards and vulnerability	Qualitative and or quantitative assessment of risk to enable estimation of the benefits of the adaptation measure
Stage 4	Identify different risk-reduction and climate-adaptation measures, taking into account the urgency of their implementation; depending on the dynamics of the natural environment, economic and social sectors and the dynamic of the climate change impacts	Identify alternative adaptation measures that address current risks and projected risks, considering the dynamics of the underlying economic systems and the dynamics of climate change impacts
Stage 5	Evaluate alternative adaptation options, using cost–benefit analytical framework (process), recognising context-specific relevance and/or usefulness of qualitative, semi-quantitative and/or qualitative information	Step-wise assessment of each adaptation option against the pre-identified criteria (from Step 2) Identification of baseline needs, data gaps, before undertaking detailed CBA where appropriate Selection of a preferred adaptation option

Stage 6	Conduct a detailed design and implementation plan, including identification of indicators of the effectiveness of the measure, time horizon; and implement	A feasible and cost-effective design
Stage 7	Monitor and evaluate the adaptation measure, and adjust throughout implementation in the light of changes in socioeconomic, technological conditions, as well as new scientific information	Learning by doing Adjustments over time as new information becomes available Adaptive management
Source: Adapted from Olhoff and Schaer (2010), US National Academy of Sciences (2010); Willows and Connell (2003).		

As discussed in Chapter 5, in most countries, the relationship between goals, sector objective and activities is not always clear, particularly since most countries have not completed the mainstreaming exercise across the different levels of government, and in most countries sectoral level plans do not reflect climate change considerations. Where some linkages can be found, for example in Nauru, this is observed at the level of national development goals and the sector objectives, but not necessarily between the sector priorities and on-the-ground projects. In some cases, pilot project activities are underway to inform the development of the national sector policy and framework (e.g. in PACC, Tuvalu project, see case study on water security). Similarly, the National Transport Plan in the Solomon Islands clearly articulates the need for climate proofing of infrastructure as highlighted in its NAPA. But strategies for operationalising this are yet to be developed. In Tuvalu, the water security priority can be traced to its NSDS, and the priority sector identified in the NAPA and the first national communication. However, the relationship between the overall water security goal and the objectives and the design of the various water projects is difficult to identify.

The link between national, sector, program and project level adaptation measures could be strengthened by a systematic and cascading approach to risk identification and risk management across the decision-making levels, informed by more specific and explicit relational information.

3.5 Climate change adaptation: Technical aspects

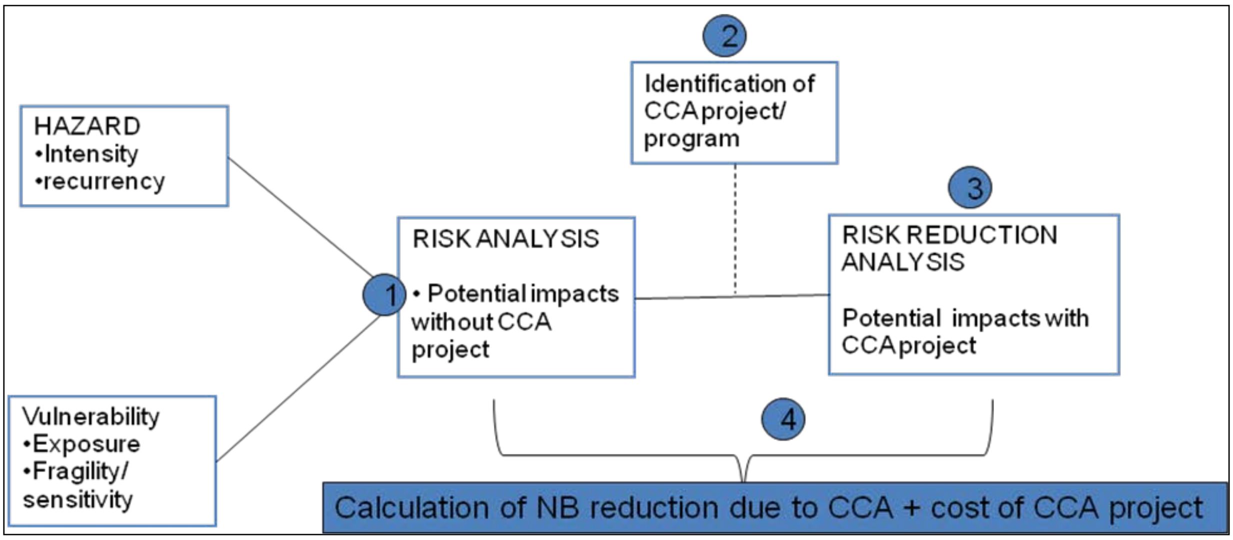
Making informed decisions about CCA would ideally require assessing risks without adaptation initiatives and then comparing the benefits and costs of risk reduction expected with the adaptation measure, together with other considerations highlighted above in Section 3.2. Risk and risk-reduction analysis to inform adaptation choices will ideally draw on many different disciplines, and traditional knowledge. It would also involve backward assessment of past disasters to inform the forward-looking responses in the face of projected climate change, or forward-looking assessments based on scientific modelling.

In terms of DRM, the benefits of CCA are essentially the social and economic costs of damage, losses of disaster avoided (Mechler, 2005; ECLAC, 2003), and the costs are those associated with the particular adaptation measure. Economic CBA is an established tool for determining the economic efficiency of development activity, particularly when there is pressure to achieve highest benefits with minimal investment. An adaptation measure is considered to be efficient if the benefits outweigh the cost of that policy, program, or an activity reflected in indicators such as net benefits (benefits minus costs), NPV, benefit–cost and/or internal rate of return. The CBA framework in the context of risk management comprises four key elements as illustrated in Figure 11 (Mechler, 2005; Moench, Mechler et al., 2007; Mechler and The Risk to Resilience Study Team, 2008):

1. Risk analysis – analysis of risks of potential impacts of climate change without risk management, and involves determining hazards exposure and vulnerability
2. Identification of management/adaptation measures and associated costs, based on potential adaptation activities and alternatives and their respective costs;
3. Analysis of risk reduction – i.e. estimated benefits of reducing risks
4. Estimation of economic efficiency, assessed by comparing benefits and costs of ‘without’ adaptation activity and ‘with’ adaptation activity; economic efficiency is the criteria of comparison.

CBA has been widely used by the World Bank, the Asian Development Bank (ADB) and the Inter-American Development Bank, as well as OECD countries to evaluate DRM efforts, including in development assistance (e.g. DFID, 2005; Mechler, 2005; Moench, Mechler et al., 2007; IFRC, 2009; Venton, Venton et al., 2009; Vernon, 2010). Note though that a CBA alone is not always sufficient for making adaptation choices based on reasons discussed below. Nonetheless, the CBA framework still helps to systematically identify, evaluate and consider all impacts and their costs and benefits, rather than providing an exact economic value of an adaptation measure (Mechler, 2005; Moench, Mechler, et al., 2007). The use of CBA as a framework is also useful to arrive at an expression of society’s preferences.

Figure 11 CBA of climate change adaptation measures using 'with' and 'without' risk assessment



Source: Mechler (2005)

3.5.1 Risk analysis

Risk analysis comprises three key components: hazard analysis, vulnerability assessment and climate risk analysis. Under each climatic future, hazard analysis would involve determining the intensity of hazards that a particular area and community may be exposed to. The BOM and CSIRO modelling exercise discussed in Chapter 2 shows there is still significant uncertainty in determining projected climate futures for the Pacific islands. It is also difficult to empirically identify impacts on the different sectors, which as seen in Chapter 2, will depend on the changes in the specific climatic conditions that will be experienced in that country and locality. Nonetheless, one can assess current disaster effects and make some educated projections about the future events, using the best scientific information available and expert judgements.

A disaster affects various capital assets, such as financial, physical, natural and social, as well as flow of income or benefits (ECLAC, 2003). A holistic approach would be taken to identify the effects of climate change through the ecological and economic system as well as communities, without which adaptation measures selected may not fully address the adaptation goals of building resilience to climate change (see infrastructure case study for an illustration of this issue).

From an economic perspective, effects of a specific climatic condition (i.e. damage and losses sustained) vary between direct or indirect, and monetary and non-monetary. The types of direct and indirect damage and loss are summarised in Table 11).

Table 11 Damage and loss and direct and indirect impacts from a disaster event

Category of impacts		Example
Direct	As a result of direct contact with the hazard, usually immediate effect on assets or stocks: • such as physical structures (homes, roads and other infrastructures); natural capital (land, reefs, mangroves); financial capital (peoples' savings, governments assets) • flow of goods and services, household income • loss of human life	Damage to houses, roads due to flooding following cyclone; Loss in value of crops damaged during flooding
Indirect	Occurs as a result of the flow-on effect of direct impact on social wellbeing, such as human health	Increased waterborne diseases following flooding Loss in wages because businesses were closed during cyclone
Monetary	Impacts that have market value, and measured in terms of monetary value	Cost of building material required to repair the flood damage; or the costs of medicine required to treat water-borne disease
Non-monetary	Impacts for which there are no direct market values	Cost of human suffering; the value of human life; nutritional benefits of improved food security

To understand the potential impacts of climate change from a technical perspective, understanding the ecological pathways through which the impacts are realised and vulnerability assessments could be useful. Climate change risks are, as mentioned above, determined not only by the hazard, but also by the society's vulnerability.

Ecosystem-based assessment requires an understanding of the underlying biophysical system, and its interaction with weather and climate conditions, and using environment impact assessment methodology could help identify the impacts on the ecosystem and the livelihoods that depend on it (e.g. Walker and Johnston, 1999; CBD, 2002; RAMSAR, 2007; Fothergill, 2010).

Vulnerability assessment would thus involve understanding people's context-specific needs and aspirations, and the sensitivity of their livelihoods to hazards, including their asset base, lifestyle, economic activities and wellbeing. V&A assessment is based on rapid rural assessment and sustainable livelihood assessment (SLA) framework. The SLA framework provides a more rigorous basis for assessing people's sensitivity to hazards of a specific intensity and scale, understand the local level risks, risk management and resilience at the household and community level (IISD, IUCN et al., 2003; Elasha, Elhassan et al., 2005); SLA is also often used as a practical tool for designing programs and evaluation strategies aimed at improving livelihoods.

A different technical analysis is required to inform CCA decisions. The technical analysis needed will vary according to the type of hazard and the priority sector(s) being affected, as well as the pathway through which the impacts are realised.

For example, in the case of the food security case study discussed below, the establishment and spread of, and the scale of TLB incidence is a function of not only the presence of TLB spores but also factors such as humidity. To understand projected increase in risks due to climate change, several key technical assessments are required: the effect of increased precipitation and increased warmer nights on the establishment and spread of TLB, as well as taro crop varieties available in the Asia–Pacific region that exhibit resistance to TLB. Such information was drawn from previous scientific research and used in the detailed design of the CBA included in this report [4.1].

Whereas, in the case of climate proofing road infrastructure in the Solomon Islands, key assessments required to inform adaptation decisions include:

- projected changes in rainfall averages, storms and extreme events
- change in rainfall–run-off patterns in the main streams and rivers, and projected scale and recurrence of flooding incidences of different scales;
- effect of increased rainfall on landslides and debris mat formation and their impacts on bridges and other waterways infrastructures
- flooding intensities and tolerance thresholds of bridges and other crossings.

The case studies studied in detail illustrate the types of technical information and expertise drawn from different disciplines. Access to multiple data sources required for adaptation vary with the underlying risks and relevant context-specific adaptation options. Such information will then be used to determine the current situation and projected changes in the economic and social conditions, considering also the other underlying drivers of human conditions. Such analysis will thus be very context-specific. Combined information on the likelihood of hazard, the community's exposure to it and vulnerability to a hazard events, and social and economic impacts, would then be used to quantify risk and risk-reduction benefits of adaptation (Chapter 4).

3.5.2 Challenges in the Pacific in making informed choices

In the Pacific, detailed technical assessments of climate risks and risk reduction are sparse at best or generally have not been attempted; or, if attempted, assessments are often partial. Qualitative assessments are also common (such as in the case of coastal relocation projects in Vanuatu, and water security projects in Tuvalu). In a few, usually externally funded projects (such as the climate proofing of long-lasting investment in road infrastructure), detailed quantitative assessment is undertaken, drawing on different professions, such as engineers, economists, and environmental scientists, to inform at least the design of an adaptation choice based on partial CBA [case study 4.4]. Analyses are usually constrained by limited baseline scientific data, and the difficulty in accessing existing data scattered across agencies. This is illustrated in three of the case studies examined [case studies 4.2, 4.3,4.4]. In the food security case study, there was sufficient previous scientific research information available to inform the risk-reduction strategy. Although, some creative approaches still had to be used to determine economic value of crop improvements in Samoa and Vanuatu [4.1].

In some cases, risk assessment and risk-reduction assessments are constrained by the perspective adopted by the developers of the project. For example, in the case of the SIRIP 2 sub-project, some aspects of climate risks in the project area (such as landslides and changing river courses) were, however, not fully considered when designing adaptation measures, suggesting a narrow sector-focused approach to climate proofing. Non-engineering solutions, although identified in the environmental assessment report, were considered outside the scope of the projects' terms of reference (SIRIP 2 sub-project [case study 4.4]). Similar issues can also be observed in the various water security projects in Tuvalu examined in the water security case study 4.2.

Common reasons for limited technical assessments also include limited technical expertise in-country (Wickham, Kinch et al., 2009). Project managers are often time constrained due to the demands of day- to-day management and often do not have sufficient time to fully attend to detailed technical issues (personal observation and experiences). At times, the projects are complex, requiring technical inputs from multiple disciplines beyond the scope of many project managers. In addition, some projects are implemented without adequate resources allocated for externally sourced, potentially expensive technical input.

Quantitative assessment of underlying risk and risk reductions to inform economic and social cost and benefit assessments of adaptation measures may not always be critical. Decisions could still be based on qualitative information about underlying risks and risk-reduction potentials, together with limited empirical cost and benefit measures. Such an approach could be sufficient, particularly when initial assessments are required to identify broad strategies, or when there is sufficient local-level knowledge, the scale of the project is small enough, and the local conditions do not warrant spending resources for detailed assessments to fine tune CBA of adaptation options.

As a minimum though, systematic identification of context-relevant sources of risks and risk-reduction measures is required to inform social and economic cost and benefit assessment of adaptation measures, even if some measures could only be identified in qualitative terms. The Vanuatu relocation case study illustrates how a systematic application of risk management and CBA frameworks could be used to provide a more comprehensive basis for comparing alternative relocation options and the selection of a 'no regrets' site that could have been suitable in multiple climate change scenarios. If baseline data were available, a detailed CBA could have been undertaken. However, this was not critical to this small project. On the other hand, in a more complex adaptation project such as climate proofing of road improvement in the Solomon Islands, a rigorous interdisciplinary-based risk and risk-reduction assessment together with a detailed CBA of alternative adaptation design was warranted, particularly since it is a large investment and a project with a long life. But even in this case of climate proofing, some non-monetary social costs of current disasters and social benefits of climate proofing options were considered only in qualitative terms (using multi-criteria analysis, as discussed below), when deciding on the preferred adaptation design.

Progressing from qualitative to quantitative assessment-based decisions

In addition, acknowledging that quantitative social and economic assessment of adaptation measures is not always possible, particularly due to data and capacity constraints, decision-makers could take a tiered assessment approach (Ranger et al., 2010). Initially, analysts may undertake a broadbrush qualitative assessment as decision-makers progressively move from qualitative to semi-qualitative to quantitative assessment, if adaptation and management response warranted the detailed assessment.

A broadbrush risk screening is likely to be acceptable at the national planning level, where key policy decisions need to be made regarding national development, development of national action plan for DRM, NAPA and the joint National Action Plans (Figure 17). In such contexts, aggregate level baseline information could be sufficient to identify the broad scale and direction of risks and adaptation measures required to address climate risks (steps 3, 4, 5 in Table 8). At this level, governments are typically faced with making decisions that broadly balance their key economic, social and development goals, and broad assessment-based adaptation paths could suffice (such as the approach adopted in Nauru when mainstreaming climate change at national planning and budgetary level – Chapter 5). Such a broad-level assessment may also be useful when selecting an appropriate adaptation strategy, using priority pathways considerations, discussed below.

A more detailed level of information and assessment would generally be required at the sector level, when identifying specific sectors to target as well as when developing detailed sectoral level strategies and programs for action (again, such an analysis will be undertaken in steps 3, 4, 5 but at the sectoral level). This level of assessment would usually result in both quantitative and qualitative information and could also rely on expert judgements. At times, perhaps a more systematic multi-criteria analysis could be used to inform choices, as was the case in Nauru (Chapter 5 for details).

As discussed below, quantitative CBA of adaptation options is generally useful where choice between adaptation options will be improved by detailed quantitative assessment of risks and uncertainties, particularly where the adaptation has a long shelf life. Once again, in the case of project development, such a detailed context-specific analysis ideally would occur during steps 3, 4, 5 illustrated in Table 8 above. As one progresses from CCA policy formulation to sectoral programs and project selection, specific investment decisions are usually made, and increased levels of context-specific empirical information would usually be required. At the project level, too, selection of adaptation choice may depend on criteria other than economic efficiency, particularly when information is limited and quantification of benefits and costs is not possible.

3.5.3 Selection of adaptation measures: Economic and 'Economic Plus'-Criteria

Recognising the multiple dimensions of CCA challenges discussed above, multiple objectives usually form the basis for deciding upon appropriate adaptation measures, including economic efficiency, social vulnerability and other criteria.

Cost–benefit analysis and economic efficiency

An economically optimal adaptation measure is one which is most efficient, that is, one that generates the greatest benefits after the costs of implementing it have been considered. If the probability of events and impacts can be quantitatively determined, as mentioned above, the 'expected losses' without adaptation can be estimated using loss frequency curves (Mechler, 2008).The benefits of adaptation can then be determined, comparing expected economic values associated 'with and without' the option, as illustrated in the food security, water security and infrastructure case studies. If benefits of an initiative are expected to occur over extended periods of time, the appropriate measure of comparison is then the present value of costs and benefits, discounted using rate of time preference of the community for the present over the future. Indicators often include expected net economic benefits; expected BCR, EIRR, with an adaptation measure that gives a higher value selected over one that has a lower value of such indicators. CBA in food security, infrastructure and water case studies reported measures of BCR and net benefit (NB). The infrastructure case study also used EIRR.

International literature suggests that if detailed probabilities for events and impacts are not known, then sensitivity analysis helps reveal additional information to inform the trade-offs that may be necessary (Hallegatte, Hourcade et al., 2007). Sensitivity analysis was used in the infrastructure and water security case studies. However, a more structured approach to making trade-offs is often warranted. For example, using criteria such as 'maximin', the best outcome of the most pessimistic scenario is selected. Such an approach may also be used where an adaptation scenario is considered to be unacceptable for political reasons and thus rejected (Hallgate et al., 2011).

Limitations of CBA-based decisions

There are several challenges in identifying the 'optimal' adaptation measure on the basis of economic efficiency. Firstly, the principle generally assumes that all benefits and costs of risk reduction are identifiable, quantifiable and quantified in monetary terms. In reality, this may not always be possible, as illustrated by partial CBA in the Solomon Islands climate proofing case study, as well as the food security and water security case studies. CBA assessments are often undertaken making several assumptions, using proxy measures and creatively using available social and economic information sourced from multiple sources [case studies 4.1, 4.2, 4.4].

In some cases, ex-post CBA cannot be performed because empirical baseline data is not collected before the project was designed and implemented, as was the case of the relocation case study [4.3]. In some situations, such as the PACC water security project in Tuvalu, even though the project document calls for a CBA, such an analysis was difficult because of limited empirical baseline data collected at the project design stage, and could only be undertaken after making several assumptions and extrapolating results of past research projects [case study 4.2]. The four case studies highlight that detailed quantification of the benefits of some adaptation measures in the Pacific may also not be feasible because:

- baseline data are frequently limited
- there may be a high degree of uncertainty concerning future scenarios
- climatic risks and potential impacts of climate change, variability and extremes can be difficult to determine in the absence of relevant scientific knowledge.

In the face of uncertainties, probabilistic CBA is difficult. Instead, deterministic CBA together with sensitivity analysis around key uncertain parameters can help provide additional information to make informed decisions [case studies 4.2, 4.4]. In case study 4.4 on the SIRIP 2 sub-project on climate proofing of Western Guadalcanal Road improvement, the analysts assumed different projected rainfall conditions under future climate, translated these into the effects on recurrence period of flooding intensity, and identified engineering design implication for bridges and other water crossings. Such a sensitivity analysis was then followed through in the CBA of alternative adaptation measures, considering also increased threshold requirements of the engineering designs. It was through such a detailed analysis that the SIRIP 2 sub-project team and the Solomon Islands Government then selected the preferred climate-proofed design [case study 4.4].

When undertaking CBA, vulnerability of the local communities, their risk preference and the potential impact of the adaptation measure would also need to be understood, and equity and other social criteria would require explicit consideration when making CCA decisions. For example, in the Vanuatu relocation adaptation project, easier access to freshwater catchment provided under a previous rural development project had a higher priority over the project team’s concern about the flooding due to coastal storm [case study 4.3]. Economic efficiency-based decisions do not typically reflect consideration of who bears the cost of a measure and who enjoys its benefits. Further analysis could help differentiate between the groups in society that may be most affected and assessment of the spatial distribution of hazards. Temporal dimensions could be adequately factored in only after adopting some agreed discount rate; often there is no agreement over the relevant discount rate to use (Mechler, 2005; Moench, Mechler et al., 2007; Stern, 2007; Mechler and The Risk to Resilience Study Team, 2008).

Choice of project versus portfolio

CBA is best suited to deciding about individual activities. But governments often have to decide on a portfolio of activities, that is, decide on investments to address current development needs as well as current exposure and vulnerability, while also preparing for uncertain longer term climate scenarios. In such a situation, there is no single approach or criteria that countries can use in assessing and prioritising adaptation measures. Instead, a government needs to simultaneously balance between the different development goals.

In deciding upon the portfolio of adaptation activities, the broader functioning of the national economy, transport, communication, education and other systems, may have more fundamental implications for exposure, vulnerability and risk than individual, or multiple, hazard-focused interventions (Moench, Mechler et al., 2007).

When considering a portfolio of adaptation measures, the geographic scale of the sphere of influence of possible adaptation measures is often large, and benefits may accrue across hard-to-identify groups of people. CBA as an assessment tool may not be appropriate for making detailed choices.

In the case of suite of water security-related projects in Tuvalu that dealt with the same issue but designed and implemented in parallel to some extent, a considerable degree of difficulty was faced in identifying the scope and scale of the impacts of the different adaptation projects. This made it difficult to undertake CBA of the individual project. For example, all projects include objectives to improve water harvesting, thus improving sanitation and water use efficiency. However, it is difficult to identify the percentage of total improved water quality, for example, that is attributable to any one project versus another. Consequently, benefits could only be considered collectively. Due to the numerous water projects underway in Tuvalu at the same time as the three assessed, it was difficult to identify the likely situation in Tuvalu, had the three case study projects not existed ('without scenario').

Choosing measures in the broader context of development

For the Pacific, the choice of adaptation measures is also most likely to be guided by criteria such as considerations of existing development challenges, current disaster risk, and or the need for strengthening institutional capacity in the face of projected climate change and associated uncertainties. In the situation where immediate development needs are considered to be of higher priority than addressing projected climate risks in the future, this may take precedence over considerations of the impact of future climate events. This, for example, seems to have been the criteria behind the Tuvalu water projects, where current water security needs are extensive, and the projects were largely designed to tackle current risks.

In some cases, priority may be given to an adaptation measure that provides multiple benefits over just a single purpose adaptation activity (IPCC, 2011). For example, as discussed earlier, adaptation measures that helped address income-generating and economic development needs, while also addressing the current adaptation gap and decreases people's vulnerability to current hazards, would make sense from a development perspective, irrespective of the future climate (Hellmuth, Moorhead et al., 2007), and can be applied across all levels of decision-making and at all scales. An example of this is how the crop improvement activities in the region, such as the TLB project [case study 4.1] addressed immediate development needs. These projects also helped develop skills and processes that would be relevant, irrespective of the future climate.

Countries may wish to explicitly prioritise initiatives that would help create an enabling environment and lay a solid foundation to improve the effectiveness of future climate adaptation decisions. Such foundational measures could include baseline database and institutions and human capacity to make more informed decisions. Concrete examples of such a foundational adaptation strategy in the Pacific includes regional and national germplasm conservation and TLB-resistant taro crop improvement [case study 4.1] and a flood early warning system (Holland, 2008).

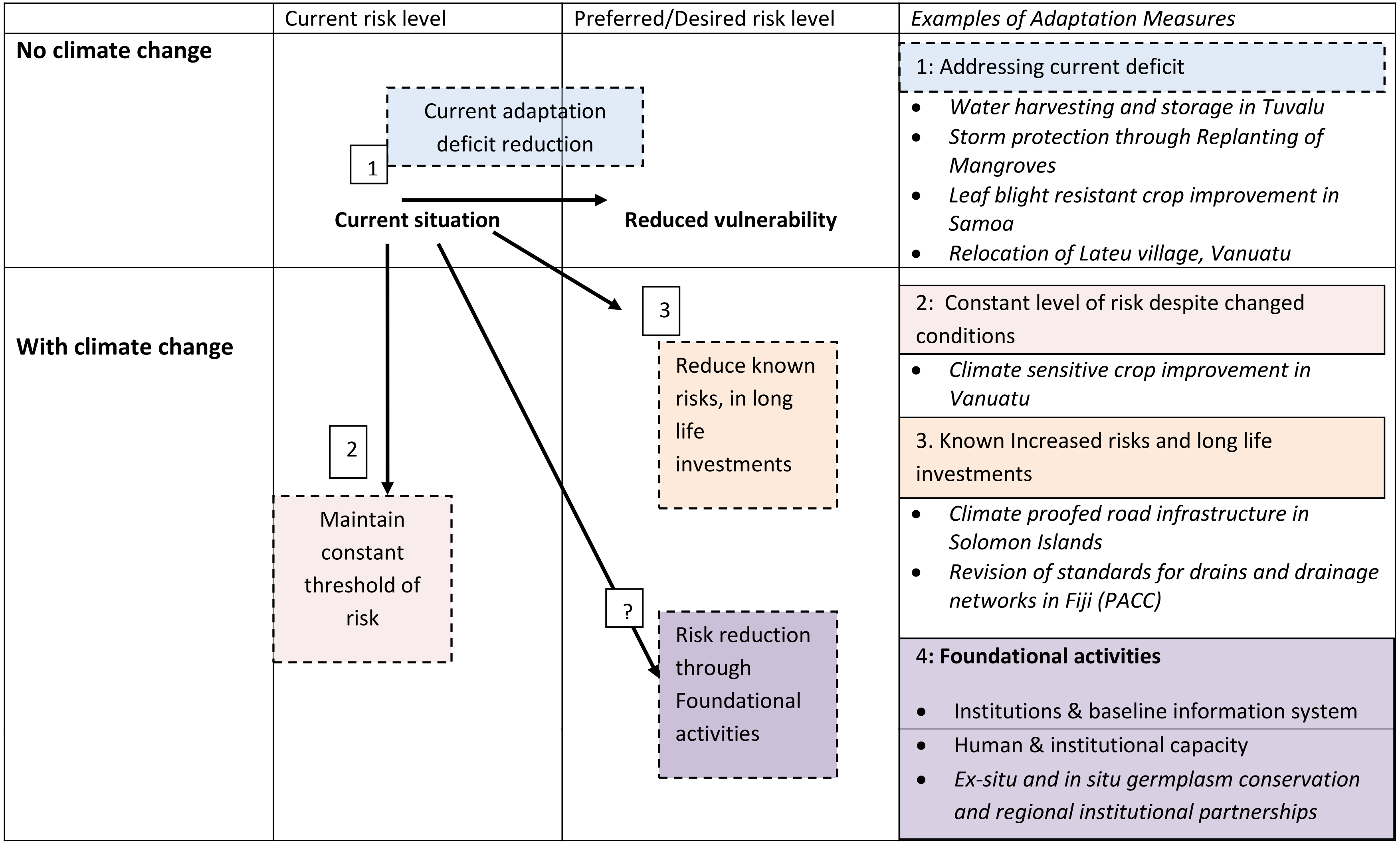
It is thus very likely that measures of economic efficiency alone cannot be used as criteria. Instead, at least qualitative assessment of social and economic impacts of

CCA measures could inform CCA decisions, together with other economic and social development objectives. The choice of priority strategies would also be informed by other criteria that relate to national development needs, including, for example, technical and economic feasibility and the effectiveness of a measure in the light of uncertainties (US National Research Council, Committee on America's Climate Choice, 2011).

Criteria to inform adaptation choice would vary from context to context, and thus selection of decision-making criteria would need to be an explicit step in the climate risk management decision, as is the local level of risk perception and risk-tolerance threshold. No doubt the selection of the relevant decision-making criteria would need to be an explicit step in the climate risk management decision, and informed by development needs, local level of risk perception and risk-tolerance threshold.

Figure 12 gives a few practical Pacific examples of the kinds of adaptation projects that may be considered priority 1, 2 or 3.

Figure 12 Prioritisation based on urgency, longevity and foundational requirements and activity examples from the Pacific



3.5.4 Concluding remarks

The above discussion emphasises that to strengthen knowledge-based adaptation decisions in the Pacific, two aspects need particular attention: the decision-making context and linkages between levels of adaptation measures; and technical risk and risk-reduction analysis informed by robust baseline data and other knowledge. In the Pacific, there is the added challenge of the availability of limited robust technical information about climate science, environmental and socioeconomic impacts of climate change (acknowledging that communities have observed some recent changes, in particular flowering and survival patterns of plants). Furthermore, it is important to recognise that such decisions are made in the context of addressing current risks and development needs, while responding to projected increases in climate risks.

4. Pacific challenges in economic and social assessment-based climate change adaptation decision: Lessons from the detailed assessment of four case studies

Social and economic assessments and other considerations have informed national policies, programs and projects, with varying degrees of detail and rigour. National and sectoral adaptation measures have largely been guided by international and regional disaster risk and climate change instruments, whereas project-level activities have largely addressed current disaster deficits with some consideration of climate change, adopting the DRM framework.

Using the broad policy/project cycle process and CBA analytical framework, two types of assessment are provided below to illustrate the types of issues that need particular attention for improving knowledge-based climate adaptation in the Pacific:

- a detailed analysis of four adaptation projects to highlight diversity of issues of relevance when making knowledge-based CCA decisions (Chapter 4)
- a brief review of national/sectoral planning and DRR projected, provided to highlight the role of economic and social assessment (Chapter 5).

To identify key issues and constraints surrounding the adoption of knowledge-based CCA decision-making processes at the project level in the Pacific, a case study approach was adopted. Four case studies covering priority sectors of concern in the Pacific countries: water, agriculture (food security), infrastructure and coastal (relocation) were selected for detailed assessment. These case studies were selected to investigate adaptation activities and decision-making processes in an atoll (Tuvalu) and in high island countries such as Vanuatu, Solomon Islands and

Samoa. An adaptation project that was already completed (Latea village relocation) was also investigated and several projects were also in progress. These also covered adaptation needs that might occur in relation to the effects of projected climate change in precipitation (drought and flooding), temperature (humidity) and minimum night time temperature; sea-level rise and storm surges (Table 12).

Four CCA initiatives were selected to also identify the role of social and economic assessment of CCA decisions, and to identify in more detail the issues and constraints faced in undertaking economic and social assessments-based CCA decisions. The case studies also highlight the relevance of systems/ ecosystems approach to risk assessment and some suggestions for overcoming key constraints in adopting such an approach.

Table 12 Case studies selected for detailed country level assessment

Case study	Climatic parameters	Island characteristic/ island	Status of project
Assessing the social and economic value of germplasm and crop improvement as a climate change adaptation strategy: Samoa and Vanuatu case studies	Precipitation (humidity) and minimum night time temperature	High island Samoa Vanuatu	Samoa – the initial phase primarily completed (2010), although crop improvements ongoing Vanuatu – primarily completed in 2008 although, crop improvements ongoing
Assessing the social and economic value of climate change adaptation in the Pacific region: A case study of water quality, quantity and sanitation improvements as an adaptation to climate change, Tuvalu	Precipitation (drought and flooding)	Atoll island Tuvalu	Ongoing

Social and economic assessment-based climate risk management: a case study of sea-level rise and relocation of Lateu community, Vanuatu	Precipitation (river flooding)	High island Solomon Islands	Due to complete in 2012
Making informed adaptation choices: A case study of climate proofing of road infrastructure in the Solomon Islands	Sea-level rise and storm surges	Coastal Vanuatu	Completed in 2005

The food security and crop improvement case study involves a number of discrete sets of activities (rather than a discrete project) supported by several different development partners and implemented over time, all leading to improved crop varieties introduced in Samoa and Vanuatu.

In comparison, the water security case study considers three separate projects running in parallel, all addressing similar national priority issues with potentially limited coordination. The climate proofing of road improvement in the Solomon Islands is an example of a project with long investment life funded under a loan from an International Financial Institute (ADB), AusAID and New Zealand Agency for International Development (NZAID). ADB, has used clear climate-proofing policies to implement a large consulting company with extensive experience in infrastructure projects.

The coastal relocation project in Vanuatu has been identified as the first project to be implemented in the Pacific that directly addressed challenges of sea-level rise and storm surge (e.g. Caldwell, 2005; Environment News Service, 2005).

The case studies examined for each of the CCA projects considered several issues such as:

- risk planning approach adopted and the decision-making processes used, including the extent to which project cycle processes were followed
- the risk-reduction analysis undertaken before implementation, that is, estimated benefits of reducing risks; and the extent to which knowledge drawn from integrated risk and risk-reduction assessments were used, together with stakeholder experiences
- the analytical approach used to identify management/adaptation measures, select adaptation response and associated costs, different degrees to which CCA choices were made using economic, social and or other criteria
- semi ex-ante/ex-post estimation of economic efficiency where possible
- data and information issues.

Detailed case study reports were prepared by the following team of researchers under the leadership and guidance of IUCN (Table 13).

Table 13 Case studies' research team

Case study	Title	Authors
1. Food security	Assessing the social and economic value of germplasm and crop improvement as a climate change adaptation strategy: Samoa and Vanuatu cases studies	Andrew McGregor with Peter Kaoh, Laisene T. Marina, Padma N. Lal, Mary Taylor
2. Water security	Water quality, quantity and sanitation improvement as an adaptation to climate change, Tuvalu	Federica Gerber, Paula Holland and Padma N. Lal
3. Relocation	Social and economic assessment-based climate risk management: a case study of sea-level rise and relocation of Lateu community, Vanuatu	Padma N. Lal, Wendy Proctor, and Kim Alexander
4. Infrastructure	Climate proofing of road improvement in North-western Guadalcanal, Solomon Islands	Padma N. Lal and Valentine Thurairajah

Detailed case study reports are included in a compendium volume. A summary of the case studies only is provided in this overview document [4.1–4.4]. The key findings from the case studies include the following:

- All the projects were implemented as stand-alone activities in a policy vacuum in their respective countries, and thus the scope for using lessons learnt from the projects for scaling up and out is limited.
- All projects directly focussed on addressing current disaster risks, reacting to recent disaster experiences, although climate change concern was mentioned in each. The infrastructure projects, also reacting to recent flooding events, explicitly considered future climate change scenarios following the second flooding event in two years.
- The project cycle process was used in all case studies, although only some steps can be observed
    - Initial problem and solution analysis in three of the four case studies—4.1, 4.2, 4.3—were largely based on recent disaster experiences. In all cases, adaptation solution/responses was already predetermined before the projects were implemented and confirmed by qualitative V&A (either conducted as part of NAPA and the National Communication process, or as part of the project process). The results of V&A in some projects are difficult to decipher as the line of sight could not be established due to lack of documentation of the project implementation process. In addition, the

stakeholder-based V&A conducted did not always inform the project design [case studies 4.2, 4.3, 4.4].

  - The vulnerability-first planning approach used qualitative risk and risk reduction to inform adaptation decision is the norm. The exception was the infrastructure project, which used a hybrid of impacts-first and vulnerability-first approach, with partial modelling results used to inform the design of climate proofing of key infrastructures.
  - CBA is not an integral part of decision-making, except in the large- scale infrastructure project. Adaptation choice was made using multiple criteria, including immediate development needs and urgency in addressing the existing disaster risk. CBA as an activity is noted though, in one of the water security activities, although how the results would be used is currently difficult to assess.
  - Economic efficiency criteria were considered only in the infrastructure project. That, too, was undertaken using only deterministic CBA, combined with sensitivity analysis to inform the choice of an adaptation package of changes in the design of a specific sets of infrastructure.
  - Had the CBA been undertaken in the other three case studies, the selected adaptation projects would still have made economic sense in the case of food security [case study 4.1] and water security projects; although some sensitivity analysis in the water case study gave negative returns, or less than 1 CBR. In the relocation case study, a different adaptation decision may have been made.

- Availability of relevant spatially disaggregated baseline data, particularly about the impacts of past climate-related disasters and the sector-specific effects of projected changes in climate change risk-reduction measures on the physical and human systems, including social and economic costs and benefits, are almost non-existent. There is limited scientific research in the region to help understand such effects. In all the cases, some aggregate level baseline data does exist in-country, although these are scattered across several agencies and are often difficult to access.
- In-country institutional capacity to respond to current risks and make risk analysis-based decisions is limited in all the case studies, making informed decisions in the context of changing and uncertain climate risks is even less likely.
- More specific details about the key aspects of risk based-project cycle steps followed are summarised in Table 14.

Table 14 Summary of the key findings from the four case studies with reference to project cycle-based risk management steps

	Key messages from the case studies			
	4.1 Food security	**4.2 Water security**	**4.3 Relocation**	**4.4 Infrastructure**
Key focus	Reactive response to recent climate-sensitive crop, disease-related disaster event and development needs; and preparing for future climate risks Laying foundational institutional capacity to cost effectively respond to projected risks in the future Low regret 'soft' solution (#1, # 2 and # 4)	Reactive response, addressing current water security needs and current disaster risks (# 1)	Reactive response, addressing increased risk due to geo- and hydro-meteorological hazards (#1 and #2)	Reactive response to current disaster and projected climate futures Example of 'hard' adaptation solution (#1 and #3)
Risk planning approach	Vulnerability-first	Vulnerability-first	Vulnerability-first	Hybrid impacts-first and vulnerability-first
Vulnerability assessment – focus	Current risks Development needs	Current risks Development needs	Current risks Development needs	Current and projected flood risks
Vulnerability assessment – situation analysis (Step 1)	Observed/recently experienced disaster	Stakeholder-based assessment for NAPA and National Communication to UNFCCC Community specific Community V&A; Plus GIS-based community survey	Project specific community V&A	Hydrology and hydraulic modelling Community survey

	Key messages from the case studies			
	4.1 Food security	**4.2 Water security**	**4.3 Relocation**	**4.4 Infrastructure**
Explicit risk and risk-reduction assessment to inform adaptation responses (steps 2 and 3)	Indirect and semi-quantitative assessment	Partial stakeholder-based assessment & qualitative	Stakeholder-based qualitative	Explicit technical-based risk assessment, but focused only on flood hazard; other rainfall-related hazards only partially considered; sea-level rise impacts not considered
Solutions considered (Step 4)	Predetermined based on scientific assessment	Predetermined Later confirmed, using partial and semi-qualitative supply and/or demand assessment	Predetermined – but adjustment made, following stakeholder engagement	Engineering only Non-engineering solutions considered either beyond the scope of the project or difficult due to land tenure constraints
Social and economic analysis - CBA (by the project) (Step 5)	No. Ex-post CBA confirms the value of the germplasm and crop improvement-based strategy adopted	Noted, but unclear as to the role of CBA in decision-making	No. But had the CBA been used even to guide the analysis, a different adaptation decision could have been made	Partial CBA of risk-reduction assessments Deterministic with sensitivity analysis Qualitative social benefits assessment and considered using multi-criteria analysis
Decision-making process (Step 5)	Limited project cycle-based processes adopted	External project-based; sectoral policy to be developed in the project	Limited in-country processes; external project-based processes	Sectoral policy exists and mentions climate change, but project approval process does not

	Key messages from the case studies			
	4.1 Food security	**4.2 Water security**	**4.3 Relocation**	**4.4 Infrastructure**
				explicitly include risk consideration Subject to development partner process Incremental changes with climate risk considerations considered, following additional flooding experience
Data and information issues (steps 1-5)	Past scientific research-based knowledge Aggregate data production and trade data used	Limited baseline information, and limited empirical baseline data collected Multiple sources of in-country data could have informed underlying analysis and decisions	Limited empirical baseline data collected or accessed from government Limited geospatially disaggregated empirical data on hazards, vulnerability available	Limited context-specific data on precipitation, floods etc.; variable access to existing in-country data Climate scenario Technical models for Solomon Islands not available CBA based on mainly engineering
Technical capacity (steps 1-5)	Mainly regional level capacity with some in-country skills	Limited technical skills	Some capacity but limited human resources	Technical skills provided through external consultancy team In-country skills to assess climate risks limited

4.1 Food security: Assessing the social and economic value of germplasm and crop improvement as a climate change adaptation strategy: Samoan and Vanuatu cases studies

PICs rely on their agriculture sector for much of their food and nutritional requirements, as well as income. It is a sector that relies primarily on rain-fed small-holder commercial production systems. As such, the people and their economic activities are highly vulnerable to trends and variability in weather and climatic conditions. Coastal areas are also vulnerable to sea-level rise due to climate change and usual variations due to ENSO events and storm surges, causing salinisation of the farming areas.

The effects of climate change are already being experienced, with decreases in crop yields, changes in flowering and crop suitability over different altitudes, as well as outbreaks of pests and diseases due to changes in temperature and humidity. Such effects are expected to be exacerbated with projected changes in climate variability and extreme weather events, sea-level rise and increased storm surges. In the face of climate change and a high level of climatic variability, a range of agricultural sector-related climate-sensitive and climate-ready adaptation strategies and coping mechanisms have been recognised for implementation, including:

- enhancing the resilience of traditional and sustainable cropping systems
- promoting appropriate traditional planting material preservation
- developing improved germplasm for crops that is better suited to climatic extremes and the associated pest and disease problems
- ensuring that secure and effective planting material production systems (community, national and regional) are in place. These systems need to be supported by efficient distribution systems (which ensure planting material is available immediately when required or are in advance of climate-induced disease outbreaks) coupled with knowing the climatic limits of the crops and varieties.

This case study discusses cost–benefit assessment of germplasm conservation and crop improvement as a CCA strategy by focusing on three different approaches:

- reactive program of activities that addresses climate-sensitive TLB disease outbreak in Samoa (pathway #1 – addressing current risks)
- proactive program of activities that focuses on increasing genetic diversity of traditional crops in farmers' fields in Vanuatu (pathway #2 –preparing for longer term changes)
- proactive program of activities that helps lay a solid foundation for adaptive responses to uncertain variability and extreme events (pathway #4 – foundational activities)

4.1.1 Reactive response: Taro leaf blight-resistant crop improvement

Traditional Pacific island crops are particularly vulnerable to disease due to their narrow genetic base. This makes root crops particularly susceptible to the impact of diseases brought about by the impact of climate change such as TLB.

TLB is a fungal disease which prefers high night-time temperatures and relative humidity. The fungal disease significantly reduces the number of functional leaves, and can lead to yield reductions of over 50 per cent. TLB was first detected in Samoa in 1993 when it rapidly spread across the two main islands, Upolu and Savai'i. Various factors contributed to the rapid spread of the disease in Samoa, including factors such as planting of the same variety of taro in large areas which effectively ensured a mono-cropping situation, comprising a highly susceptible variety and the significant replanting effort of taro which took place in the aftermath of Cyclone Val, which also added to the movement of planting material between islands. The weather conditions at the time were conducive to the rapid spread of the disease and quickly reached epidemic proportions; strong winds and high relative humidity; high night-time temperatures and high relative humidity are ideal conditions for the spread of the fungal spores.

Projected changes in climate across the region, including warmer conditions and a rise in minimum night time-temperature and relative humidity, increase the likelihood of the TLB spreading to locations that are currently free of the disease. Areas that are now free of TLB, such as Fiji, Tonga, Vanuatu, the Cook Islands and higher elevation areas of PNG, are all susceptible and are all seen to be at high risk. TLB could become established and/or more prevalent in such countries which are projected to have average warmer conditions combined with wetter to much wetter conditions (Figure 4a above).

The Samoan case study demonstrates that a TLB epidemic represents a major disaster with large economic and social consequences.

TLB had a devastating impact on the Samoan taro production, with an annual loss in production valued at (Western) Samoan Tala (WST) 25 million (or A$11 million) between 1994 and 1999. For five to six years following the arrival of TLB, little taro was consumed in Samoa; distinctly different from the 1989 census records which showed that almost 96 per cent of agricultural households grew and consumed taro. Combining these two, Samoa suffered an annual loss in foregone domestic taro consumption valued at WST 11 million and a taro export valued at WST 9 million.

Management responses

The initial response to TLB consisted of standard agricultural farm management practices, including spraying of infected planting material with fungicides, which proved to be ineffective. Farmers were reluctant to incur the extra costs involved, even with the government subsidy towards the cost of the fungicide. Although quarantine measures were also put in place to restrict the movement of planting material, and supported by an awareness campaign, the TLB could not be contained as the climatic conditions favoured rapid disease development.

After the traditional methods for the control of TLB did not provide positive results, attention focused on the introduction of exotic varieties resistant to TLB (in particular from Asia and Palau). Although the introduction and use of these TLB-resistant taro varieties enabled Samoan farmers to once again cultivate taro, there was general consensus that these varieties were not ideal because of the strong variation in taste. Such attention shifted towards a longer term breeding of taro. The challenge was to not only find resistant varieties but also to meet the demanding taste requirements of Samoan communities at home and abroad, and to provide for a shelf life that would allow export by sea.

The challenge was met by using a classical plant breeding approach, which incorporated a high level of grower participation. The initial breeding program involved University of the South Pacific (USP) plant breeders and the Ministry of Agriculture staff using their own funds. Later, external funds of about WST 18 million (A$8 million) were incrementally obtained between 1994 and 2010 from partners such as AusAID (Taro Genetic Resources: Conservation and Utilisation or TAROGEN project), Australian Centre for International Agricultural Research (ACIAR) (DNA fingerprinting and virus testing protocol development projects), and NZ Ministry of Foreign Affairs (assessment of TLB resistance methodology), to support the breeding program that eventually led to the introduction of TLB-resistant varieties in Samoa. AusAID also contributed towards the establishment of regional germplasm conservation at CePaCT.

This breeding program was informed by scientific knowledge, including genetics and crop breeding techniques, and farmer experiential knowledge and farmer trials, as well as community preference trials in Samoa. The preferences of the Samoans living aboard were not initially tested. Farmer participation in the field trials ensured trials across many locations and quick uptake.

Ex-post estimation of economic net benefits of TLB- resistant crop improvement as a CCA strategy

Even though TLB-resistant crop breeding activities were developed incrementally over time, the cumulative result of the largely publicly funded TLB-resistant crop improvement program far outweighs the costs. Production of Colocaisa taro for the domestic market has increased from virtually zero to 9000 tonnes in 2010, with some 500 tonnes sold in the Fugalei Market. Local consumption is valued at WST 21 million (A$9.3 million) and the Free On Board (FOB) value of exported taro is estimated to be WST 1.1 million (A$0.5 million).

The export value of actual taro crop outputs for export and domestic markets and subsistence consumption over the period 1994 through to 2010, is 10 times the cost of the breeding and germplasm conservation program. The latter was estimated as a pro-rated cost of the regional CePaCT germplasm conservation program. Sensitivity analysis, using a range of discount rates between 2 and 15 per cent, provides a BCR ranging from 10.7 to 12.5.

Drawing on several different data sources, and making some assumptions about expected growth in the domestic consumption, considering recent trends in the consumption of rice and wheat (Table 15), the economic value of taro at the Fugalei market is projected to be about WST 25 million (A$11 million) by 2030. With the projected increase in the markets, and continued breeding and extension program at nominal costs, the projected BCR is 16.4 for a zero discount rate to 15.1 per cent at 15 per cent discount rate.

Table 15 Information needs, respective relevant disciplinary expertise, and sources of relevant data: CBA of disease-resistant TLB crops, Samoa

Examples of information needs	Examples of relevant disciplinary skills	Source of data/information
• Climate forecasts • Average and trend in o precipitation forecast (rain, drought, and humidity patterns) o temperature – particularly minimum night-time temperature o weather extremes and frequency of extreme events	Meteorologists and climate modelling	Published and grey literature Meteorological services Climate modelling institutes
• Cropping patterns (mono cropping or traditional mix cropping systems) • TLB disease characteristics and disease behaviour • Weather and climate conditions conducive to the establishment and spread of the TLB fungus • Effects of TLB on crop yield	Plant pest and disease specialist plant pathologist Root crop agronomists Farming systems	Published and grey literature Agriculture specialists
• Taro varieties conserved in various germplasm banks in the region and elsewhere • TLB resistance characteristics of the commonly planted taro in Samoa, and elsewhere in the Pacific	Crop germplasm specialists and plant breeders Root crop agronomists	Published and grey literature Root crop specialists
• Taro farm production costs, and taro yield in farmers' fields with TLB and without TLB • Price of taro, price of taro substitutes for consumers	Agricultural economists	Published and grey literature Farm extension services and expert knowledge Market and farm surveys; trade data
• NB of TLB-resistant crop improvement • NB of linked regional and germplasm banks	Economist	Agricultural economics research Trade data, consumer surveys

The success of the Samoan taro breeding programmed can be attributed to:

- a major crisis that made it possible to focus the minds of government decision-makers and donor agencies to eventually secure the necessary coordinated and sustained response of the funding and implementing agencies. Eliciting an ex-ante response of equivalent scale is much more difficult task, although this is what is now required for other countries and for other traditional crops
- the high calibre of the key people involved in the identification of the project and its subsequent implementation. In particular, the USP taro breeder has, from the outset been critical to the success of the program
- the direct involvement of farmers in the taro breeding program
- the existence of regional germplasm banks at SPC and USP. Importantly, the success of the taro breeding program resulted from access to diversity through the Pacific region’s genebank, in particular, the south-east Asian taro from the Taro Network for Southeast Asia and Oceania project which provided the much-needed diversity to progress the breeding program to the stage it is at today. For Samoa to have imported this material directly would have been very difficult, especially given the need for virus testing.

The Samoan program took several years to get started due to delays in funding, although once partners became convinced of the urgency of addressing this problem, resources were made available from several different sources, including ACIAR, NZAID and AusAID. The delays meant there were substantial economic costs in terms of lost benefits due to the spread and establishment of the disease across the country and loss of export markets, which are often difficult to re-establish.

The net benefits of the TLB crop breeding program show significant value. However, the economic and social benefits could have been much greater if Samoa or the regional germplasm banks had already contained key taro genetic material from the region, as well as Asia.

To address Samoa’s TLB disease outbreak, several years were spent getting a cohesive crop improvement program based on genetic material sourced initially from Palau and later from FSM, the Philippines, and other south-east Asian genetic material maintained in CePaCT. Such delays and costs to local communities and loss in the export markets could have been avoided had the investment in regional ex-situ germplasm banks been made much earlier.

An important lesson learnt for other countries is the need to be able to respond quickly to the arrival of diseases such as TLB (as well as being prepared for potential changes in the distribution of the TLB due to projected changes in the range in climatic conditions and extremes). For this, easy and prompt access to diversity, through a strengthened planting material distribution system, involving national and regional germplasm banks is essential.

However, a complete reliance on regional and national germplasm banks is not an ideal risk management strategy, as ex-situ germplasm banks, especially field collections, have been known to lose key collections due to diseases, financial unrest and other types of accidents (Caillon et al., 2004). A proactive response is required, with the germplasm in-country and, ideally, in the hands of the farmers prior to the arrival of the disease. The Vanuatu program, discussed below, is an example of how this can be done.

Investing in foundational institutional capacity

Due to the severe consequences of the TLB disaster, it was possible to eventually focus the attention and support of national government agencies (primarily the Samoan Ministry of Agriculture), regional bodies (SPC and USP), and development partners (AusAID, NZ AID and ACIAR). To avert similar disasters occurring in other PICs, proactive action is required by these countries for other traditional crops, especially in light of the expected challenges of climate change. Without this proactive approach, the ability of, and the time it will take, for the countries to recover from these challenges is likely to be severely impacted.

An example of such a proactive step in the region is the Vanuatu germplasm distribution program which is analysed in the second case study.

4.1.2 Proactive response: strengthening flexible and sustainable capacity in Vanuatu

The Vanuatu approach, in contrast to that described for Samoa, relies on evaluating local diversity, incorporating some exotic diversity, and then distributing large volumes of planting material for farmers to select from, and then to conserve. It relies very much on the interest and enthusiasm of the farmer to want greater diversity, and importantly, not to abandon any old traditional varieties for this; this could be unique to Vanuatu farmers. Unlike the more targeted approach as illustrated by Samoa, the diversity in the Vanuatu farmers' fields is significantly enhanced, which could have huge benefits in managing climatic variations, and pests and disease outbreaks.

Vanuatu, in common with other PICs and beyond, has a poor record in sustaining germplasm collections in research stations. To safeguard against the loss in genetic diversity in ex-situ (off-farm) germplasm collections, effort is now being made to establish 'collections' in farmers' fields. Vanuatu Agricultural and Technical Centre (VARTC) developed a pilot project to test and evaluate on-farm conservation by introducing new genetic material into Vanuatu's traditional cropping system, and allowing 'natural' distribution of new genetic material through traditional cultural practices of exchanging planting material. The objective was to broaden genetic diversity in village farmers' fields that included varieties that had some key resistant characteristics, thus providing protection against future epidemics and biological disasters. The trials also addressed desired eating and agronomic qualities.

This 'no regrets' adaptation strategy established reservoirs of genetic diversity in taro (*Colocasia* spp.), yams (*Diascoera* spp.), sweet potato (*Ipomoea batatas*)and cassava (*Manihot esculenta*) in 10 villages across Vanuatu. These villages were classified either as yam or taro-based. 'Yam villages' are generally located in the drier areas of the leeward sides. The 'taro villages' are located at higher attitude or moist windward sides of islands. The planting material was produced on VARTC research stations. The bulking up and distribution has been in collaboration with the Farm Support Association, a local NGO. New genetic varieties spread naturally through the cultural exchange mechanisms. Two years after the material was distributed to the 10 villages, monitoring of farmer's fields indicated an 86 per cent net gain in the diversity for yam villages and a 61 per cent gain for taro villages, enriching farmers' varietal portfolios. Traditional root crops have to be planted and replanted to ensure their maintenance. Taste and texture were the most important positive criteria for the adoption of new varieties, whereas the negative agronomic characteristics were the most important criteria for rejecting a variety.

There are significant upfront costs in screening the germplasm material for distribution and establishing new varieties. The cost of that program was Vanuatu Vatu (VUV) 9 million (A$70 000), 60 per cent of which was the vegetative field maintenance, with the remainder for inter-island shipping of planting material.

Social and economic assessment

Social and economic assessment of the 'no regrets' strategy of establishing 'reservoirs' of genetic diversity in farmers' fields is difficult, as much of the benefits would occur in times of future pest and disease outbreaks, and climate-related disasters. The benefits will also depend on the maintenance of the genetic diversity in farmers' fields.

The benefits can be measured in terms of imported grain if there is a catastrophic loss of subsistence crops. It is estimated on this basis, a mere 5 per cent increase in Vanuatu's grain imports would have a cost of VUV 67 million (A$520 000) per annum. A 25 per cent increase would have a cost of VUV 336 million (A$2.6 million) per annum. The probability of Vanuatu having a root crop biological disaster over the next decade that resulted in at least a 5 per cent increase in grain imports is seen as quite high.

If the full benefits of in-situ germplasm conservation as a CCA strategy are to be realised in a reasonable time frame, then consolidation and expansion of the regional and national germplasm conservation and crop improvement effort is required now. This goes beyond a pilot project as this case study emphasises (an outline for such a project, suitable for donor funding is provided in the compendium volume of case studies).

'No regrets' strategy building on natural risk minimisation strategy

This pilot project demonstrates the potential for building on the traditional practice in the Pacific of maintaining diversity in crop varieties in family gardens, and accessing them in time of need, following changes in climatic and other conditions. The strategy begins by building on the Melanesian cultural practice of openly sharing crop varieties and adopting a proactive 'no regrets' approach to maintaining genetic material in regional and national germplasm collections as well as reservoirs in farmer's fields. It is then possible to ensure the countries have sufficient genetic diversity to help meet their food and nutrition security as well as their income needs in the face of climate change. Such a foundational investment can help meet current disaster risks as well as longer term challenges due to climate change and climate variability.

4.1.3 Germplasm conservation and crop improvement programs in Samoa and Vanuatu: lessons for strengthening CCA for food security

The success of the TLB-resistant taro breeding program in Samoa and the proactive 'no regrets' approach to crop germplasm conservation adopted in Vanuatu, emphasise the importance of adopting a holistic and systematic approach to climate risk management on several levels. This includes the project or program level, adopting different pathways: addressing current risks (pathway #1), addressing projected risks and being ready for future climatic risks (pathways #2) as well as the longer term foundational institutional level (pathway #4).

They demonstrate that adaptation activity in the agriculture sector that targeted specific 'root causes' of observed disease to climate change, or other specific climate change effects—crop vulnerability (or sensitivity) to the disease (the dynamics of which depend on weather and climatic conditions)—has very high net economic returns.

The effective realisation of the benefits is no doubt also due to the systematic use of appropriate project cycle-based risk management approach—integrating scientific and traditional knowledge, and targeting production-consumption characteristics. The program also highlights several key points about risk management:

- current climatic risks must be urgently addressed, while also preparing for projected changes
- holistic risk-based planning and management is required, identifying a portfolio program of work that includes specific response activities for local needs, as well as activities that build flexibility and strengthen institutional (national and regional) capacity.

Project cycle based-risk management-related lessons

The Samoan TLB-resistant breeding program and the Vanuatu project on introducing and establishing new genetic material in farmer's fields illustrate the importance of:

Prioritising current and preparing for projected risks:

- addressing the immediate needs of the communities, as well as their active involvement in the research phase, ensured quick uptake of the planting material
- adopting both reactive and proactive measures towards dealing with climate change risks

Risk management approach:

- adopting an integrated impacts-first and vulnerability-first approach to risk management (even if implicit in the steps followed)
- developing targeted risk management responses to current risks supported by robust scientific understanding of issues, and good analytical skills to analyse root causes
- adopting integrated scientific, social science and traditional knowledge to address current and projected biological and climatic risks and to identify appropriate response solutions, and drawing on different information sources

- adopting economic CBA and sustainable livelihood frameworks for choosing between adaptation options is relevant even though empirical assessment of economic and social benefits of individual activities, net of costs, may not have been done for each of the sub-activities (or for that matter may not have been possible given the incremental trials and experiments). Qualitative assessment of such activities supported by robust scientific knowledge and consumer preference information could have been sufficient to support the choices made before the mass distribution of planting material.

Baseline and foundational investment

This case study also points to the importance of investing in foundational institutions to backstop future needs under alternative climate futures. The earlier investment in the establishment of CePaCT through the AusAID-funded TaroGen project played a major role in establishing the taro collection and taro breeding program.

CePaCT maintains collections of key traditional crops for the Pacific, including taro, other edible aroids, yam, sweet potato, cassava, and bananas, and it can easily import, multiply and then distribute genetic material as and when required. In the process, CePaCT's presence enables countries to conserve, share, and evaluate their own resources and more effectively take advantage of developments outside the region. This, without doubt, puts the countries in better stead to produce other climate-resistant or climate-ready improved crops over time as and when changes in climate are experienced. As such, linked regional and national systems, where present, could enable countries and the region to better manage climate change.

Even though the demand for TLB-resistant taro germplasm is not perceived by the growers as an adaptation to climate change, but more, as meeting their current vulnerability to loss in taro crops due to TLB, the approach adopted in this project is easily replicable to produce crops suitable under alternative climate change scenarios. On the other hand, the introduction of new genetic material and the maintenance of this genetic diversity in farmers' fields in Vanuatu has also provided an insurance against similar outbreaks of diseases in Vanuatu. This is likely to occur given the projected changes in climate change in the region.

Prioritising foundational adaptation measures

- the need for a combined national and regional germplasm conservation and crop improvement programs and the need for a flexible and sustainable capacity for future crop improvements
- the relevance of longer term investment in introducing and conserving diversity in crop genetic material in regional and national collections, supplemented by genetic reservoirs in farmers' fields as proactive 'no regrets' strategies for addressing current and projected changes in risks associated with climate change
- the importance of taking systematic steps towards producing and distributing adaptation products (disease-resistant varieties), provide the steps that are sequentially undertaken, building and extending previous works, within a logical portfolio of program of work

Partnership

- the challenges of climate risk could, at times, be beyond the capacity of any one organisation, and strong partnerships across agencies and countries may be required.
- the importance of strong public-private sector-community partnerships to help keep down the costs of trials and swift adoption by farmers once new varieties showed promise.

4.2 Water quality and quantity management in Tuvalu

With climate change expected to negatively impact Pacific island communities through rising sea levels and increased threat of extreme events (drought, storms, and floods), there is an increased potential for climate change to adversely impact water quality and quantity in the Pacific. Tuvalu is no stranger to such issues. Water scarcity and quality has long been a major issue. Indeed, a drought-induced national emergency was declared in September 2011. The potential of climate change to worsen water security is a concern.

Access to quality freshwater is one of the highest concerns for Tuvalu, a country constrained by limited roof catchment areas for harvesting rain during the wet season and limited ground water. According to Tuvalu's NAPA and NSDSs, water and sanitation have been a priority for the Government of Tuvalu since independence in 1978. Officially, it has been highlighted as a priority in the country's national development plan, Te Kakeega II and the Malefatuga Declaration.

The latest forecasts from BOM and CSIRO suggest that Tuvalu can expect some change (–5 to +15%) in average annual rainfall and will likely have moderately warmer (0.5 to 1.50°C) average annual temperatures by 2030 (BOM and CSIRO, 2011c). While Tuvaluans are not expected to experience significant water shortages due to projected decrease in rainfall, it nonetheless will face water shortages due to a variety of factors including the demands of increasing population size, limited rainwater catchment surfaces and unusable groundwater. Given that sea levels are expected to rise in line with climate change, and islands continue to subside over time in certain parts due to isostatic change (Webb and Kench, 2010) and intensive king tides already experienced, groundwater is further threatened by salt intrusion and contamination from improper liquid and solid waste management. In addition, given the geophysical characteristics of the atoll islands and the regular high tides and storm surges experienced in Tuvalu, Tuvalu can expect regular flooding-related hazards; the cost of poor water and sanitation in 2006 for Funafuti residents of some 4500 people was US$4.75 million per year (Lal, et al., 2006).

Several development partner-funded projects have been implemented in Tuvalu, including those conducted as part of larger regional projects such as the European Union (EU) Envelope B Water Project, the GEF-funded Pacific Integrated Water Resource Management (IWRM) project and the UNDP-GEF PACC project. The former two projects are executed through SOPAC, while the PACC is executed through SPREP.

These three projects target similar issues in water security in Tuvalu by addressing variously reduced consumption of scarce freshwater, improved supply of water and/or improved sanitation and groundwater/coastal quality. Combined, the projects should increase water availability (e.g. by promoting water use efficiency or rainwater harvesting) or improve water quality (e.g. through the promotion of composting toilets or improved sanitation practices) (Table 16).

A preliminary review of these three projects highlights potential benefits from water adaptation to climate change as well as opportunities for enhanced benefits in the Tuvalu case (e.g. through heightened awareness and communication of how the projects interact).

4.2.1 Risk (Hazard and vulnerability) assessment

The project documents that describe the three water projects flagged all make reference to current water scarcity and quality issues in Tuvalu, projected climate changes and the impact of climate change and variability on the quality and supply of water and vulnerability. These assessments were also largely covered in various Tuvalu Government documents, including Te Kakeenga II, Tuvalu Government 2002; NAPA, First National Communication prepared for UNFCCC. Limited further reference to projected climate change was made in the actual design of the solutions, although project managers observe that climate change would be expected to exacerbate the water problems the projects were targeted to address. It could be argued that the proponents implicitly used the vulnerability-first approach to risk assessment.

Table 16 Three water security projects in Tuvalu: EU Envelope B (SOPAC), GEF-IWRM (SOPAC) and UNDP-GEF-PACC (SPREP) as of Q4 2011

	Project target	Increased water supply activities	Improved rainwater quality and sanitation activities more generally (training and awareness-raising)	Improved water use efficiency (and associated sanitation) activities	Mainstreaming and governance activities
EU B-Envelope (2008–2013)	*Improving drought period water security in Tuvalu* Focus: Improving communal rainwater harvesting as a dry season back-up to household rainwater harvesting approaches, both on the Outer Islands and in Funafuti	310X 10000-litre communal rainwater tanks Truck to transport desalinated water in times of drought or water shortages in the homes	Training and awareness-raising	Training and awareness-raising	N/A
GEF-IWRM (2009–2013)	*Sustainable integrated water resources and wastewater management* Focus: National water security and water quality issues No rainwater harvest tanks supplied but	Development of rainwater storage model for each of the islands and whole country to optimise household, community and island-level supply	Training and awareness-raising on rainwater treatment and rainwater system maintenance at the household levels Training and awareness-raising on sanitation management and	Trial sanitation options for replication and up-scaling, facilitating catalytic change through installation of composting toilets – 20 installed and 20 more to install	Identification of legislation and policy issues to be resolved in the near future, such as: engaging community support to draft the building code; review and update the draft national water policy, and review and update draft water resources plan

	training focussed on water use efficiency Demonstration of compost toilets		impacts on health and quality of groundwater and coastal waters		Mainstreaming IWRM-governance principles, with significant increase in stakeholder engagement in governance
PACC (2011-2013)	*Piloting climate change adaptation in water* *resources management in Funafuti Island, Tuvalu* Focus: To enhance, and where necessary, develop water infrastructure for the island of Funafuti	Communal water storage tank Promotion of composting toilets and associated sanitation	Training and awareness raising about rainwater treatment, water conservation and rainwater system (roof/guttering) maintenance at the household level (but no water harvest and storage tanks supplied)	Training and awareness-raising on a household basis Expected to introduce composting toilets, depending on the outcome of the GEF-IWRM project	PACC Project document refers to : • the revision of water sector policy and incorporation of climate change risk and resilience aspects ▪ the development of National Climate Change Policy ▪ development of guidelines to integrate climate risk into the water sector and its demonstration activities Unclear from the implementation so far as to what is being addressed – limited documentation was available at the time of the assessment (although quarterly SPREP-PACC media articles available on SPREP website)

4.2.2 Problem and solution identification

From the project documentation that was submitted to the funding agencies, the following observations can be made. First, all projects refer to the various assessments done by the Tuvalu Government in response to external requirements and results of external activities. Additionally, the EU Envelope-B project's focus can be traced back to the decisions made by Tuvalu Government stakeholders, including the National Water and Sanitation Committee, the NAPA Country Team, and the International Water Program (IWP) National Task Force, and later endorsed by the Prime Minister of Tuvalu (Government of Tuvalu and European Union, 2008). Similarly, some elements of PACC projects could be traced to NAPA and the IWP conclusions, as well as the results of the First National Communication report submitted to the UNFCCC. The selection of priority sectors for support under PACC was made based on the three criteria: the Government's program priority (as noted, for example, in the Tuvalu NAPA and Te Kakeenga II); sector with baseline assessment already completed; and, project activities had already been identified that needed implementation and had available co-financing. Specific water management strategies were drawn from the broad problem statements identified in the IWP report and National Communication (UNDP- nd). The focus of the GEF-IWRM project can be traced back, in part, to an earlier executed GEF-funded project on IWP (SOPAC, 2007) as well as the findings of an independent hotspot analysis conducted specifically for the national GEF-IWRM demonstration project and in line with GEF requirements.

Both SOPAC-supported projects, the EU B-Envelope project and the GEF-IWRM project undertook current on-the-ground risk assessments to identify risk management strategies (termed 'water demand and gap analyses' and 'diagnostic analysis', respectively). The EU B-Envelope project produced a GIS-based household water 'infrastructure' inventory, including information on things such as catchment roof area, state of gutter etc. (Table 17).

The PACC project undertook detailed GIS-based assessment of water demand. At the time of the case study assessment, it was unclear how this assessment was used to inform the identification of project activities as documentation had not been finalised. As a result, the link between the water demand assessment and the adaptation options implemented (particularly given that the PACC project ultimately focused on policy and governance issues) remained unclear.

Table 17 Risk assessment and project cycle for water security projects in Tuvalu: EU B-Envelope (SOPAC), GEF-IWRM (SOPAC); and UNDP-GEF-PACC (SPREP)

	EU Water	GEF- IWRM	PACC project
Diagnostic analysis/risk analysis	Geographical information system (GIS)-based community survey undertaken to identify current situation with rainwater collection systems and gaps GIS-based information system established that could be used to identify current gaps in water security and areas to target	Detailed diagnostic analysis in the project design phase. Hotspot assessment undertaken with stakeholders to prioritise issues and identify highest priority project Limited documentation of how the social and economic information generated was used for subsequent project design	GIS-based survey of households water demand management survey Development of updated GIS model for climate change vulnerability and adaptation mapping; monitoring and evaluation On-the-ground V&A undertaken, but documentation unavailable at the time of this study so its impact on project design could not be ascertained at that point
Priority adaptation option selection process	Difficult to identify the processes and criteria used to select priority actions as little documentation available. Nor could project staff provide any insights on this subject at the time Water catchment and storage to 600 households identified, using the GIS water demand and supply gap situation Demonstration compost toilets installed in several locations but no scaling-up plan in place	Choice of compost toilet as an adaptation strategy confirmed based on community discussions Distribution of composting toilets engaged in a more inclusive nomination protocol Institutional and legislative change as a result of diagnostic analysis and consultations	From limited documentation, it was unclear what criteria were used to decide on the adaptation strategies and measures, except key governance-related activities reflected the Tuvalu Government 2002 water management document Communal rainwater

			catchment tank to be installed on very low-lying area in Lofeagai but limited documentation at the time of the study meant that the level of feasibility assessment work undertaken prior to design could not be determined A list of activities identified through stakeholder discussion. No detailed plan of implementation available at the time of study to consider planning or prioritisation of activities or technical feasibility
Project planning and design	Difficult to assess the extent of project planning that was carried out, as documentation of the processes used, and in-country project implementation plan was not available at the time of the project. Discussion with project staff in-country did not assist at the time of assessment Community engagement operation through the Tuvalu Association of NGOs	Community not involved in the design stage but consulted during the project scoping/development stage	Difficult to assess the extent of project planning that was carried out, as documentation of the processes used, and in-country project implementation plan, was not available at the time of the assessment. Discussion with project staff in-country did not assist at the time of assessment

4.2.3 Project target, feasibility assessment and design

The process used to decide the actual project designs is summarised in Table 17. It was not always easy to ascertain the details as only limited documentation on the implementation of the projects could be accessed. The GEF-IWRM project refers to an earlier economic analysis of composting toilet for waste management (Lal, Saloa et al., 2006) to contextualise the focus on establishing compost toilets in that project. It also used the household-based national GIS database on water 'infrastructure' inventory to identify households most vulnerable to dry season water shortages and with inadequately guttered roofing. Presently lacking from the study is quantitative evidence of how the composting toilet demonstration is improving water quality and thus is yet to emerge (this may take time).

The PACC project proposes an economic assessment of the pilot work conducted at Lofeagai and Vaiaku sites. The aim of constructing this cistern is to provide increased water security for the poorer/more vulnerable community at Lofeagai, especially during drought periods, in addition to the several government underground rainwater cisterns that are already in existence. At present, some questions remain about the final location of the water cistern. Improved communication on how the cisterns are to be designed would assist in project assessment.

The purpose of the proposed economic assessment of the PACC project is unclear, especially given that procurement for construction materials onsite has already begun. Nevertheless, an economic analysis will create opportunities for potential ongoing refinement of the projects and may even identify new design options for the storage tank. These objectives have not yet been articulated in PACC documentation, but the opportunities exist nevertheless.

4.2.4 Cost–benefit analysis of the adaptation projects

The economic analysis of the projects was conducted using a cost–benefit framework. The absence of a detailed probability distribution on the impact of different climate change scenarios on quality and quantity of water supply meant that a probabilistic CBA associated with CCA was not possible. Instead, only a deterministic CBA could be attempted, together with sensitivity analysis around key economic assumptions. The three projects are still ongoing and thus the CBA is largely ex-ante.

Given that the three projects target similar and complementary activities (e.g. more than one targets improved water quantity, more than one targets improved water quality etc.), an analysis of the combined potential impacts of all three projects was attempted, rather than three separate analyses. As the projects are ongoing (assessment ex-ante), scenarios about the potential impact of the projects in the future were used (likely impacts indicated in Table 18). Numerous assumptions were used to describe the extent to which the projects might ultimately impact water quality, quantity and flow-on effects. These are described in detail in the case study report itself.

Table 18 'With and without' benefits and costs of the three water projects in Tuvalu

A: Without the projects	B: With the projects (for the period 2008–2028)
Costs	
• Imported bottled water purchases • Use of expensive desalination plant • Waterborne and water-related health costs • Lack of water security and associated costs of water shortages/drought periods	• Financial costs of initial project implementation and continued incremental investments over time (e.g. for maintenance and awareness-raising)
Benefits	
• None	• Improved sanitation and associated avoided waterborne and water-related health costs • Reduced expenditure on imported bottled water consumption • Reduced expenditure on desalinated water consumption • Non-quantifiable benefits such as psychological peace of mind due to secure water supply • Catalytic changes to sanitation and household water-use efficiency driven through regulations and legislation changes • Increased efficiency in use of existing resources, resulting in reduced periods of restricted water supply and associated health and social benefits

Based on data available and the assumptions made, the expected pay off from the three projects over a 20-year time frame was estimated to be in the order of 1.8:1, that is, a saving of almost A$2 for every dollar invested in the projects (Table 19). These benefits were noted to be a minimum and likely underestimate of potential benefits for a number of reasons (e.g. no attempt was made to value the ecological benefits of improved water quality in the lagoon).

Table 19 Potential combined net benefits ($A) from the three water projects

Total present value of benefits	$ 2 663 989
Total present value of costs	$ 1 474 391
Net present benefit	$ 1 189 598
Benefit: cost ratio	1.81

The estimates are not certain. The health benefits estimated for the projects may be overstated as not all existing symptoms related to waterborne disease may have been caused by poor water; it is difficult to separate the underlying causes of the waterborne diseases as such information is not regularly noted. Where problems are due to other causes, such as poor hygiene, health benefits associated with the projects may be overestimated. On the other hand, the potential benefits of some impacts of the projects are understated in many respects. For example, estimated project benefits do not include estimates of the value of water savings from a proposed PACC water cistern for the Lofeagai community, or values from improved coastal ecosystems and fishing opportunities, any reduction in chronic health problems and or reduced stress. Some of these benefits could be large. Critically, no estimate is made of the value of benefits associated with activities inspired by the projects. This is important since some of the projects are specifically intended to catalyse other projects and act as demonstrations of the value of specific activities.

The estimates were also generated with limited data on actual changes that will occur in the future over the next 16 or so years. The estimates were therefore generated using assumptions and the values provided are highly sensitive to certain ones. The parameter most affecting the potential benefits of projects is the assumption of the extent to which the incidence of waterborne disease is reduced and the speed at which composting toilets are adopted. As an example, the benefits presented above assume that the projects would generate a reduction in the incidence of waterborne disease by 15.5 per cent. If this was raised to 25 per cent, the NPV of the three projects might be expected to double to A$2.4 million with a BCR of 2.6. By comparison, if the projects achieved a reduction in incidence of waterborne diseases of only 6 per cent, the NPV of the three projects might be expected to fall substantially and only just above the costs. When a number of assumptions are varied at the same time, in the worst case scenario (no reduction in bottled water purchases are achieved over time; composting toilets used at only 50% capacity for first 20 years due to initial community reluctance; projects achieve only a 6% reduction in illness, there is no increase in population size) a BCR of less than one is also obtained.

The CBA exercise conducted for the water case studies highlights difficulties in trying to undertake a quantitative assessment of CCA options in the absence of easily accessible baseline information. It underscores the value of information (e.g. health impacts in Tuvalu from improved water quality or the potential catalytic impacts of demonstration activities on changing behaviour and investment in Tuvalu into the future) and that improved access to such data (if indeed, it existed) would substantially ease quantitative estimations. Running project ideas through a simple cost–benefit framework when considering potential projects could contribute in this respect in that, the exercise would support the identification of critical data and potentially allow for more targeted quantitative appraisal of project impacts. Nevertheless, such data may not be readily accessible (e.g. how much demonstration activities lead to further investment in more of that activity in the future) or, where projects target environmental improvements, data on such impacts may remain difficult to access given that the time frame of the projects is short while environmental impacts can be expected to take place over the medium term. The use of CBA framework is also useful to guide aspects of the vulnerability-first approach to risk management.

4.2.5 Monitoring and evaluation and long-term sustainability

While reporting of project activities and progress is conducted regularly, it is difficult at this stage to comment substantially on the sustainability of the three Tuvalu water projects assessed beyond general intent and advocacy, as data are limited. In any case, the projects are still underway/commencing and so time is needed before environmental change can be achieved.

4.2.6 Final comments

Overall, the water case study was based on the three independent water security adaptation projects in Tuvalu which had complementary objectives. The case study arguably reflects:

- a vulnerability-first approach to CCA to design and more effectively monitor and assess adaptation projects where country-specific empirical data about climate change science, including inherent uncertainties, and their impacts is limited. It can help identify appropriate adaptation measures for consideration;
- deterministic ex-ante CBA of adaptation project, or a portfolio of projects. This is feasible if the project is designed such that the sum of the activities can deliver on the expected benefits and these can be clearly articulated and benefits and costs can be quantified. However, as a minimum, a 'without' project empirical information about the social and economic wellbeing, and expected change in the wellbeing as a result of the 'with' adaptation project, is required to do a quantitative CBA
- in the absence of more accessible data, only an indicative assessment based on key assumptions and sensitivity analysis. It is likely that this lack of accessible data itself reflects the fact that two of the projects were not in themselves intended as adaptation projects (although they still have applicability).

Data relevant to undertaking social and economic assessment of water-related CBA required is summarised in Table 20, which can be obtained from a diversity of sources. Table 20 also lists the types of disciplinary and other expertise that could assist with integrated CBA of water security-related adaptation measures.

From the water CBA conducted, the case study suggests that CBA may, as a minimum, assist assessors to (i) inform the design and monitoring of adaptation projects (ii) structure benefits and cost assessment 'with and without' the project, as a component of the vulnerability-first approach to CCA decision-making. Knowledge-based decision-making processes, using project cycle-based risk management might also be improved by strengthening capacity in the use of such analytical and decision-making processes across all levels.

Following: Table 20 Examples of information needs to underpin water security: improved rainwater harvest, storage and management

Examples of information needs	Examples of relevant disciplinary skills	Source of data/information *sources of data used in the case study
• Climate forecasts • Average values and trend in o precipitation forecast (rain, drought, and humidity patterns) o temperature o weather extremes and frequency of extreme events	Meteorologists and climate modelling	Published and grey literature Meteorological services Climate modelling institutes
• Household water storage capacity and costs o water catchment, gutters and tank o maintenance of water catchment, storage structures	Water engineer/ Builders Social researcher	National census reports* Household survey* Community vulnerability and adaptation survey (CV&A)* Government agencies (Public Works Department)* Published and grey literature, including from other projects*
• Current use and trend in household water demand o Number of members and water consumption pattern o Population trend and trend in water demand o Volume and cost of alternative sources of water: ▪ imported bottled water ▪ desalinated water	Statisticians Social researchers	National census reports Social/household surveys* Community vulnerability and adaptation survey (CV&A)* Government agencies Published and Grey literature, including from other projects(e.g. World Hydrological Cycle Observing System – HYCOS, IWRM)*
• Water quality	Government water-testing experts	

• Relationship between precipitation and human health conditions (specific insect- and water- borne diseases)	Medical health specialists	Human health research Government agencies Published and grey literature, including from other projects
Household insect- and water- borne disease incidence and status	Medical researchers , district/hospital nurse	Government health records and or Hospital/district nurse records* Household survey Published and grey literature, including from other projects
Costs of treating insect- and water-borne diseases	Researchers/economist	Government /local hospital, (private) pharmacies Published and grey literature*
Sources of pollution, including coastal storm surges, king tides and water quality measures	Water quality specialists/chemists/ local government health officers	Government records Department of Environment/ NGO consultations Published research Field water quality surveys*
Relationship between water quality and human health conditions (specific insect- and water-borne diseases)	Health specialist and researchers	Published and grey literature Local health research
Local records of the change in the incidence of diseases as a result of changes in water quality	Health officials	Published* and grey literature Department of Health/local hospital/local health clinic
Estimation of the costs and benefits of improvements in water supply (compared with the current status)	Water economist/health economist/climate change adaptation economist	Water economics, human health economics, CCA economics analysis

4.3 Sea-level rise and relocation as an adaptation strategy for Letau community, Vanuatu

Relocation as a CCA strategy has been seriously considered since projections about sea-level rise came to the forefront. Global warming-induced sea-level rise scenarios often raise many emotive arguments in terms of loss of basic human rights, watching the islands 'drown' and calls for the protection of climate refugees (Farbotko, 2010). Whether the increased risk of coastal erosion, storm surges and/or coastal inundation is caused by islands sinking due to tectonic shifts, such as is the case in the Torba Province, Vanuatu (Ballu, Bouin et al., 2011) geomorphic change in Vanuatu (Webb and Kench, 2010) or rising sea level due to climate change (Mcleod, Hinkel et al., 2010), the challenge of making an appropriate adaptation decision remains.

In 2005, under the Canadian International Development Agency (CIDA) funding, SPREP assisted the Vanuatu Government to implement a CCA project aimed at assisting a coastal village on the island of Teguato to relocate. Letau is a coastal village in the Torres Province, The process involved about 10 households (about 100 people) relocating from their existing location to a nearby site on the same island. The households removed their sleeping house and cooking house and rebuilt them at the new site. The key objective behind the relocation was to reduce the risks faced by the villagers from regular coastal inundation, causing damage to their homes and assets, poor health, and general inconvenience.

This assessment is based on the review of Capacity Building for Development of Adaptation Measures in the Pacific Island Countries (CBDAMPIC) documents made available by the project team, Taito Nakalevu of SPREP and Brian Phillips, of the Climate Change Unit, as well as those accessed from the web. In April 2011, a specific field visit to the island of Tegua was made for discussion with the community members who were involved in the relocation; this field work was undertaken jointly with Ms Olivia Warwick and the description of the detailed social assessment is reported in Warwick (2011).

4.3.1 Background

With CIDA support, SPREP coordinated and executed the CAN$2.2 million-funded CBDAMPIC project tin four countries: Samoa, Cook Islands, Fiji and Vanuatu.

The project had two main objectives: to increase the capacity of Pacific island government institutions to deal with climate change risks through mainstreaming, and to increase the resilience of communities to climate-related risks through implementation of adaptation recommendations (Nakalevu, Carruthers et al. 2005). A two-tiered, 'top-down' and a 'bottom-up' approach was adopted in the project, linking government institutions with communities. The project involved:

- capacity development at the national level with the concept of mainstreaming CCA into institutional frameworks, sectoral policies and ministries' operational plans
- community-level capacity development in using a participatory approach to assess and evaluate vulnerability to climate change and adaptation options in order to plan and implement locally appropriate adaptation activities.

In Vanuatu, both these capacity-development exercises were indirectly provided through 'hands-on engagement' in the design and implementation of the relocation of the Lateu village.

4.3.2 Risk analysis and identification of adaptation options

The CIDA-funded project essentially took a vulnerability-first approach to risk management, making reference to the broad climate change futures projected for the country, and involving key stakeholder groups. The community-based participatory risk assessment process involved: Tegua villagers; key government agencies such as the Department of Geology, Mines and Rural Water Supplies, Department of Health, Department of Meteorology, the Department of Environment; the Torba Provincial Government representative; and the Melanesian Church.

The project team conducted workshops in the village and undertook a CV&A, using a process designed by SPREP (Nakalevu, 2006). The CV&A essentially mirrors key elements of the basic project cycle steps (adaptation context assessment, diagnostic assessment, assessment and evaluation, development, implementation and monitoring), and builds on the principles of rapid rural assessment, participatory learning and action and comprehensive hazard and risk management tools advocated in the Pacific (Nakalevu, 2006). It also reflects elements of the sustainable livelihood framework.

Several environmental hazards were identified, including sinking of islands due to earthquakes, flooding during king rides and regular inundation of the village and storm surges in times of high tides and strong wind (Table 21). However, the project was reported globally to be the first community 'migration'/relocation due to climate change risks (e.g. Caldwell, 2005; Environment News Service, 2005).

Table 21 Key results of the V&A assessment, Lateu village

Hazards	Impacts	Effects
• Coastal erosion of 50 m (or 2.5 m/yr) • Seal-level rise • Geological processes • King tides and high spring tides and south-westerly winds	• Raised underground water lens • Village surrounded by permanent (?) pools of water near the swamp • Village grounds and housing area regularly flooded	• Rapid deterioration of housing • Prevents or completely stops the use of cooking place • Dampness in the house • Pit toilets overflow, contaminating the only underground water well • Waterborne and insect-borne diseases, including malaria, diarrhoea and skin infections, especially among children
Source: Phillips (nd)		

Climate change risk perception and risk reduction priorities

Although the project was identified by SPREP and the Department of Environment as an initiative aimed at addressing the risk of sea-level rise and associated flooding, for the community this was also an opportunity to address their key development need—access to freshwater. This was revealed during the field visit by the IUCN team in April 2011. The benefits of the relocation were gauged using a semi-structured survey of the community households, including focus group discussion and individual discussions, community perceptions and views about climate change risks, and reasons for the relocation.

Community members noted that they were initially reluctant to relocate because the Lateu village had a good supply of freshwater harvested from a catchment roof and communal water tank supplied by the government's Rural Water Supplies. The community decided to consider relocation only after the project team promised to supply (under the CIDA funding) additional 'white man's' houses in the form of women's club, aid post, plus additional water tanks (Jean Piere Laloya, pers. comm.).

Thus it seems that, although flooding was a concern to the community, their priority was a secure water supply. It may be possible that the community implicitly had a lower concern for storm surge and flooding, as these problems became more evident after the major 1997 earthquake when the island had sunk, whereas, water security concern has been a constant issue. Since 1997, the island is believed to have risen once again due to tectonic shifts; this phenomenon was recently confirmed for a nearby island of Loh in the same province (Ballu, Bouin et al., 2011).

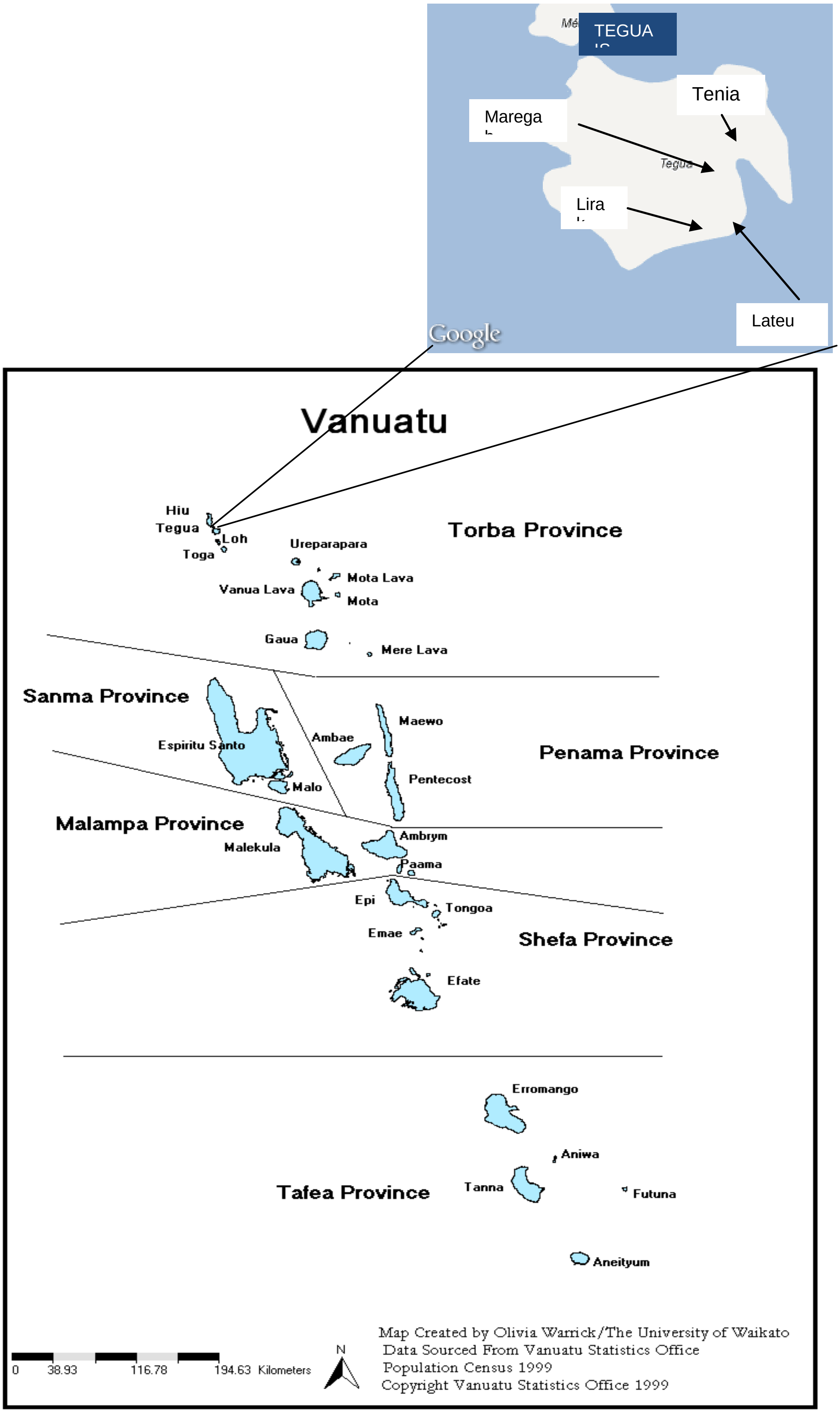
It is also possible that since the variations in the sea-level rise and storm surges are experienced regularly in the South Pacific due to ENSO events (BOM and CSIRO, 2011), any changes in climate may not have become part of their consciousness. Yet, the community is aware of the concept of climate change through radio programs and the visit by the project team.

The villagers did comment though, on some changes they have observed in the cropping and fishing cycles, including the fact that some crops, such as yams do not grow as well as previously with the flowering patterns of many trees such as oranges, breadfruit and nandao (a fleshy fruit), changing to the extent of not flowering at all and therefore having less fruit. These are usually attributed to changing climatic conditions in other parts of the Pacific (Bourke, 2010).

4.3.3 Selection of preferred options

Relocation, it seems, was not a new concept to the Lateu people, as the village had started talking about relocating, it seems as far back as the early 1970s. At that stage, the community had talked about moving to Tenia, a site some 100 m from the Lateu village site; the same site that many are now rethinking of moving to. Tenia is also the site where one of the villagers had decided to move to when the rest of the community moved across to Lirak (Figure 4.1).

Figure 13 Map of Vanuatu with Tegua Island insert



The community had three options from which to choose. Lirak is the site chosen by the Chief and endorsed by the government and project team and Tenia is preferred by the community. Meregab is the site further up the hill and some distance from the coastal spring water but closer to the community gardens. These three options had slightly different characteristics (Table 22).

Of the three alternatives, most people preferred Tenia, as it had all the characteristics found at the Lirak site, with the added advantage of easier ground for making houses, and gardens. The Tenia site was a little (five to ten minutes) further away from the coastal freshwater spring used by families to wash their clothes. However, from the documents that could be accessed, it is not clear if villagers explicitly considered the pros and cons of the alternative sites before a decision was made. The choice of Lirak over Tenia could be justified for many reasons, including (as emphasised by the village chief) proximity to coastal springs and therefore, less work for women for washing, bathing etc. and closeness to the sea and the beach. However, there are also significant advantages of the Tenia site where most of the villagers preferred to move, including the fact that it was only 10 to 15 minutes from the gardens, only a further 10-minute walk to the springs (and slightly further to the sea). The ground is also easy to dig and most importantly, less vulnerable to the impacts of sea-level rise and storm surges.

Had a systematic CBA approach been used to guide community decisions, Tenia may have been selected. Based on the informal household surveys in April 2011, villagers apparently agreed to move to the Lirak site to maintain their social harmony as the traditional Chief had already started clearing a site at Lirak to construct his house. For some villagers, this site, although better than the Lateu site, was not ideal as there was not much land for building additional homes for adult sons, and the Lateu ground was difficult to work. Many households are now thinking about relocating again, but this time to Tenia.

4.3.4 Project design

Villagers rebuilt their homes using their traditional designs and building material sourced from the bush. A few households decided to raise their houses and build on short stilts, perhaps in response to their experience of flooding at the Latea site. The detailed design of the ‘white man’s’ house (guest house, kindergarten, and house of the local women’s association) was developed by the government draughtsman, and houses were built under the supervision of a builder contracted by the project team. Material was purchased by the project team and shipped from the nearby island of Santo.

Although participatory processes were used in the initial consultation and in the CV&A undertaken to identify hazards and risks, and possible responses, they did not appear to have been used to inform the design of ‘white man’s’ houses, including the selection of the posts for the house (this could not be confirmed as the project documents accessed did not cover the issue of decision-making process used). One of the consequences of non-participatory processes was the inappropriate use of ‘white wood’, a soft wood timber that is not suited for the conditions found on the island (Jean Piere Laloya, pers. Comm.). Similar, rebuilding of the Church seemed to be required because of the tall building design not being suited for the area (Jean Peire Laoya, pers. comm.). When further explored with the villagers, it seems that the communities ‘went along’ with the project team’s decisions even though they were aware that the ‘white wood’ was not a suitable material for their island. Three years later, the villagers had to replace the posts with hardwood sourced from their forests, as the original posts had rotted away (Photo 1). It was not possible to confirm who and how the decision was made about the selection of construction material, as the original department files could not be located; they seem to have been misplaced in the relocation of the department to their government offices.

Lirak village could have also been better prepared for projected climate change, had the design of the water tanks and catchment area also had taken into account likely water needs in times of drought (Kouwenhoven and Cheatham, 2006). The current water tank size and catchment areas (6000 L each with a catchment area of about 35 m^2) could provide water for the village for about seven weeks of dry weather; an assessment that Kouwenhoven and others had done, using information and models available from the Department of Meteorology.

4.3.5 Ex-post evaluation of the relocation project

It is not possible to do an ex-post evaluation of the CBDAMPIC relocation as little empirical information about original conditions were reported and the project did not explicitly consider alternative designs or options (Kouwenhoven and Cheatham, 2006). Qualitative assessment immediately completed after the project does give an insight into the benefits that the communities highlighted. Anecdotally, the villagers noted a decrease in the incidence of water and insect-borne diseases. It is difficult to attribute the change in the number of malaria cases solely to the relocation, as a Torres-wide malaria eradication program started in 2006. It is likely that the relocation project may have contributed to the reduction in malaria and other disease risks at Lirak, which has more open space than Lateu, less sitting water, and local respondents believed there were fewer mosquitoes. Villagers also reported limited flooding, except for the households located at the foot hills; water did not stay for long though and houses did not rot away as quickly as they used to.

Table 22 Key characteristics of the three alternative sites for relocation and the original village site, Lateu

Characteristics	Lateu – original village site	Lirak	Tenia	Meregab
Location		500 m down the coast from Lateu and approx. 30 m inland where most of the community now live	An alternative relocation site chosen prior to the relocation project where one family now lives. About 150 m inland, and 10-minute walk from Lateu to Lirak	A site up the hill – in an elevated area in the middle of the island where the gardens are located
Distance from sea	Adjacent	Adjacent but a few metres from the sea on the north west direction	Further away, about 10-minute walk from the coast	Up the hill (traditional location of the missionary influence)
Distance from coastal spring water	Adjacent	Adjacent but a few metres from the sea on the north-west direction (extra two to three minutes)	Further away, about 10-minute walk from the coast, and an extra three to five minutes from the springs	A distance and hike up hilly terrain
Flooding	Every heavy rain and high tide	Some flooding; but clears quickly	Nil	N/A
Ease of digging the ground	Coralline and difficult to dig	(Same as Lateu) Coralline and difficult to dig	Sandy, easy to dig	Easy ground to work
Distance to hill/food gardens	25–30 minutes	25–30 minutes	10–15 minutes (more space and better ground near the house)	two to three minutes
Cash income sources	Cash crops: coconut crabs, copra, lobster, kava, root crops	(Same as at Lateu) Cash crops: coconut crabs, copra, lobster, kava, root crops	(Same as at Lateu) Cash crops: coconut crabs, copra, lobster, kava, root crops	(Same as at Lateu) Cash crops: coconut crabs, copra, lobster, kava, root crops
Access to well water	Watertable <50 cm	Watertable <50 cm	Deeper well (??)	

4.3.6 Concluding remarks

For the people of Tegua Island, relocation was not a major issue, as they had been thinking of moving for some time. The community has experienced flooding during storm surges and heavy rainfall, particularly after the 1997 earthquake when several islands in the Torba Province had been reported to 'sink'. For the community, the recent increased risks may not have been directly attributable to climate change, it nonetheless was reported as such globally. Climate change may have contributed to the increased flooding of the village, although this is difficult to demonstrate in the absence of good data and country-specific climate models.

Taking a holistic approach to risk management, the CBDAMPIC project addressed the current risks and prepared villagers for further environmental threats, at least in the short term. This relocation project highlights several issues of relevance to future adaptation projects including:

- local engagement and consultation is essential in learning about people's experiences, what people want and project designs that could benefit from the local knowledge that they possess and can pass on
- local-level CV&A can help to assess how concerned people are about climate change and what sort of information exists, and new information that may be necessary to encourage better informed decision-making
- stakeholders involvement throughout all stages of the project cycle can help avoid maladaptation to changes in the natural or human systems that inadvertently increase vulnerability
- careful consideration of the existing governance processes, including traditional governance, is important in order to address the decision-making process, ensure equitable decision-making, encourage fairness and social justice and to emphasise the importance of leadership
- in the absence of baseline empirical information, the importance of undertaking hazard mapping with local communities can serve as a second-best strategy; essentially undertaking the first few steps of the vulnerability-first approach to risk management
- a systematic application of the project cycle-based risk management framework, together with CBA as a process can still assist in informed decision-making, by explicitly considering many economic and social costs and benefits, expressed qualitatively and/or quantitatively
- better access to different sources of data and local knowledge, together with access to appropriate technical expertise (Table 23) also help improve adaptation decisions

International literature highlights other issues that may also need to be considered in the broader context of climate change-induced relocation and when dealing with climate refugees, including:

- other drivers of vulnerability, such as geohazard events, population growth and movement etc.
- land ownership. Although in this project relocation was to their own land, the situation can be more complex when relocation involves moving to land owned by

other communities. In which case lengthy negotiation for access to land may be necessary, or governments may need to consider acquiring land to resettle people. It is vitally importance to address the legalities of protection of future refugees (such as fairness, justice, sovereignty and security) in the adaptation policies. This is particularly important if large communities are involved and there are different interest groups and different categories of disadvantage groups.

Coconut trees that died as a result of being permanently inundated with sea water, following the 'sinking' of the island of Loh

Photo 1 Posts in 'white man's' houses rotted away and needed to be supported using local hard wood shown here.

Table 23 Examples of information needs, respective relevant disciplinary expertise, and sources of relevant data that could help underpin a project such as the sea-level rise and relocation of Letau community, Vanuatu

Examples of information needs	Examples of relevant disciplinary skills	Source of data/information
Climate forecasts Average and trend in o precipitation forecast (rain, drought, and humidity patterns), temperature, wind, sea-level rise o weather extremes and frequency of extreme events	Meteorologists, Coastal sea-level rise specialists and climate modelling	Published and grey literature National Meteorological Services Climate modelling institutes, such as CSIRO, NIWA
Geo-referenced incidence and trend in local hazards: flooding, droughts, sea-level rise and storm surges	National disaster specialists, and government officers GIS specialists and database managers	Department of Meteorology & Climate Change National Disaster Management Office Provincial Government offices Grey and published literature
Relationship between climate change and incidence of hazard conditions, and hazards	Climate and hazard modelling	Published and grey literature National Meteorological Services Climate modelling institutes, such as CSIRO, NIWA Empirical /analytical research
Local vulnerability assessment • Household-level economic and social wellbeing • Community health status: status and trend in water and insect borne diseases	Sectoral government specialists and statisticians Social researchers with	Sectoral agencies at the provincial/national level National Bureau of Statistics District/Provincial government offices (health, disaster management, agriculture/fisheries/natural resources Project specific CV&A workshops

	expertise in CV&A methods, problem, root cause analysis	Grey and published literature
Social effects of relocation	Geographer/sociologist/ anthropologist	Context-specific research/observation and grey and published literature
Economic costs and benefits of relocation as a CCA strategy	Climate change economist /resource and environmental economist	Government and local pharmacies; department of health, district nurse, expert opinion

4.4 Climate proofing coastal road infrastructure, SIRP 2 sub-project, Western Guadalcanal, Solomon Islands

The Solomon Islands are located just south of the equator and regularly experience climate-related extreme events, including tropical cyclone-related heavy rains, damaging winds and storm surges. Storms and associated flooding comprised 80 per cent of all reported disasters between 1980 and 2010. In total, these reported climate-related events affected about 300 000 people and killed at least 180 people (Provention webnet.html, accessed 2 October 2011).

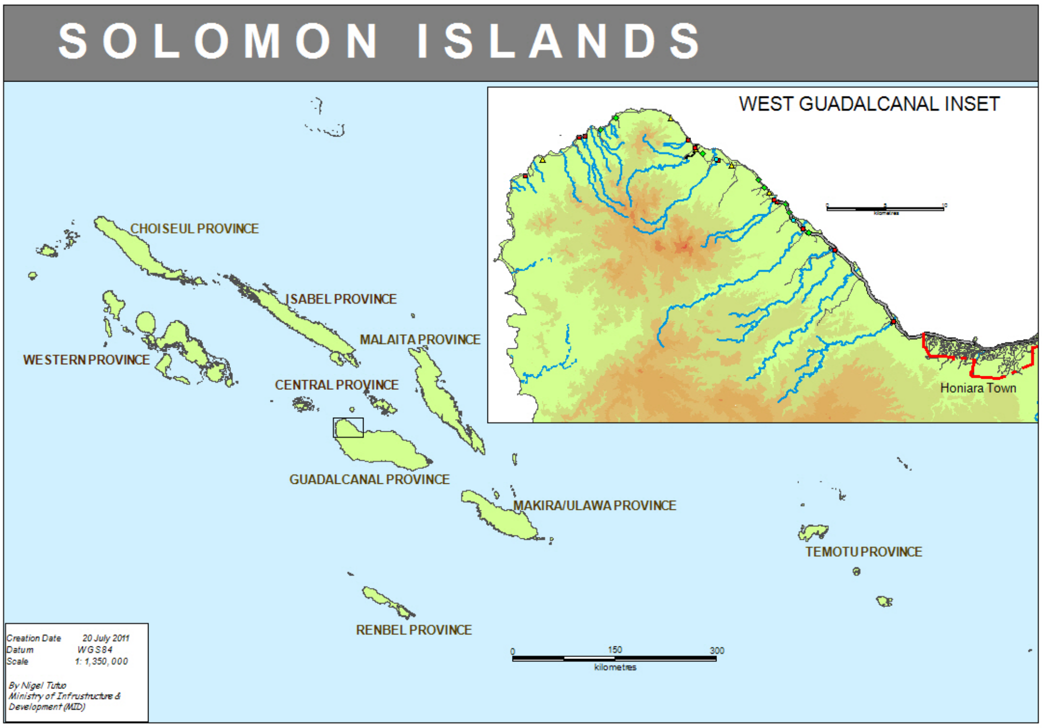
This time frame includes the 1-in-50 year 2009 January–February heavy rains that caused extensive flooding in the western and eastern parts of Guadalcanal, including the area between White River and Naro Hill, Selwyn College (Figure 14). This event brought heavy rain combined with high tides and high winds, and the road between White River and Naro Hill experienced significant damage to existing bridges, wet crossings, engineering fords, causeways, extended bridge slabs and bridge wing walls. Heavy scouring took place at pile foundations of access for the local communities as well as physical damage to the road itself. The local communities also suffered widespread damage to housing and food gardens, and an estimated 2000 people were displaced and 13 people killed or drowned (Cardno Acil Report No.40, June 2009).

At Sasa and Tamboka bridges, floodwaters left behind huge logs and debris, extending some 200 m on the upstream of the widened river, causing river diversion of about 50 m of the existing structure. The rivers and streams in West Guadalcanal flow over soft alluvial soils; this is an area that is renowned for water courses to change regularly during rainy season, with debris flows coming down the hills often compounding the problem.

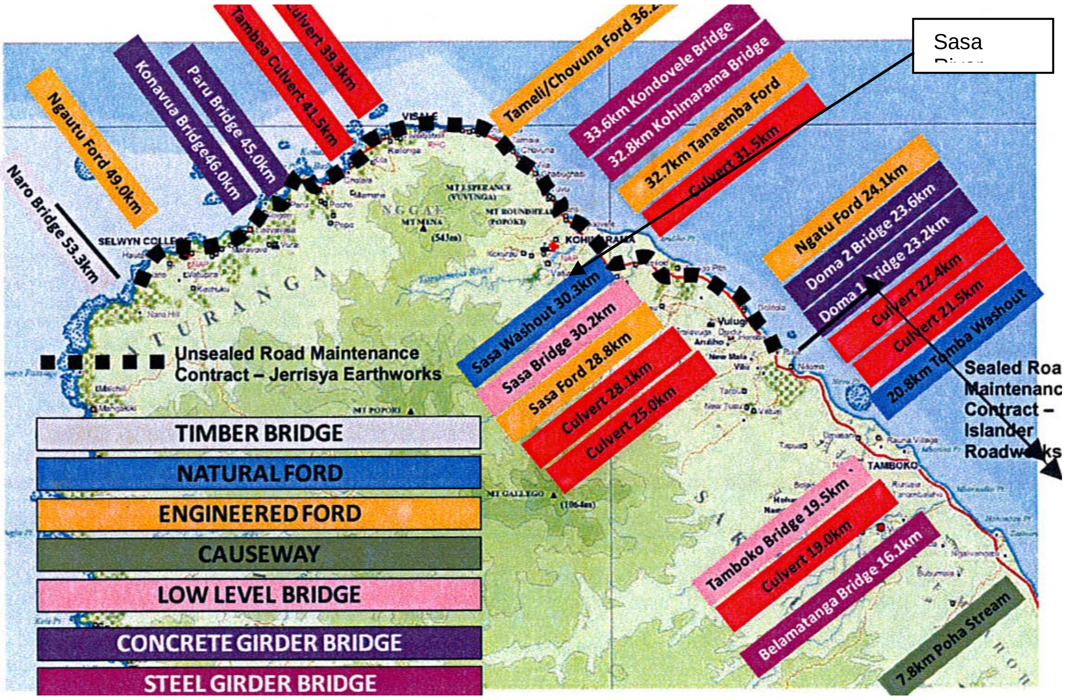
In response to regular flooding and other damage, the Solomon Islands Government with the assistance of ADB, the Australian Government and the New Zealand Government, undertook a program of road rehabilitation, the Solomon Islands Road Improvement Project (SIRIP). The SIRIP's goal was to rehabilitate the roads to be able to withstand a higher category of weather event. The original SIRIP 2 sub-project was designed in response to current disaster risks (Cardno Acil, 2009) to repair and improve the road between White River and Naro Hill, which was extended to Selwyn College, following the January–February 2009 floods.

This was subsequently revisited following the 2010 floods to reflect projected increases in climate risk considerations in the rehabilitation design before actual construction works began (Cardno Acil, 2010b).

Figure 14 Map of Solomon Island Road Improvement Project (SIRIP 2 sub-project): Western Guadalcanal Road Improvement Project



Source: Ministry of Infrastructure and Development



Source: Cardno Acil (2009)

This case study examined the extended SIRIP 2 sub-project plus additional climate proofing activity.

4.4.1 Climate risk management process

The SIRIP 2 sub-project development followed the key steps of the standard risk assessment steps outlined in Figure 9. Cardno Acil Ltd, the consultant team hired to undertake the initial project design as well as subsequently implement the SIRIP, undertook:

- key context analysis in relation to hazards and identification of problems and possible solutions
- assessment of solution measures and selecting of preferred choice based on key threshold criteria
- project design
- CBA
- climate change scenario analysis and 'climate proofing' of preferred options.

The SIRIP 2 sub-project was designed to reduce the impacts of regular high intensity precipitation and associated flooding on key road infrastructure in the Western Guadalcanal, including culverts, bridges, causeways and roads. The terrain is also subject to heavy river flows, changing rivers and stream location as well as associated scouring of land around streams, rivers and physical infrastructures. This is compounded by large volumes of debris coming down the main rivers and streams. Deforestation, combined with poor forest management practices, is a major source of logs in the debris flows that block main streams and rivers (Bonte-Grapentin, 2009); it is not uncommon to find rivers and streams finding new and unpredictable routes (Figure 15).

Current risk and risk-reduction analysis

Scientific impact assessment formed the basis of the current and projected hazard and risk assessment, as well as risk-reduction assessment. Hazard analysis was conducted, using hydrology modelling-based analysis to produce estimates of river flow velocity, depth, frequency and flooding at each of the stream/river crossing. In the absence of detailed stream flow modelling information for the rivers in the north-western Guadalcanal region, the consultants used the rainfall data for Honiara to determine daily rainfall extremes expected for 1-in-2 year (or a 2-year return period), 1-in-10 year (10-year return period), 1-in-50 year (50-year return period) and 1-in-100 year (100-year return period) rainfall events; the 2009 rainfall, as mentioned above, was considered to be 1-in-50 year annual recurrence interval (ARI) event (Cardno Acil, 2009) (Table 24).

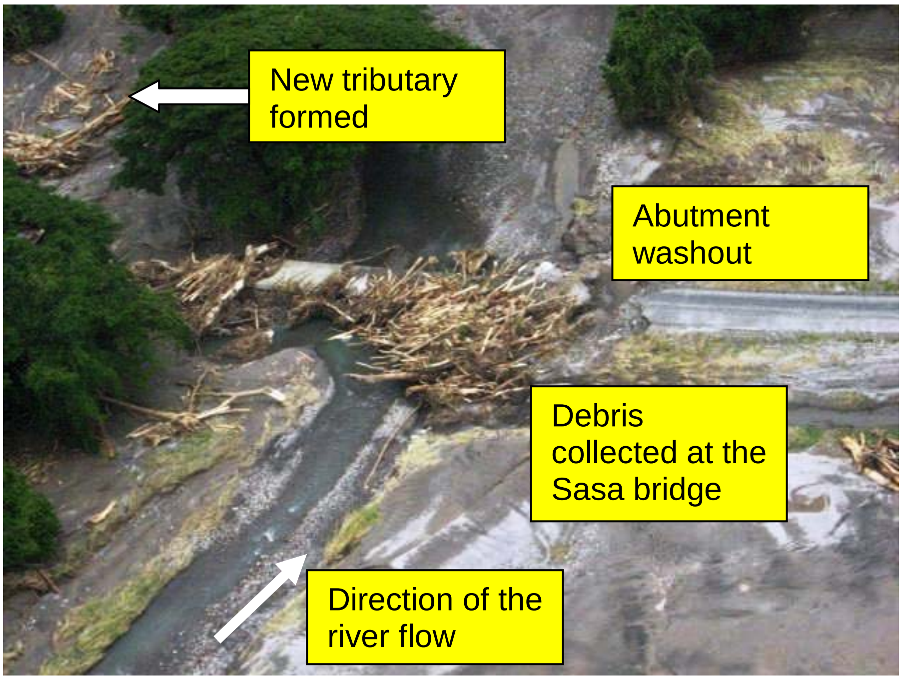


Figure 15 Sasa Bridge immediately following the 2009 heavy precipitation and flooding

Photo: Terry Telford, Cardno Acil Ltd.

Table 24 Modelling-based rainfall pattern associated with various extreme rainfall events

Rainfall extreme event (or return periods)	Maximum rainfall (mm/day)	Daily rainfall intensity (mm/hr)
1-in-2 year (2 year)	106.1	4.4
1-in-10 year (10 year)	194.6	8.1
1-in-50 year (50 year)	254.0	10.6
1-in-100 year (100 year)	282.1	11.8
Source: (Table II.1 Cardno Acil 2009)		

The 'Rational Method' was used for the estimation of flood flows at stream crossings for 2-, 10-, 50-, and 100-year return periods. This was combined with compensatory factors recommended for PNG to determine the respective flood levels and velocity of river flows at the crossings associated with the respective return periods and for each of the rivers and streams in the project area. The team noted that the compensatory factor could not be calibrated due to the absence of rainfall or flow data collected in the catchments in north-west Guadalcanal. However, some river flow modelling information is available from the Department of Water Resources for nearby rivers in the eastern part of the Guadalcanal. Using this information, flooding regimes for each river and stream were estimated, although the team noted that the accuracy of the flood predictions based on the above method [Rational Method] is unknown (p. 10, Cardno Acil, 2009).

The results of the Rational Method were then used to determine appropriate design of culverts and bridges to cope with different return periods, such as a 1-in-2 year event, and 1-in-10 year event. The effect of debris flow on the structural designs was fully considered though, except for the larger structures.

In the design of the roads and crossing structures, engineers faced many challenges, including considerations of the effects of high intensity precipitation, flash flooding, landslide and debris flow and moving river channels due to soft alluvial soils. Western Guadalcanal is prone to serious landslides, which is related to rainfall, slope, and soil characteristics. These are mentioned in the assessment reports, including options for strengthening scour protection, widening the bridge span on large bridges and river training. However, landslide risk assessment and terrain analysis were not undertaken, neither were the effects of upper catchment land use changes. This was particularly due to the commercial forestry analysed; these were considered beyond the project scope. In the SIRIP 2 sub-project, a debris impact assessment was taken into account in the engineering designs of selected bridges, such as Tamboko Bridge, where it was designed for the depth of debris mat and scour below the streambed level.

Parts of the road, not the bridges, in the project area are also within metres of the coast. However, potential impacts of sea-level rise, including storm surges, were not factored in the risk reduction consideration. Recent data suggest that the Solomon Islands has experienced about 8 mm since 1993 and is projected to experience 400–1500 mm by 2030 under high emission scenario to sea-level rise (BOM and CSIRO 2011a). Potential impacts of sea-level rise, including storm surges, were not factored into the risk reduction consideration; although some parts of the road, but not the bridges and other crossings, run close to the sea. These observations thus raise the question about what effect an integrated risk assessment would have had on the risk thresholds and the engineering standards adopted for the structures at each of the rivers and streams along the White River–Naro road, as well as costs and benefits and the choice of repair and road improvement options examined in the SIRIP 2 sub-project.

The focus of the SIRIP 2 sub-project was on ‘hard’ engineering solutions, targeting reduction in the impacts of regular high intensity precipitation and associated flooding on key road infrastructure in the Western Guadalcanal, including culverts, bridges, causeways and roads. Non-engineering solutions, although noted in the assessments, were not pursued due to land tenure issues or considered to be outside the scope of the project’s terms of reference.

Choice of risk reduction option

Engineering approaches and solutions were the primary focus of risk-reduction measures considered by the team, targeting different types of river-crossing structures, such as causeways, fords and different types of bridges. The team had also decided not to do any significant realignment of the existing road inland as recommended in the Cardno Acil report (2010b), although the instability of the soft alluvial soils, which may necessitate realignment inland by about 1.5 km, was acknowledged. This adaptation measure was not explored because of concerns particularly about land tenure issues (Tony Teleford, Cardno Acil, pers. comm. June 2011). Risk-reduction measures did include some minor road realignments on land belonging to the same customary landowners, as well as drainage improvements, scour protection and some river training. The team had, however, noted but not pursued, the need to also pursue non-engineering climate adaptation strategies. For example, better land management included minimisation of the impacts of commercial logging practices, deforestation, and reforestation (Cardno Acil 2010 b).

4.4.2 Choice criteria: acceptable threshold

The choice of the risk-reduction and CCA measure was based on a predetermined minimum risk tolerance threshold, assessed 'by serviceability [of the roads] in floods arising from high intensity storms' and 'as far as economically feasible' (p. 11 Cardno Acil 2010). For each of the physical structures, a decision was made about the level of risk threshold that could be tolerated, taking into account the magnitude of flooding events assessed, using hydrological modelling discussed above (Q_2, Q_{10}, Q_{50}, Q_{100}), modelled flow velocities, as well as expected flood levels for particular streams and rivers (see Table II.5, Cardno Acil, 2009). Taking into account the design of structures required to withstand different magnitudes of rainfall events, and acceptable threshold levels, engineers then identified three engineering project designs, in addition to the 'do nothing option' as discussed below. Given the dynamics of the rivers and streams and associated low-lying landscapes, it seems that the cost of particular acceptable risk-tolerance threshold was implicitly considered when deciding on which level of the acceptable threshold would be used for the river- and stream-crossing structures along the Poha–Naro road.

Figure 16 Maladapted Causeway at Tomba Stream which effectively dammed the stream, resulting in downstream erosion and structural failure during extreme flood events

Before flood (2008) *After flood*

(source: Cardno Acil 2009)

The project team considered three engineering project designs in addition to the status quo. These reflected alternative design structures that could withstand different magnitudes of rainfall and flooding events, and acceptable threshold levels. With the acceptable risk tolerance threshold identified, some cost implications of different design standards were revealed.

The four SIRIP 2 design options, A, B, C and status quo, were then subjected to financial and economic CBA (Table 25). Costs considered included the capital costs of the structures, operation costs and respective regular maintenance costs. Benefits of the upgraded road infrastructure were assessed in terms of savings in regular maintenance and repairs and benefits of maintaining access; the loss in earnings to communities in the immediate vicinity of the road avoided by having structures under floodwater; and/or breaks in the river crossings, preventing movement of vehicles and people. Such benefits were assessed using field traffic surveys; social survey of communities serviced by the road and the savings in repair of flood-damaged structures (Cardno Acil, 2010).

4.4.3 Cost Benefit Analysis

ADB's internal economic criteria for accepting a project suggests that a project may be considered to be economically efficient if the EIRR exceeds the relevant opportunity costs of capital; ADB's guidelines suggest an opportunity cost of capital of 12 per cent.

Based on the economic assessment and using economic efficiency as criteria, the SIRIP 2 sub-project team selected Option B as the economically feasible road-improvement option. Option B structures were designed to tolerate at least 1-in-2 year flow; and for some structures during 1-in-10 year events vehicles with higher clearance could pass through, even though some flooding of the structures may occur. Option B gave the highest EIRR (Table 25).

Table 25 Economic evaluation of the increased level of threshold tolerance under options A, B and C compared with the 'Do-nothing' option

Option	Do-nothing	A	B	C
	Emergency repairs only Major damage and need for repairs expected in times of heavy rains Maintenance costs expected to increase annually by at least 5 per cent	Restore to accommodate 2-year ARI flows	Allow at least the 2-year ARI flow Expect some overtopping during 10 years ARI event, but expect to maintain connectivity for higher clearance vehicles	Similar to Option B Offers a greater proportion of infrastructure designed to allow 100-year ARI flows
PV cost	$6.84 million	$12.52 million	$15.93 million	$20.88 million
Net PC cost (compared with Do-nothing)		$5.62 million	$9.10 million	$14.05 million

PV benefits (compared with Do-Nothing Option)		$11.96 million	$23.18 million	$23.93 million
NPV		$6.28 million	$14.09 million	$9.88 million
EIRR (%)		28.1%	30.8%	20.5%
BCR		2.1	2.5	1.7
Source: Table 5.1 in Cardno Acil (2010)				

It is against Option B that the effects of projected changes in precipitation due to climate change structures were subsequently assessed.

4.4.4 Cost–benefit analysis of climate-proofed measures

Climate change was not initially included in the project design despite the generally recognised need for climate proofing of infrastructure that has a long lifespan (ADB, 2005). Changes to the infrastructure design were considered following another major flooding event in 2010 and before the construction work had actually begun.

A preliminary climate change assessment was commissioned. The preliminary assessment relied on the Fourth Assessment Report scenarios for the South Pacific region and projected changes in precipitation, temperatures, cyclones and sea-level rise to draw general conclusions about-climate change scenarios.

In the absence of detailed climate change predictions, the SIRIP 2 sub-project team assumed climate change would result in increases in rainfall intensities of 20 per cent in large storms over the 20-year planning horizon. For frequent storm events, such a 1-in-3 month rainfall event, it is assumed that the frequency will remain unchanged. Using these assumed climatic parameters, the team then estimated the expected frequency of a given design flood over the 20-year planning horizon. For example, under the assumed increase in rainfall intensity under projected climate change, the current 10-year ARI, design flood would be equivalent to a 5-year ARI design flood. Based on these assumptions, and using 6-hour rainfall intensities from the engineering report, the existing rainfall intensities were converted to a 2-year, 10-year, 50-year and 100-year ARI design event.

Using these general projections, engineers identified possible consequences for the road infrastructure and the changes in the engineering designs that were required (Cardno Acil, 2009b). Specifically, for each physical infrastructure, engineers determined the types of actual adjustments needed to be made to the initial design choice (under Option B) of road repairs and improvements, using different levels of acceptable thresholds. Thus, for example, in the case of Sasa Ford (#13 the Option B was designed to withstand 2-year events, or Q2). Under the climate change scenario, the Sasa Ford design was increased in standard to withstand a 1-in-10 year precipitation and flooding event (or Q10), thus ‘climate proofing’ that ford. In comparison, the Selwyn Ngautu Ford’s design quality was increased from Q2 to Q20. In the case of structures that were already designed to withstand a 1-in-10 year event, such as Sasa washout, no changes were required to cater for the projected increase in threshold tolerance. This was done for all major structures.

Such threshold decisions would have reflected considerations of the projected changes in weather patterns, changes in flooding risks and likely impacts on the road and crossing infrastructures, and potential costs of repairs and maintenance.

Cost benefit analysis

The economic net benefits of the climate-proofing-related changes to Option B were then compared with the net benefit of the chosen Option B without climate proofing. As the CBR was greater than one and the EIRR was estimated to be 14.4 per cent (that is greater than 12%, considered to have been the acceptable threshold); the decision to proceed with the changes in the engineering solutions was made (Table 26).

Table 26 Economic cost benefit analysis of Option B with higher design standard, and no increase in climate risk

	Option B	**Option B with climate risk consideration**
PV cost	$16.10 million*	$19.23 million
PV benefit of CCA		$3.90 million
NPV		$0.774 million
EIRR%		14.4%
BCR		1.2
Source: Table 5.9 Cardno Acil (2010b) *This value differs slightly from the figures quoted in Table 28, due to some changes made to design of some key structures in the original Option B.		

Sensitivity analysis did not change the conclusion of Option B-CCA response as the preferred strategy. A sensitivity analysis was done by testing a 10 per cent and 30 per cent increase in rainfall intensities in 20 years' time (i.e. by 2030). This analysis indicated that, should changes in the rainfall intensities increase by only 10 per cent in 20 years' time, then the EIRR would be 10.8 per cent, which is still considered to be within the acceptable range (BOM and CSIRO 2011c).

Potential impacts of sea-level rise, including storm surges, were not factored in the risk reduction consideration; although some 'sea-level rise' information has been collected since 1991 in the Pacific, including for the Solomon Islands (http://www.bom.gov.au/pacificsealevel/project_info.shtml).

These observations raise the question about what effect a comprehensive integrated risk assessment would have had on the risk thresholds and the engineering standards adopted for the structures at each of the rivers and streams along the main road, and the effects these would subsequently have had on the costs and benefits and the choice of repair and road improvement options.

4.4.5 Key lessons from the SIRIP 2 sub-project

This review of SIRIP 2 sub-project climate-proofing case study highlights several issues of relevance when considering social and economic assessment-based CCA decisions.

Proactive adaptation

While a proactive adaptation strategy may increase the costs of a project, it can still be more cost efficient than retrofitting. This was despite the fact that climate proofing of repairs and an improvement project were considered after the project had been approved, following the 2010 flood event, but before construction had begun. The benefits of proactively climate proofing road infrastructure, as compared with retrofitting in this project, is consistent with other assessments commissioned by ADB, Kosrae for example (ADB 2005).

Integrated risk assessment

The SIRIP 2 sub-project project systematically followed key steps involved in the risk management cycle. The focus of the assessment was on rain-induced flooding risks and its effects on crossing structures designed for various rivers and streams. Other geophysical systems dynamics and their impact on river flow, flooding and hazards were only partially considered.

An integrated climate risk (hazard and vulnerability) assessment is relevant when weather and climate conditions generate multiple hazards, as is the case in the Guadalcanal SIRIP 2 project area. Current weather and projected climate change risks in the Guadalcanal region are a product of the weather and climate conditions and the sensitivity of the physical/ecological system in the area that drives the scale and scope of local hazards and vulnerability (as well as the sensitivity of the local communities and assets). Such an integrated assessment is required to not only identify current and projected risks, but also to identify and assess alternative risk-reduction measures, chiefly where local physical/ecological systems are sensitive to changes in weather and climate conditions.

The robustness of science or impacts-first-based risk assessment implicitly adopted in the SIRIP 2 sub-project to address current weather-related risks depends on the underlying data. Where data and models are borrowed from other countries, the robustness of the risk assessments could be improved by triangulating those models against known scientific information in published and/or grey literature produced under other development projects. Where possible, key modelling parameters could be adjusted by comparing information from other sources with the available data. This could have been easily done, as there are many sources of data information that could have been sourced from within the government and from modelling results from other detailed hydrological assessments in the country (Table 27).

Information systems need urgent strengthening. A national system of climate information services, linked to a geo-referenced data system, could encourage access to, and use of relevant data and information maintained by different government agencies and ministries to inform CCA decisions. The recent decision by the Solomon Islands Government to task the newly amalgamated Ministry of Environment, Climate, Disaster and Meteorology to also provide key weather and climate data services is a first step. In conjunction with the Climate Change Working Group, this would go towards strengthening knowledge-based decision-making.

Given the level of uncertainty associated with climate change, not only because of difficulties in downscaling GCMs, but also because of uncertainties associated with limited scientific understanding about dynamics of the local physical/ecological systems, sensitivity analysis-based approach adopted in SIRIP 2 sub-project provides a better information base to support key decisions.

In the presence of limited empirical data and scientific understanding, translating the effects of the climate change on hazards and vulnerability conditions can be difficult. In addition, it can be equally challenging to identify relevant solutions to address the respective vulnerability conditions. All that may be possible is some qualitative assessment, and making some decisions based on expert knowledge and experiences, using tools such as multi-criteria analysis.

Although it acknowledges that significant mainstreaming has been included in national economic development policies and sectoral policies, there remains an institutional weakness in implementing these policy commitments. Climate risk considerations in the project development and evaluation process, including environmental and social impact assessments, could be made an explicit requirement for all major projects, taking advantage of existing development and environmental legislative requirements. This, together with a fully functioning newly established Climate Change Working Group, consisting of departments, development partners and NGOs and supported by key technical working groups, would strengthen knowledge-based CCA decision-making.

Key recommendations

A systematic application of the hybrid 'impacts-first and vulnerability-first' assessment approach-based risk assessment helps identify what can be empirically assessed and qualitatively described. Then using the CBA framework, different costs and benefits of current risks and of risk reduction through adaptation measures can be identified and quantified where possible. Where quantitative estimates are not feasible and there are multiple objectives, qualitative information and expert judgements can be used with quantified economic efficiency measures to inform choices by using a multiple-criteria approach to decision-making.

As a first step towards this, climate risk considerations in the project development and evaluation process, including environmental and social impact assessments, could be made an explicit requirement for all major projects, taking advantage of existing development and environmental legislative requirements and decision-making processes. The SIRIP 2 sub-project assessment also emphasises CCA decision-making processes. This could be strengthened by making robust knowledge-based climate risk and risk-reduction assessment explicit requirements of all externally funded projects, and strengthening the interface between the government agencies and development partner processes.

In conclusion, this assessment of the SIRIP climate-proofing project in the north-western Guadalcanal highlights key challenges faced by a government when addressing a cross-cutting issue such as climate change with requirements such as:

- clear establishment of the relationship between national development policies, sectoral goals and programs and outcome-focused projects operationalising government development policies
- cross-sectoral collaboration and coordination of efforts across government agencies
- government policies and decision-making processes that reflect an understanding of the dynamics of not only weather and climate systems, but also the dynamics of social and economic systems affected by weather and climate hazards
- community needs and aspirations, their vulnerability and perception of current and projected risks, and their risk tolerance threshold
- integrated climate risk assessment and risk management that requires a number of different sets of data collected and maintained by different agencies, as well as experiential knowledge of the local communities in DRM
- institutional and human capacity and tools to undertake hazard mapping, and vulnerability, risk assessments and risk management decisions
- making robust knowledge-based climate risk and risk-reduction assessment an explicit requirement of all externally funded projects, and strengthening the interface with development partner processes.

Future infrastructure development projects in the Solomon Islands would no doubt benefit from the strengthening of institutional and technical capacity in-country. Other benefits are to be gained from ADB's strengthened infrastructure project development processes that involve integrated climate change risk considerations, and mandatory climate risk criteria in project selection, together with economic, environmental and social selection criteria.

Following: Table 27 Climate proofing of road infrastructure, SIRIP 2 sub-project, Western Guadalcanal, Solomon Islands

Examples of information needs	**Examples of relevant disciplinary skills**	**Typical source of data/information** ***sources of data used in the case study**
Climate forecasts • Average and trend in o precipitation forecast (rain, drought, and humidity patterns) o temperature o weather extremes and frequency of extreme events • Uncertainties	Meteorologists and climate modelling	Published and grey literature – global and sub-regional modelling results Time-series historic weather and climate data from meteorological services* Climate modelling institutes Empirical probabilities from modellers Professional /Expert judgement about confidence statement*
Relationship between rainfall, run-off, stream flow and flooding	Hydrologist and rainfall–run-off modellers	Climate services (meteorological services; climate-modelling institutes) Modelling results*
Landslides, debris mat	Land use specialists, and geologists; environmental impact analyst	Geo-referenced past hazard records Soil type and sensitivity to extreme rainfalls Grey and published literature
Flood plains dynamics	Geologist, geographer, ecologists	Geo-referenced past hazard records Modelling results Grey and published literature

Effects of rainfall, flooding, debris mat and landslides on roads, bridges, culverts and other physical infrastructures across rivers and streams	Hydrologist Civil engineers	Modelling results
Impact of flooding and sea-level rise on road infrastructure	Government Ministry of Infrastructure Development National disaster management officers Damage and loss assessment specialists (disaster economists)	Time-series historic record of road infrastructure impact of different categories of weather and climate events Published and grey literature
Flood inundations and impacts on communities (social impacts) • impacts and exposure to disasters • loss of lives, assets, crops, and household wellbeing • incidence of waterborne and insect-borne diseases • social (poverty) and human health impacts • economic and employment impacts	National disaster management officers Damage and loss assessment specialists (disaster economists) Medical researchers , district/hospital nurse and other health department officials	Time-series historic record of the impact of different categories of weather and climate events Published and grey literature (for Solomon Islands of comparable situations elsewhere Government records of disasters, post disaster economic wellbeing Government health records and or hospital/district nurse records Post disaster surveys by National Disaster Management Office, Ministry of Infrastructure and Development Specialised context specific surveys*: • field traffic surveys

		• social surveys – community and household survey • household income and expenditure surveys • employment data
Costs of treating insect and water-borne diseases	Researchers/economist	Government /local (private) pharmacies/health clinics/district nurses
Engineering standards and flood impact thresholds	Civil engineer	Modelling relationship between flood category and design standard for flooding tolerance (including impact of debris mats etc.)*
Economic engineering costs of road infrastructure (capital, maintenance)	Infrastructure economist	Domestic and international prices, adjusted for tax and subsidy* Provincial and local government data on road infrastructure
Net benefit of road improvement sub-project 'with and without' climate proofing, considering uncertainties and under different climate scenarios	Transport economist/CCA economist, working closely with engineers and climate scientists	Cost and benefit measures determined using above information, sensitivity analysis

5. Mainstreaming of climate risks at national and sectoral levels: some observations from the Pacific

The vulnerability-first approach has been the cornerstone of national- and sectoral-level policy, planning and programming of climate risk management in the Pacific. Climate risk management decisions in the Pacific are generally considered with regard to current DRM and CCA, focusing on the aggregate level issues and supported by broad considerations of hazards and vulnerability across the country. At the medium- to long-term national sustainable development plan level, climate and disaster risk management goals feature in some countries, such as the Cook Islands and Nauru.

With the assistance of SOPAC (SPC) and SPREP and development partners, such as AusAID, ADB, UNDP and the World Bank, much attention in relation to DRM and CCA has been on supporting countries to produce their national action plans and priorities for DRM and CCA. This has been guided by, respectively, the Pacific Disaster Risk Reduction and Disaster Management Framework for Action, 2005-2015, and Pacific Islands Framework of Action on Climate Change (PIFACC) and National Communications Guidelines produced by UNFCCC.

National action plans for DRM have been developed as a country's medium-term DRM plans that identify strategies and actions, targeting a country's vulnerability to natural and human-made disasters. A conventional policy planning process was adopted, involving situation analysis of hazards and disaster risk, followed by multi-stakeholder workshops for inputs from communities, government sectoral agencies, and NGOs to identify priority hazards and risks to be targeted and priority strategies for addressing those risks. Essentially problem-solution tree analysis was used to guide the workshop participants through the process of risk assessment and risk management strategies. This process exhibited key elements of the Comprehensive Hazard Assessment Management (SOPAC 2002). Much of this was based on qualitative assessments undertaken by national disaster management officers and supported by technical persons from regional organisations and using whatever country-specific empirical data and information was available.

Under climate change, adaptation priorities were initially identified during the Initial National Communication reporting process, guided by the guidelines provided by the UNFCCC secretariat. In order to inform these adaptation priorities, countries used past hazard data in addition to assessment of broad aggregate level social and economic information on their current disaster risks. Future hazard conditions were identified from available global level climate change scenario information together with any unpublished regional- or national-level information available from organisations such as NIWA, CSIRO or the National Oceanic and Atmospheric Administration. Projected impacts were assessed and identified by special technical working groups established as part of the process used to prepare National Communication reports to UNFCCC (such as Vulnerability and Adaptation Thematic Working Group in Nauru). A slightly more systematic approach to the development

NAPA was adopted in least developed countries, using the NAPA guidelines prepared by the UNFCCC Secretariat (UNFCC, 2002). The preparation of the NAPAs included: synthesis of available information, participatory assessment of vulnerability to current climate variability and extreme events and of areas where risks would increase due to climate change, identification of key adaptation measures as well as criteria for prioritising activities, and selection of a prioritised short list of activities. NAPA's focus was on urgent and immediate needs, those needs for which further delay could increase vulnerability or lead to increased costs at a later stage (http://unfccc.int/national_reports/napa/items/2719.php).

Sectoral level impact assessments had usually been qualitative, with technical working groups drawing on sector status reports prepared for the adaptation planning process. Prioritisation of key sectors to target for adaptation effort has implicitly followed the CBA process outlined above. In some countries, priority sectors were identified, using expert judgement of the technical working groups. For example, members of technical working groups in countries such as Vanuatu ((Vanuatu Government National Advisory Committee on Climate Change 2007), and Nauru (Nauru Department of Commerce Industry and Environment, 2010 - draft) used specific weighted scores for sectors based on available quantitative information about hazards, social and economic conditions, expected benefits (or avoided costs) of adaptation, and multi-criteria analysis to arrive at the nationally important sectors under their National Climate Change Adaptation Framework. However, such systematic assessment, scoring and multi-criteria analysis is not evident in the identification and implementation of CCA projects on the ground, as discussed below.

Parallel efforts for DRM and CCA

The two streams of disaster and climate risk management have generally been pursued in parallel in the region, both at the national and regional level. This is also the experience internationally, although substantial efforts have been made in the last one to two years in the Pacific to streamline and link activities more strategically. For example, in August 2011, the regional Pacific Disaster Platform agreed on a road map for a joint CCA/DRM strategy that will be presented to the leaders for consideration. At the country level, there is arguably little coordination or integration of the two approaches, neither between institutions supporting DRM and CCA. This also applies during the implementation of policies, plans, programs and activities, and is even more marked in the approaches and tools used in respective decision-making processes (Hay, 2009a; Hay, 2009b; Gero, Méheux et al., 2011). This is despite both instruments being based on essentially the same risk management framework and guided by similar risk management principles (Hay, 2009b). Some PICs have recently moved towards integrating DRR and CCA, by producing a joint national action plan) for climate change and DRM (Tonga and RMI), or by using a common government agency platform under which both the instruments are implemented (such as in Palau and the Cook Islands.) Organisationally, too, countries are attempting to coordinate DRM and climate change risk management by bringing together the two national offices either under a national climate change advisory committee (as is the case in Vanuatu), or under the same Ministry, like in the Solomon Islands (see Solomon Islands case study for details).

Effort is being made to develop sector plans that integrate climate change considerations (Table 28). For example, the Solomon Islands and Palau are both working on developing national climate change policy for their agricultural sectors (PACC Mid-term Review, Port Vila, 1–5 August 2011). On the other hand, Tuvalu and Nauru are developing their national water policies/plans under their PACC projects, adopting stakeholder-based workshops. Specific methodologies for the sectoral level mainstreaming are being developed through a 'learning by doing' in each country; this process could though be greatly enhanced by more systematic adoption of risk management policy cycle.

Table 28 Example of CCA measures identified for development as part of the GEF-funded PACC projects

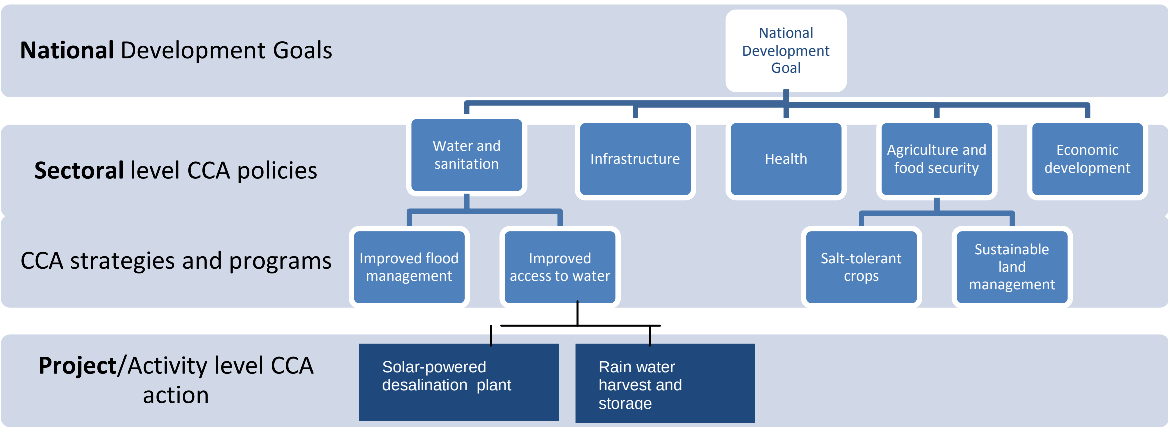
Countries	Target sector	Policy	Sector plan	Adaptation activity
Fiji	Food security (infrastructure)		Guidelines for climate proofing drains and drainage	Drains and drainage network redesign with respect to increased rainfall and sea-level rise Revised drainage Act
Cook Islands	Infrastructure	Proposed RM-CCA-RE policy		
Nauru	Water	Nauru water, sanitation and hygiene policy, reflecting climate change considerations	Drought management strategy plan under the disaster risk framework Water, climate change action plan	Salt water reticulated system, solar water purifiers Rainwater harvesting catchments
Tonga	Water	National water policy	National CCA action plan for the water sector	Water supply
Tuvalu	Water	National climate change policy	National water policy revised to include climate change considerations	Water harvesting and storage
Source: SPREP (2011)				

Interface between national and sectoral policies, plans and strategies

Normally, if a systematic approach is adopted during the policy planning and programming process, regardless of the entry points and the sequence of their development, one could expect to find a direct relationship between, for example, national development goal, sectoral plans and policies and specific adaptation activities on the ground (Figure 17). From the case studies undertaken and through analysis of a selected number of additional examples a number of conclusions have been drawn.

The Solomon Islands medium-term development strategy includes an objective 'to ensure sustainable utilisation and conservation of natural resources, protection of the environment and successful adaptation to climate change'. It also notes the implementation of strategies to ensure effective mitigation and adaptation to climate change' (Solomon Islands Government, 2008).

Figure 17 Climate change adaptation measures – relationship between national development goals and sectoral-level CCA measures – policies, strategies and actions



However, the relationship between goals, sector objective and activities is not always clear. In Nauru, for example, a link between national development goal and the sector objectives can be found, but not necessarily between the sector priorities and on-the-ground projects implemented under the PACC project (Table 29).

Table 29 National development goal, sectoral plan and priorities and on-the-ground project/activities identified by Nauru

Output of climate change mainstreaming	Climate change adaptation measure
NSDS goal in relation to water and sanitation	Provide a reliable, safe, affordable, secure and sustainable water supply to meet socioeconomic development needs
Water sector plan and priority sector strategies	National Water Plan 2001 priority actions identified included:
	Establishment of a secondary desalination plant, extraction from the fresh surface layer from the groundwater lens (if possible)
	Installation of groundwater monitoring wells and clear delineation of the extent of underground resources so as not to risk over-pumping
Examples of an adaptation activity	PACC:
	Solar-powered desalination at the household level
	Salt water reticulated system
	Water harvest and storage

Source: Nauru Department of Commerce Industry and Environment (2010 - draft); SPREP (2011)

Similarly, the National Transport Plan in the Solomon Islands clearly articulates the need for climate proofing infrastructure as highlighted in their NAPA. But there are no specific strategies aimed at operationalising this (see detailed case study on Solomon Islands and climate proofing), and it notes that 'currently, engineers are designing ridges and wharves to withstand extreme events caused by climate after past experiences and... there is no clear direction of taking future climate change impacts into account' (Government of Solomon Islands, 2010).

Even at the national and sector development plan level implementation, a direct relationship is often difficult to find. For example, in the Cook Islands, the National Development Goal 6 is for a safe and resilient community. However, with a few exceptions, little in the NSDP relates specifically to enhancing community resilience to natural disasters and climate change (Hay, 2009a). Even though the NSDP in the Cook Islands calls for implementation of priority actions related to climate change that are relevant to land, coastal zone, freshwater and marine resources, many adaptation projects already being implemented, including PACC, focus on water, waste and sanitation and infrastructure (Hay, 2009a). In Vanuatu, despite recognising the need 'to build climate change issues into national development plans', its Priorities and Action Agenda (PAA) for Vanuatu 2006–2015, does not cover the issue of CCA in any other area of the document, except passing reference to it in the section on infrastructure. Nor is the issue of DRM given the treatment that it did in the Supplementary PAA attached to their previous PAA, 2005–2007 (King, 2010 - draft).

There also seems to be a disconnect between CCA plans and policies and the identification and implementation of 'on-the-ground' projects. A key feature of the locally focused on-the-ground CCA initiatives is that they are largely occurring in a policy vacuum with little budget support (Hay, 2009a). Such projects are often driven by the needs of the local communities with support from bi- and multi-lateral support, but such support is often without being an integral part of national policies, planning and budgetary processes. Because of the weak or missing linkages at the policy level, and capacity constraints, governments are also missing out on opportunities to ensure that the national-level enabling environment is supportive of the adaptation efforts at community level.

The effectiveness of CCA measures could be improved in the priority sectors if greater attention were paid to mainstreaming climate change considerations into sector policies and strategies, and these prioritised programs were then implemented at the community and project level (Wickham, Kinch et al., 2009).

6. Conclusion and way forward for strengthening informed climate change adaptation decisions in the Pacific

To strengthen knowledge-based adaptation decisions, several areas require attention across all the PICs. However, country-specific priority and entry points for this strengthening may depend on a number of factors. These include the status of baseline data and past research, institutional capacity to make informed decisions, the urgency for addressing development and DRM needs and dealing with the challenges of climate change, and the relevance of strengthening a foundational-enabling environment.

6.1 Linked national-sectoral-project process

From the case studies and selected additional examples, a cascading set of processes is suggested for strengthening knowledge-based and linked national and sectoral policy and planning and community/project level risk management decision-making processes. This process also recognises uncertainties associated with climate change, impacts and adaptation responses, limited baseline information and capacity (summarised in Figure 18 below).

At the policy level, integration of climate change considerations should normally follow the policy cycle process, whereas at an individual activity level, project cycle-based iterative risk management is appropriate. A seven-step decision-making process could be used across all levels, using the best information available, including a step for the identification of relevant decision-criteria to inform adaptation choice. The policy/project cycle usually follows the key steps of: context analysis, risk identification and assessment, response identification and analysis, adaptation option assessment, design, implementation, monitoring, evaluation and feedback. Some of these steps may be combined during implementation.

For synergistic outcomes and efficient use of limited resources, one would expect a direct relationship between adaptation decisions made at the national level (national priorities), sectoral level (sector policies, objectives and priority programs), and community-based and other projects will put into effect sector policies and strategies.

Each layer of adaptation decisions, at the policy/sector program and community/project levels, would be guided by a hybrid of vulnerability-first and impacts-first approach to CCA decision-making. This would recognise climate risks and associated uncertainty, and an explicitly agreed upon relevant decision-making criteria to inform adaptation measures. This would be collectively agreed to by relevant stakeholders following current hazard and vulnerability assessment.

6.2 Knowledge-based decision-making processes

Knowledge-based policy and project cycle-based decision-making processes can help systematically assess a number of factors. These are exposure, vulnerability, risks, and the risk reduction benefits of identifying adaptation measures that address the desired goals across national and sectoral policy and planning levels and at the project level. Technical, social and economic assessments are integral aspects of making informed decisions about CCA across all levels of decision-making, even if not all benefits and costs may be quantifiable. Country-specific priority and entry points for such strengthening may though, depend on and institutional capacity to make informed decisions and the current status of baseline data and past research.

Risk analysis is the analysis of risks of potential impacts of climate change without risk management. It involves determining hazards exposure and vulnerability; identification of management/adaptation measures and associated costs based on potential adaptation activities and alternatives and their respective costs; and analysis of risk reduction, that is, the estimated benefits of reducing risks.

Each stage of adaptation decision-making will be informed by knowledge drawn from interdisciplinary and integrated risk and risk- reduction assessment of adaptation measures and stakeholder experience.

Vulnerability assessments help us understand the potential impacts of climate change, which depends on the hazards, exposure and vulnerability. Vulnerability assessment tools based on rapid rural assessment and SLA framework are commonly used to identify and assess people’s sensitivity to hazards of a specific intensity and scale; and to understand the local-level risks, risk management and resilience at the household and community level. Several different tools are available for risk and risk management assessment, including vulnerability and assessment tools, such as CV&A, SLA, combined with key disciplinary-based detailed analysis of hazards, impacts and responses in environmental, economic and social systems.

A context-specific assessment of a 'holistic systems' approach would need to be adopted to identify appropriate risk reduction measures for those risks. Without such an approach, adaptation measure may not fully address climate proofing and building of resilience goals.

Economic CBA is an established tool for identifying the effects of projected climate extreme and variability across ecological scales, economic activities and communities and assessing economic costs and benefits of an activity for making choices. Economic efficiency measures, such as NPVs, BCR and EIRR are used to compare and select a preferred initiative, particularly when there is pressure to achieve highest benefits with minimal investment. If the probability of events and impacts can be quantitatively determined, the benefits of adaptation can then be determined by comparing expected economic present values associated 'with' and 'without' adaptation. If the probability of events and impacts are not known, then sensitivity analysis is relevant to reveal possible trade-offs that may be necessary, including in the PICs. There are several challenges in using CBA to identify economically efficient adaptation measures, particularly as not all benefits and costs of risk reduction are identifiable, quantifiable and quantified in monetary terms. This is largely due to due to limited baseline data in the Pacific. Despite the constraints, the CBA framework aids in systematically identifying, evaluating and considering all, impacts and their costs and benefits, rather than it providing an exact economic value of an adaptation measure.

Informed CCA decisions would be based on a system analysis of changes in climate averages and variability in key parameters, the drivers of vulnerability and exposure, and incorporate a context-specific integrated analysis of climate risks and climate adaptation measures, including social and economic cost and benefit assessments. Such analyses will draw on many different disciplines and traditional knowledge. They would involve backward assessment of past disasters to inform the responses to climate change, or forward-looking assessments based on scientific modelling. Different types of technical analysis underpinned by good baseline data are required to inform CCA decisions, and the type of technical analysis will vary according to the type of hazard of concern and the priority sector(s) being affected, as well as the pathway through which the impacts are realised [case studies 4.1, 4.2, 4.3, 4.4; tables 13, 17, 24].

Adaptation choices would be made based on not only quantified economic efficiency measures where possible, but also on qualitative and quantitative assessments of social and economic impacts of CCA. Other criteria of particular relevance in the Pacific context of national development needs, including, for example, urgency of addressing immediate development needs, need for institutional foundations to support future decisions, technical and economic feasibility and the effectiveness of a measure in the light of uncertainties.

6.3 Summary of challenges in the Pacific

In the Pacific, vulnerability-first assessment has been by far the most commonly used adaptation planning approach at the policy and project levels, albeit implicitly. These though have also faced significant challenges, as illustrated by the four case studies examined in detail in this report.

Data limitations, capacity constraints and uncertainty have been the main constraints in the use of impacts-first, and to a lesser extent in the vulnerability-first planning approach. For the impacts-first approach, researchers are forced to adopt different degrees of quantitative assessments based on assumptions about climate change scenarios, impact scenarios as well as broad generalisations about adaptation measures, as well as the potential benefits of adaptation assumptions. The impacts-first approach is also difficult to use in most countries as climate change modelling expertise is limited but, more importantly, suitable climate change models are not available for the region, least of all for countries. Nor is there baseline data to inform such modelling exercises with a degree of confidence. Furthermore, for sectoral level social and economic impacts, better technical information and the country-/context-specific data needed is generally limited, or at best and in most cases not available, as illustrated by the case studies.

Institutionally, too, risk assessments are often not integral to the decision-making process of the government. Policy and project processes are often not systematically followed, and explicit use of a disaster risk or climate change lens for identifying appropriate adaptation measures is even less likely to occur.

Adaptation decisions have been constrained largely due to limitations in data, and limited capacity to use the robust technical assessments required for objective decision-making processes. Government-led and community-based projects are often implemented ad hoc and in a policy vacuum. Such projects are often stand-alone activities with limited scope for sustainability once the project funds are exhausted [as discussed in 3.3].

In-country capacity in technical assessment-based decision-making processes is often limited, even in terms of adequately evaluating assessment reports prepared by external consultants. Many externally funded community-based adaptation projects, implemented by community-based organisations and local NGOs, have adopted some elements of the vulnerability-first assessment approach, starting with community-based vulnerability assessments, using variations of CV&A tools. It is difficult to determine the extent to which project teams followed the vulnerability-first process, as the steps followed are often not documented. Personal observations of recent CCA projects in the region though, suggest that specific project activities do not appear to have been selected based on V&A assessments (i.e. risk analysis or risk management assessment and prioritisation). This is confirmed by examples raised in Section 3.4.1 and the detailed case studies examined here (case studies 4.2, 4.3).

Systematic social and economic assessment of projects (where such assessments are a requirement of donor funding) is not common in the region, and economic CBA of projects and policies is almost non-existent, except for those that are large-scale and externally funded such as infrastructure projects. Many DRM and CCA project documents make reference to their economic and social benefits, but empirical information to support such statements are often limited, doing a detailed ex-ante or ex-post probabilistic CBA is even less likely. Detailed CBA in the Pacific is often difficult because of factors such as limited empirical baseline data, high degree of uncertainty concerning future climate scenarios and impacts. In some adaptation projects, CBA could only be done using a deterministic CBA together with a series of sensitivity analysis, as illustrated by case studies on food security, water security and infrastructure climate proofing. Detailed CBA of projects may though, not always be critical to make informed choice, as illustrated by the relocation case study.

Where detailed CBA of risks and risk reduction is warranted, robust scientific information about climate change, its impacts on natural systems and their impact on economic activities and societies is critical. As a start, a holistic systems perspective would provide a context-specific all-hazards understanding of risks and would help identify appropriate, hard and soft adaptation measures for consideration and further assessment. Without such an approach, adaptation measures adopted may not be effective, and in some cases may even be a maladaptation.

Economic efficiency measures for climate adaptation projects may not always be sufficient to prioritise and choose between adaptation measures, and particularly when decisions are required to inform a portfolio of adaptation measures. The choices of adaptation measures for national development will also guided by the explicit acknowledgement of multifaceted climate risks and the interaction between development and disaster outcomes. Multiple criteria that would guide the selection may include not only the usual economic efficiency criteria but also others that recognise current development needs, current disaster risk as well as increasing risks under climate change and associated uncertainties, particularly when resources are limited [as discussed in 3.5.2, case studies 4.1, 4.4].

Where multiple objectives, and/or data and capacity constraints are found, decision-makers could progressively move from qualitative to semi-qualitative to quantitative assessment (if adaptation and management response warranted detailed assessment). As a minimum, experiences in the Pacific suggest that broadbrush, largely qualitative risk assessment is likely to be more suitable at the national planning level, where key policy decisions need to be made for national development [case study 4.5]. A more detailed level of assessment would generally be required at the sector level, when identifying specific sectors to target, as well as when developing detailed sectoral-level strategies and programs for action. A detailed quantitative CBA of adaptation options is generally useful where the choice between adaptation options that require large investments and decisions will be improved by detailed quantitative assessment of risks and uncertainties, particularly where the adaptation measure has a long shelf life.

6.4 Key recommendations

To strengthen knowledge-based adaptation decisions, several areas need particular attention across all the PICs from the case studies and selected additional examples. The country-specific priority and entry point for such strengthening may though, depend on the current status of baseline data, and past research, and institutional capacity to make informed decisions. In addition to other factors such as the urgency of addressing current development and DRM needs and the challenges of climate change, and the relevance of strengthening the foundational enabling environment.

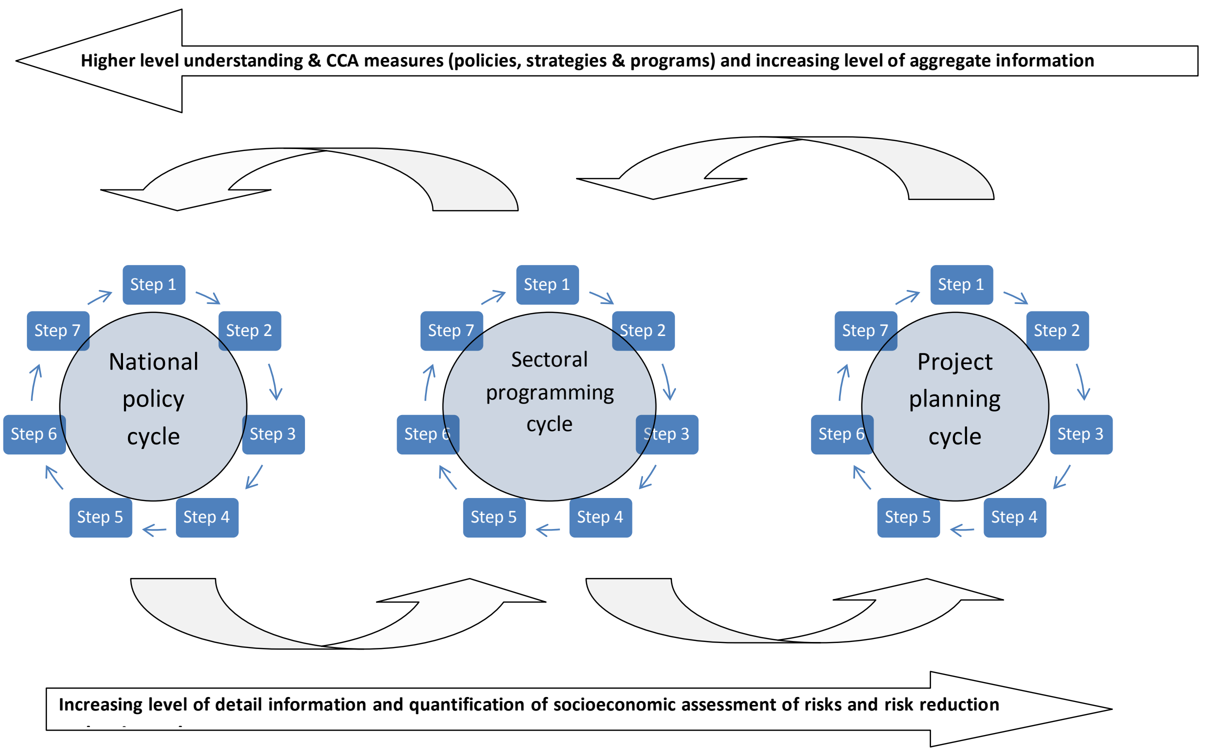
At each level of adaptation decision, decision-makers could be encouraged to systematically adopt a seven-step risk management cycle-based process. This would be founded on a stakeholder-based hybrid impacts-first and vulnerability-first technical planning approach, adopting a systems view of drivers of vulnerability and exposure. It would incorporate context-specific integrated analysis of climate risks and climate adaptation measures. Determining specific adaptation objectives to guide the choice of adaptation measures is an integral step in this process, as is the recognition that decision-makers may use iterative processes and move from qualitative to semi-qualitative to quantitative assessment as warranted.

Strengthening technical and institutional capacity to make knowledge-based decisions is required at all levels across the region, recognising uncertainties associated with climate change, risks and risk reduction potentials. Such capacity development programs need to address a wide spectrum of institutional and technical capacity needs, including:

- harmonisation of DRR and CCA plans and policies in the short term and integration of DRR and CCA decision-making processes in the medium to longer term
- integration of climate risks in policy and project cycle-based decisions-making processes
- systems understanding of the ramifications of climate change and the interactions with drivers of vulnerability and exposure as well as of the spectrum of hard and soft adaptation options available to address those climate risks
- decision-making capacity to choose adaptation measures, including portfolio of adaptation measures for national development, considering multiple criteria such as economic efficiency, other social and economic benefits and costs, and other development criteria
- economic CBA of risks and risk reduction and adaptation measures
- sustainable livelihood analytical framework and associated vulnerability assessment tools.

Figure 18 Cascading and explicitly linked CCA decision-making processes involving national policy and planning across to community/project-level risk management decisions and the information and knowledge needs

Legend: Step 1: understand social, environmental and economic context of hazards & vulnerability; Step 2: establish development goals & decision-making criteria; Step 3: identify and assess current risks; Step 4: identify CCA measures; Step 5: Assess CCA options and choose preferred option; Step 6: Project design& implement; Step 7: Monitor, lessons learnt & modify action



Knowledge-based adaptation decisions need robust data, information and knowledge drawn from across several disciplines. This assists in understanding climate science and climate change, vulnerability, social and economic impacts, and risk reduction and management measures suitable to the local ecological, social, economic and political environment.

Geo-referenced baseline information and other foundational-enabling environments urgently require strengthening across all PICs. Robust information about economic, environment and social systems and their vulnerability and exposure to climate extremes is critical for context-specific integrated assessment of risk and risk reduction-based decisions. Such environments that also need urgent attention includes inter-agency institutional arrangements to sharing of data maintained across agencies as well as to facilitate coordination of initiatives across scales and between DRM and CCA activities.

A linked regional–national climate service could be useful to provide rigorous scientific support to key in-country decisions. Such a climate service would cover climate science research, vulnerability analysis, decision support and communication; provide timely delivery of relevant information and assessments; can be used for ongoing evaluation of climate change and climate decisions; and has an easily accessible information portal that facilitates coordination of data among agencies and a dialogue between information users and providers. It would also include ‘hands on’ strengthening of a national-level decision-making process and other enabling environments that promote knowledge-based decision-making and actions, as well as technical capacity to make informed decisions.

In conclusion, the adoption of a climate risk management framework supported by the best available scientific, traditional and experiential knowledge would help strengthen systematic analysis of changes in climatic risks. It would also offer benefits to identifying, selecting and assessing adaptation measures. To encourage informed adaptation decisions, key issues regarding country-specific baseline data, analytical skills as well as institutional capacity in making risk-based policy and project-level adaptation decisions need urgent attention. Ultimately, an effective adaptation to climate change requires a national system of climate risk management supported by the best available scientific and traditional knowledge. It also requires the institutional capacity to be flexible in decision-making as new knowledge and information becomes available.

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