Assessing the vulnerability of rural livelihoods in the Pacific to climate change

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1.0 Executive summary

This report details a ten month scoping study conducted to assess the relative vulnerability of rural livelihoods across Pacific Island Countries (PICs) to climate change. The study focuses on East Timor (Timor-Leste) and 15 PICs (Federated States of Micronesia (FSM), Kiribati, Marshall Islands, Palau, Fiji, Nauru, Solomon Islands, Papua New Guinea, Vanuatu, Cook Islands, Niue, Samoa, Tokelau, Tonga, Tuvalu) (Fig. 1). This 7-page executive summary has been provided at the request of AusAID to offer an extended overview of the key issues and findings of this study. Further details are provided in the body of the report.

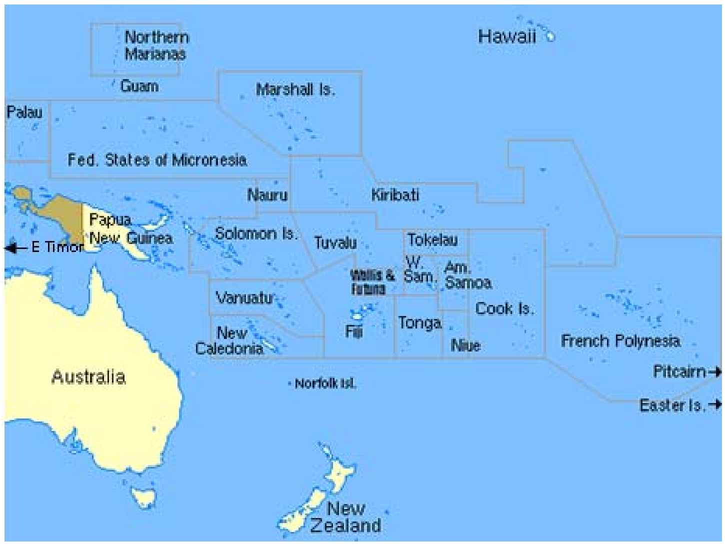

Fig. 1 PICs included in the study (source:http://www.pidcsec.org/index.asp?pageID=2145841019).

In this study we sought to synthesize existing knowledge obtained from previous assessments of the vulnerability of rural livelihood stakeholders to climate change, together with context-specific knowledge contributed from stakeholders living in and around the Pacific, and working in the area of climate change. Rural livelihoods were considered to primarily rely upon agricultural, forestry and livestock production. Whilst it is recognised that fishing activities constitute an important source of income and dietary animal protein for many rural livelihood stakeholders (Dalzell et al, 1996; Bell et al, 2009), a decision was made to concentrate the scope of the study on predominantly terrestrial activities whilst acknowledging research relating to climate change impacts on fisheries (Bell et al, 2009; Biswas et al, 2009) and more specifically on associated coral reefs (Hughes et al, 2003; Hoegh-Guldberg et al, 2007).

Stakeholder knowledge was a key input into this study and was primarily obtained during a participatory workshop held in Nadi, Fiji on 19 November 2008. The 23 participants were asked to estimate the vulnerability to climate change of rural stakeholders using the Sustainable Livelihood (SL) conceptual framework (Carney 1998; Ellis 2000). The information gained from the analysis has been used to rank the vulnerability by PICs, identify key information gaps, elicit participants' public values with regard to desirable policy and adaptation research and development (R&D) outcomes, and consider future opportunities to enhance the adaptive capacity of rural livelihood stakeholders in the Pacific. Consultation with workshop participants during the writing of this report and in particular during the identification of knowledge gaps and future R&D opportunities, has enabled the research process to be responsive to the demands of those living and working in the rural areas of the Pacific.

Definition of vulnerability

To ensure a common understanding of the word *vulnerability*, the workshop participants were asked to contribute attributes they considered appropriate to a definition of vulnerability commensurate with the project approach, aims and scope. Whilst it was considered too difficult to capture all the attributes in a single-sentence definition of vulnerability, the exercise showed the participants' view of vulnerability to be both contextual as well as necessitating more assessment focused measurements of impact and adaptive capacity. It was also demonstrated that, consistent with emerging scientific views (e.g. Nelson et al, submitted), the vulnerability assessment was considered to be an integrated activity that included consideration of climate change impact (a function of exposure and sensitivity), adaptation *and* vulnerability. Importantly, the participants saw the vulnerability assessment was not just, or even particularly, focused on mapping the likely hazards of climate change.

Assessment of vulnerability

Two key methods were used to evaluate the vulnerability of PICs to climate change; the Environmental Vulnerability Index (EVI) sub-index (SOPAC 2004) and Sustainable Livelihood Analysis (SLA) (Carney 1998; Ellis 2000).

The EVI climate change sub-index values produced by SOPAC, indicates the environmental risks likely to result from climate change. In this study, we have used these values to rank the relative biophysical vulnerability of PICs to climate change. Although the ranking indicated a hierarchy of vulnerability amongst the PICs, there was little difference between the values assigned to each country and the results indicated that adaptive capacity in all PICs is presently inadequate to address the future challenges of climate change.

In general, the EVI climate change sub-index indicated that atoll and coral islands are more vulnerable than volcanic islands. This is due to (a) a high incidence of flooding, cyclones, extreme wet periods, and the resulting stress to land surfaces and ecosystems, (b) highly fragmented and 'thin' land areas with limited refugia and ecosystem types to provide breaks and resilience to damage from natural disasters and human impacts, and (c) the presence of lowlands and associated pollution, ecosystem disturbance, flooding and coastal vulnerability.

Whilst the EVI climate change sub-index provides a comprehensive assessment of environmental vulnerability, it fails to take into account the broader economic and social capitals and interactions that are reflected in the broad range of livelihood strategies operating in the Pacific. The EVI also provides a limited opportunity for policy makers to evaluate the effectiveness of current policies or target actions to improve adaptive capacity.

To address this shortfall and to facilitate more policy relevant outcomes, we undertook a SLA to determine the relative vulnerability of rural livelihoods across the Pacific to climate change as perceived by participants. The SLA approach seeks to understand people's strengths (assets or capital endowments) and how they endeavour to convert these into positive livelihood outcomes. In the SLA assets are seen as either human, social, natural, physical or financial (Fig. 2). The analysis required indicators of vulnerability to be determined by the participants against which individual PICs were rated. The Pacific countries under consideration were divided into either volcanic or atoll and coral according to their geomorphology.

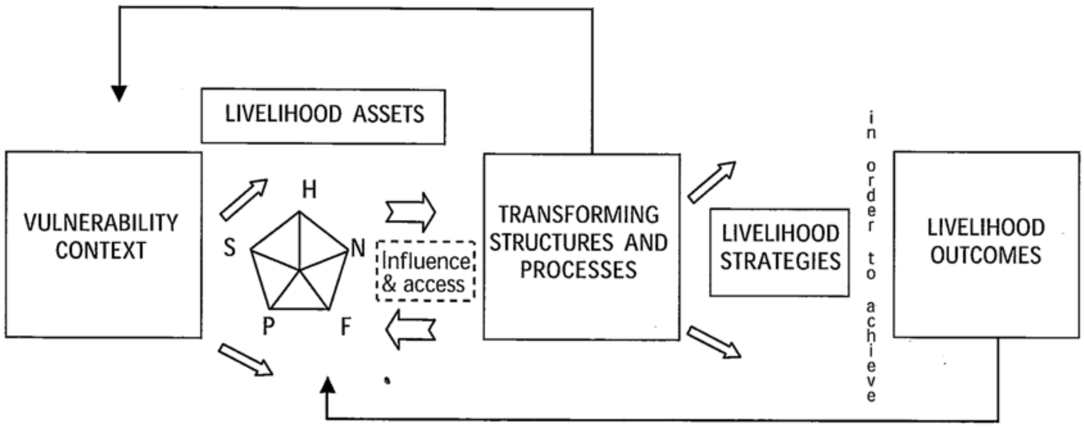

Fig. 2 Livelihood conceptual framework (DFID, 1999). Livelihood assets are divided into human (H), natural (N), financial (F), physical (P) and social (S).

The following is a summary of the key findings arising from the SLA:

- All PICs have insufficient access to human, social, natural, physical and financial capital to adequately adapt to climate change and are therefore vulnerable. Whilst this conclusion has previously been identified in many individual country and regional studies, further knowledge and analysis appears to be needed to better understand the nature, causes and dynamics of vulnerability within islands and the potential implementation of livelihood strategies that confer adaptive capacity (FAO, 2008*b*).
- A number of the vulnerability indicators chosen by the two groups of participants independently were found to be common to both volcanic and atoll and coral PICs. In terms of human capital all participants agreed that population demographics and the ability of rural stakeholders to undertake productive activities were major determinants of vulnerability. The importance of social networks and traditional governance was the only social indicator common to both volcanic and atoll and coral country/island types. Indicators of natural capital corresponded closely, with both groups recognising the importance of the availability and conservation of natural resources and biodiversity, island geomorphology and in particular the extent of low lying land, and access to good quality water. Physical capital in the form of water supply infrastructure (e.g. dams, pipelines) was identified as important to both island types and linked to access and availability of water. Financial capital common to both island type groups focussed on the importance of accessing credit, either through domestic institutions or overseas via remittances or aid agencies.
- The high vulnerability of rural livelihoods to climate-related hazards in the Pacific is largely due to (a) their heavy reliance on access to natural capital, (b) generally inadequate or poorly maintained physical capital (e.g. sewage infrastructure), (c) the weakening of traditional social networks inadequately compensated for by social capital developed through closer relationships with external agents, (e.g. aid agencies), and (d) scarce human and financial capital. In particular, degradation of the natural resources upon which rural livelihood strategies are

based negatively impacts desirable livelihood outcomes such as increased income and the sustainable use of the natural resource base. Sustainable natural resource use underpins food security for the vast majority of rural livelihood stakeholders (Hammill et al, 2005).

- The workshop participants ranked volcanic PICs from most to least vulnerable as follows:

  East Timor > Solomon > PNG > FSM > Vanuatu > Fiji > Palau > Tonga > Samoa

- The workshop participants ranked atoll and coral PICs from most to least vulnerable as follows:

  Nauru > Kiribati > Tuvalu > FSM > Fiji > Cook Islands > Marshall Islands > Tokelau > Palau > Niue

  Where PICs contain a substantial number of both volcanic and atoll or coral islands, they are included in both of the rankings above.

- Volcanic islands have relatively better access to social and natural capitals than human, physical and financial capitals. Social and natural capitals include access to information; low crime rates; social networks and traditional governance; high biodiversity; limited areas of low lying land, and adequate access to good quality water. Human, physical and financial capitals include good stakeholder health and nutrition; favourable population demographics; the ability to migrate; access to energy sources; provision of water storage and transport infrastructure; provision of infrastructure in low lying areas; adequate utilities; the ability to generate income; receipt of remittances, and access to development assistance.

- Atoll and coral islands have relatively better access to social and financial capitals than natural, physical and human capitals. Social and financial capitals include strong community groups and traditional governance systems; access to education and traditional knowledge; participation of women in decision-making; access to support groups and decision-making structures from community to national level; access to domestic and overseas credit, and low debt status. Natural, physical and human capitals include high biodiversity that is well conserved; favourable geomorphology, climate and weather patterns; access to fresh water; good communication, climate protection and water transport infrastructure; R&D infrastructure and technologies; favourable population densities and the ability to migrate; good personal productivity levels; good skills and knowledge; a healthy population, and a low risk profile. Physical capital is the most inadequate capital for atoll and coral islands reflecting, in particular, their exposure to sea level rise.

- Although the SLA did not explicitly compare the vulnerability of volcanic to atoll and coral islands, the workshop output suggests that the generally lower exposure and sensitivity of elevated volcanic islands to climate-related hazards, has enabled their accumulation of capital assets, continued development of adaptive capacity and hence generally lower levels of vulnerability compared to atoll and coral islands.

In summary, the EVI offers a limited assessment of largely biophysical vulnerability in contrast to the SLA assessment which provides an understanding of the vulnerability context within which rural stakeholders are operating and the factors determining why one country is more vulnerable than another. Knowing why exposure, sensitivity and adaptive capacity varies with access to capital assets is useful for informing the allocation of limited climate change adaptation, and more broadly, development resources.

A review of critiques of the SLA suggests that the approach may be prone to bias because of reliance on interpretation; a small sample size of respondents, and time consuming (DFID, 2000). We have addressed these points when designing the methodology used in this study. On a more conceptual level, the SL framework has also received critiques regarding three main concerns: the principles underlying the approach appear to lack a unifying purpose, an omission of essential components in SLA, and limits of the SL approach render it incompatible with other approaches (see Carney (2002)) for detailed responses to these claims).

Previous users have addressed these critiques by identifying gaps in the broad spectrum of SL applications and acknowledging and addressing the implications that SL approaches hold for institutional and organisational change. Rather than fitting in with other approaches, the SL approach is seen to offer a valuable alternative perspective that emphasises a number of core principles of good development practice, namely being people-centred, responsive and engendering stakeholder participation, providing a cross-sectoral focus on multiple levels (local, sectoral and regional, and national), and embracing a dynamic and sustainable approach (Ashley and Carney, 1999).

From this review of the utility of the SL framework it is evident that, as with any participatory rural appraisal (PRA) technique, its usefulness must be determined within recognised limits. As it has been used in this study, the SL approach has provided a conceptual framework that allows integration of both the impact of climate change and adaptive capacity as a function of human, social, natural, physical and financial capital (Nelson et al, submitted). Conducting a SLA provides not only a holistic measure of vulnerability, but more importantly, a greater understanding of the factors contributing to vulnerability, and when used in conjunction with the public values approach (Bozeman and Sarewitz 2005), is able to inform policy decisions and the development of appropriate and effective adaptive strategies.

Research and development opportunities

Research and development (R&D) opportunities have been developed from consideration of (a) key knowledge gaps identified during the course of this study, (b) public values elicited from workshop participants' contributions, and (c) knowledge and experience of science R&D technologies currently available, primarily contributed by the project team.

Public values are considered in this context as desirable outcomes for rural communities resulting from future R&D in climate change adaptation, as generally agreed and expressed by representatives living and working in the Pacific. Considering climate vulnerability investment in the Pacific in terms of knowledge gaps, public values and current science R&D technologies, enabled a narrowing of focus from a broad appraisal of what is currently unknown on the issue, to knowledge gaps that need to be addressed in order to result in desirable outcomes for rural livelihood stakeholders, and finally to science R&D activities aimed at reducing vulnerability to climate change that can feasibly be undertaken with currently available technologies (Fig. 3). This approach has been taken in response to two key requests raised by AusAID. Firstly, their desire to strengthen the evidence-based approach taken to developing aid programs and investment decision-making, and secondly, to address the need for immediate action to reduce vulnerability in rural livelihoods in the Pacific.

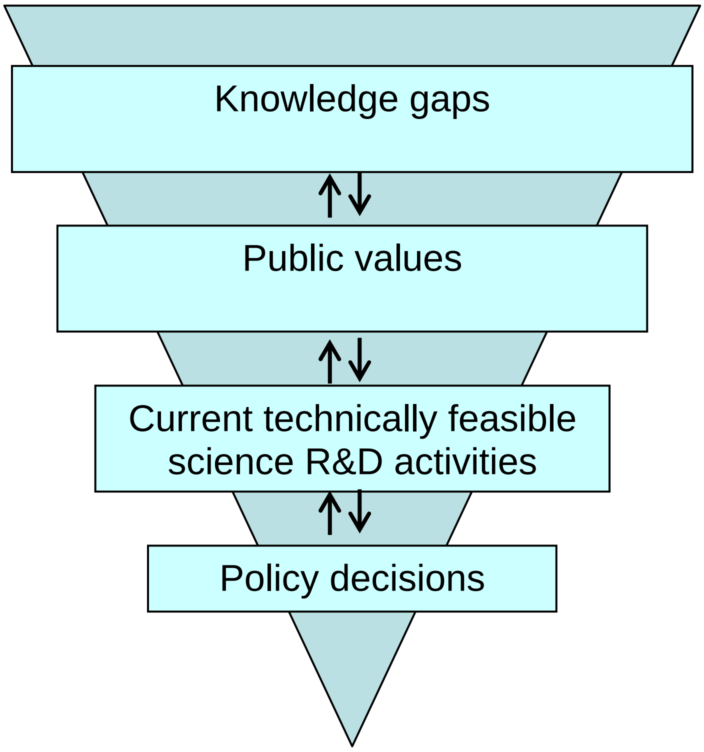

Fig. 3 Method used to narrow R&D investment decision-making from the identification of knowledge gaps, to common public values and desirable outcomes from R&D elicited from workshop participants' contributions. These have been filtered down to those public values that can be addressed with currently available technologies to produce recommendations for science R&D aimed at reducing the vulnerability of rural livelihood stakeholders.

Research and development opportunities have been categorised into four thematic areas:

- Building adaptive capacity;
- Diversification;
- Managing climate risk, and
- System constraints/barriers to adoption.

Whilst the four research opportunity themes are discussed independently, there is considerable overlap across them. For example, for all themes R&D opportunities may best be addressed using stakeholder participation to promote adaptive management frameworks and the co-production of knowledge that includes both scientific and indigenous understanding. This will enable the contextualisation of impacts to be better understood, constraints and barriers to adaptation built into the development of pathways to adoption and enabling environments, R&D activities to be outcome focused, and a better alignment between response strategies and stakeholder demand.

Another common feature in the R&D opportunities detailed above is the advocacy of analysis at the livelihood scale. Focusing on the livelihood unit essentially places the level of analysis at the scale at which many of the decisions regarding livelihood investment and actions are made. In order to ensure effective outcomes from climate change adaptation R&D, it is important to identify where, and by whom, decisions are made regarding daily existence, with the aim of developing activities that inform and support the appropriate stakeholders. Using the livelihood scale as the unit of analysis does not however exclude consideration of decision-makers at larger scales, i.e. local and national government. The interaction and impact of these larger-scale decision-makers and drivers are considered in terms of their impact on the socio-economic environment in which the livelihood unit operates.

The R&D opportunity themes cover the need to both obtain further understanding and about the vulnerability context in which rural stakeholders in the Pacific operate, and also the need to generate more information merely to understand the complexity of the problems they face. The broad scoping nature of this project has resulted in the identification of R&D opportunities broadly applicable across the range of PICs considered. It is recognised that further analysis is required to explicitly consider potential transferability between types of capital in reducing vulnerability. However, opportunities may only be realised if constraints and barriers to the adoption of strategies for reducing vulnerability are addressed. As perceived by the workshop participants, key constraints and barriers across the Pacific include insecurity of land tenure (see Boydell 2001 for an overview of this issue), poor governance institutions, under-resourced and poorly informed extension services and in some cases, resistance by rural stakeholders to consider alternative technologies and practices promoted from external sources. Effective implementation of R&D will necessitate further assessment being conducted at individual country and community levels. Individual research proposals have been developed under each of the four themes to address these more targeted R&D requirements (not included in this report).

Many of the knowledge gaps identified for rural livelihoods in the Pacific are echoed in reviews of key environmental management issues in other countries, such as Australia (Morton et al, 2009) and the United Kingdom (Sutherland et al, 2006). Whilst the relationships between production systems, land capacity and climate in more developed nations are relatively better understood than those of the Pacific, many of the ecological, economic and sociological learnings may be similarly applied to production units in PICs. A pragmatic response for decision-makers may therefore be to use current knowledge, skills and methodologies, as appropriate, to tactically address the most pressing and immediate issues for rural stakeholders, whilst simultaneously and strategically tackling more context specific long-term research objectives and critical unanswered questions. As noted by previous studies, a key constraint is limited information and in-depth analysis of climate change impacts on PICs (FAO, 2008*b*).

Evidence based policy development

This report has highlighted key attributes of vulnerability across the Pacific, the public values of a small sample of stakeholders living in and around the Pacific and working in the area of climate change, and identified opportunities for future R&D to reduce the vulnerability of rural stakeholders. As recommendations for changes to existing policy are outside the scope of this project, we have sought to support policy-makers in the development of evidence-based policies and governance by providing information produced using a defensible and scientifically rigorous methodology.

By using SLA we have provided a broad snapshot of the asset status of rural livelihood stakeholders across the Pacific and the key transforming structures and processes (as defined in the Sustainable Livelihood conceptual framework, Fig. 2) that influence the vulnerability context in which they operate. This benchmark can be used to consider future opportunities and evaluate progress. The public values provide a clear picture of the policy outcomes considered desirable by the workshop participants.

The challenge now lies in developing policies that draw upon the identified knowledge gaps and R&D opportunities to promote an enabling environment that will not only reduce vulnerability to changes in climate, but also more broadly enhance sustainable development and food security. Given the limited resources available, one of the key decisions that policy makers will face is where to finance adaptation. It is the hope of the authors and contributors to this report that the information contained here will complement other initiatives being undertaken in the Pacific in informing decision makers at all levels regarding climate change adaptation and wider sustainable development.

2.0 Introduction

The IPCC fourth assessment report states agricultural production in the Pacific is likely to suffer severe losses as a result of high temperatures, severe droughts, flooding and soil degradation (Mimura et al, 2007). Small islands are additionally vulnerable to sea-level rise, inundation, seawater intrusion into freshwater lenses, soil salinisation, and a decline in water supply.

In a recent document produced by the Food and Agriculture Organisation of the United Nations (FAO 2008*a*) it was identified that climate change will affect food security and production in a range of ways. These include changes in food availability, food accessibility, food utilization, food quality and food systems stability. These impacts, both positive and negative, will be felt in both the short term in response to changes in the frequency of extreme events, and over the long term through changes in mean temperatures, mean rainfall atmospheric CO_2 concentration and seasonal climatic patterns.

Many PIC rural communities rely strongly on subsistence cropping as well as cash crops and livestock to generate livelihoods. Communities reliant on agriculture-based livelihood systems have been identified as particularly at risk from climate change as a result of likely increases in crop failure, new patterns of pests and diseases, lack of appropriate seed and plant material, and loss of livestock (FAO, 2008*c*). These risks will further impact present environments concerns (Table 1) (see the SPREP website for more comprehensive details of environmental issues in PICs: http://www.sprep.org/). In the Pacific region, recent shortfalls in agricultural production resulting from changing export markets, commodity prices, population growth and urbanisation, have meant a greater reliance on imported foods, and increased concerns for the future security of regional food supplies.

Rural livelihoods were considered to primarily rely upon agricultural, forestry and livestock production. Whilst it is recognised that fishing activities constitute an important source of income and dietary animal protein for many rural livelihood stakeholders (Dalzell et al, 1996; Bell et al, 2009), a decision was made to concentrate the scope of the study on predominantly terrestrial activities whilst acknowledging research relating to climate change impacts on fisheries (Bell et al, 2009; Biswas et al, 2009) and more specifically on associated coral reefs (Hughes et al, 2003; Hoegh-Guldberg et al, 2007).

Table 1 Key environmental issues for a selection of PICs (Boydell, 2001).

Country	Key environmental issues
Cook Islands	None cited
Fiji Islands	Deforestation; soil erosion
Kiribati	Lagoon pollution; ground water at risk
Marshall Islands	Inadequate potable water
FSM	Overfishing
Nauru	Limited water; phosphate wasteland
Niue	Conservation, compared to slash and burn
Palau	Waste disposal; sand and coral dredging; overfishing
Papua New Guinea	Deforestation; mining pollution; drought
Samoa	Soil erosion
Solomon Islands	Deforestation; soil erosion; dying reef
Tonga	Deforestation for agriculture and settlement
Tuvalu	Soil erosion; no potable water
Vanuatu	Deforestation; lack of potable water

Whilst a sizeable number of studies have been conducted on the impacts of climate change on rural industries in PICs over the past decade, many of these have been undertaken by national environment departments under the auspices of international climate change policy reporting requirements for UNFCCC (i.e. National Communications, NAPAs) and it is not clear how, or even if, information from them has been used to strengthen the adaptation enabling environment or support the implementation of adaptation measures to effectively reduce vulnerability. In many cases, recommendations from previous studies are either too general or contain insufficient detail to enable them to be operational at the livelihood level, with few notable exceptions (pers comm. workshop participant).

Despite previous studies of vulnerability across the Pacific region, there appears to be a lack of progress in assessment methodologies, particularly in the area of quantifying impact and adaptation strategies. Quantification of temperature and rainfall impact has been conducted on agricultural production in neighbouring countries, e.g. Australia, at a range of scales from individual crop species, e.g. wheat (e.g. Asseng et al, 2004) and sugarcane (e.g. Park et al, 2007), to farm business scale (e.g. Cox et al, 2008). The absence of application of these techniques in the study of climate change vulnerability in the Pacific is notable. The IPCC Second Assessment Report (IPCC, 1995) suggests that developing a renewed international agenda to assess the vulnerability of small islands, based on the most recent projections and newly available tools would provide small islands with a firmer basis for future planning. However, there is little evidence in the Third (IPCC, 2001) or Fourth Assessment (IPCC, 2007) reports, no substantial progress has been made.

Appropriate adaptation measures can help to reduce the negative impacts of climate and capitalise on opportunities that arise for increased agricultural and forestry production. However, in order to ensure adaptation strategies offer a balance between sustainable development, increased productivity and enriching environmental outcomes, a better understanding is required of the complex and multidimensional relationships between the social and physical environments within which decisions regarding rural livelihood strategies are taken. This will ensure that a strong evidence base underpins the development of future policies and programs that foster appropriate and effective adaptation activities.

2.1 Research approach

This scoping study seeks to synthesize existing knowledge obtained from previous assessments of the vulnerability of rural livelihood stakeholders to climate change, together with context specific knowledge contributed from stakeholders living in and around the Pacific, and working in the area of climate change, rural livelihood and development. This information is used to identify relative rates of vulnerability experienced by rural livelihood stakeholders to climate change across the Pacific by the year 2050. We also identify key information gaps, public values expressed by the workshop participants and offer recommendations to assist future investments in climate-related R&D aimed at increasing the adaptive capacity of rural livelihoods.

The 16 countries included in this study are shown in Table 2, together with a broad categorisation of island type. Although not considered a PIC, East Timor has been included in this study as the livelihood strategies developed in rural areas in the country operate under similar socio-economic and biophysical conditions to many neighbouring PICs. Categorisation of PICs using a broad island type typology follows the convention of other studies of the region (e.g. FAO, 2008b).

Table 2 Countries included in the study categorised into broad island types.

Country	Island type
FSM	Volcanic & atolls
Kiribati	Atolls
Marshall Islands	Atolls
Palau	Volcanic & coral
Fiji	Predominantly volcanic, some coral
Nauru	Coral and raised atolls
Solomon Islands	Predominantly volcanic, some coral and atoll
Papua New Guinea	Predominantly volcanic, some coral and atoll
Vanuatu	Predominantly volcanic, some coral and atoll
Cook Islands	Predominantly atolls, with a volcanic
Niue	Coral
Samoa	Volcanic
Tokelau	Atoll
Tonga	Volcanic
Tuvalu	Atoll
East Timor	Predominantly volcanic

2.2 Workshop methodology

A one-day workshop was held in Nadi, Fiji on 19 November 2008. Seventeen representatives of the Pacific were selected to attend due to their recent work in the Pacific in areas related to climate change, rural livelihoods, development and natural resource management. The participants worked for a range of organisations and institutions including national and local governments and non-government organisations (NGO). The workshop participants were selected for their broad range of disciplines related to climate change and development (Fig. 3). This was considered necessary as the methodology used in the study drew heavily on this traditional/indigenous knowledge and the ability of the participants to consider the relative vulnerability of individual PICs. However, it became evident that there was insufficient knowledge regarding a number PICs amongst the participants and subsequent input into the analysis was sought from key people known to have significant knowledge of those countries inadequately represented at the workshop.

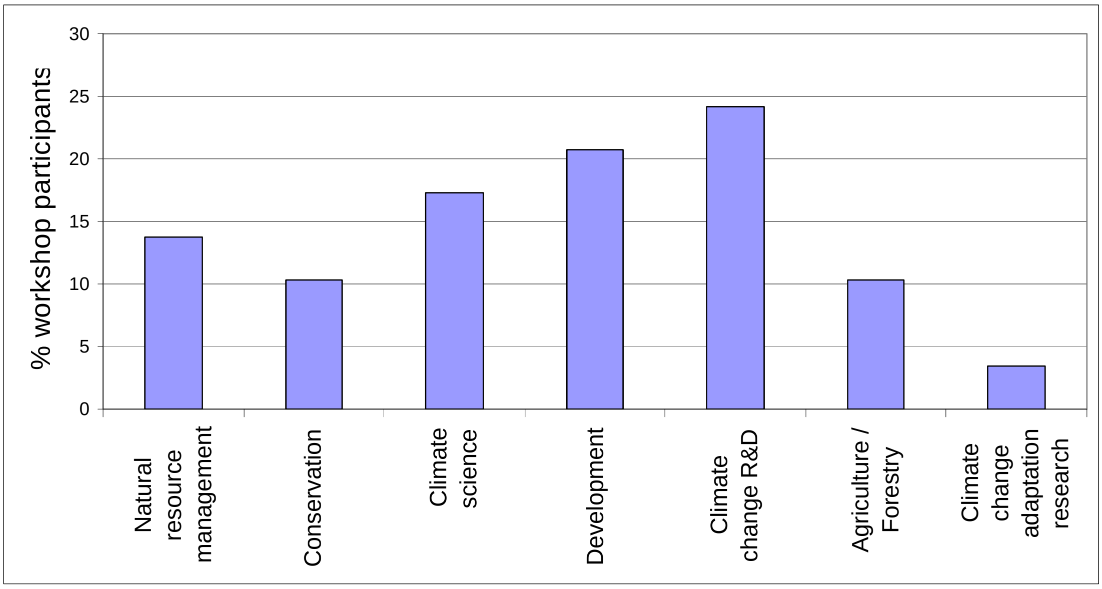

Fig. 3 The range of sectors that workshop participants worked in or had professional interests in related to climate change in the Pacific.

In addition, 6 members of the CSIRO project team also attended the workshop. Nearly half of the workshop participants had been professionally associated with climate change research and development for over 10 years.

2.3 Definition of vulnerability

To ensure a common understanding of the term *vulnerability*, participants were asked to contribute attributes they considered commensurate with the workshop approach, aims and scope. Box 1 provides a summary of the attributes agreed upon by all workshop participants.

The consideration of social, political, and economic networks and structures indicates that participants considered vulnerability to be 'contextual' and dependent upon multiple drivers in addition to climate, and their interactions. The contextual knowledge was considered to be contributed by stakeholders via participatory data collection and analysis methodologies. However, it was also agreed amongst the participants that, in some instances, there was the need to conduct more 'assessment' focused studies of vulnerability that require impact and adaptive capacity to be quantitatively measured. This measurement, although generally undertaken by 'experts' from the research domain, may include stakeholders who provide information for the parameterisation of models etc.

The attributes of vulnerability offered by the workshop participants also reflected the need for vulnerability to climate change to be considered as a function of: (a) the level of exposure that a livelihood unit experiences to climate change; (b) the relative sensitivity of the unit/system to shocks and trends, and (c) the extent of adaptive capacity embedded within the unit/system to effectively implement adaptation (Fig 4). This study utilises the Sustainable Livelihoods (SL) framework as a tool to integrate stakeholders' perceptions of all three factors, and hence the residual vulnerability of individual PICs to climate change.

Box 1 Attributes included in a definition of vulnerability commensurate with the workshop approach, aims and scope.

- General understanding that a change in practices can reduce vulnerability.
- Need to understand impacts *and* capabilities to adapt.
- Recognition of the need for supportive institutional frameworks (e.g. policy).
- Need for climate change impact and adaptive capacity to be expressed as a scale or measured.
- Need to express impact and adaptive capacity in terms of 'likelihood'.
- Need to capture the notions of 'exposure' and 'sensitivity' to stresses.
- Need to recognise people and communities, in addition to the social-political-economic networks and structures that they operate within.
- Requirement for adaptive management (cyclical monitoring and evaluation of impacts and adaptive capacity).
- Adaptation responses must be considered in terms of their appropriateness.
- Recognition that sustainable livelihoods and the environment are inseparable.
- Consideration must be given to options, opportunities, impediments, synergies and barriers to adaptation.
- Consideration must be given to the flow and ease of access of information required to assess vulnerability.

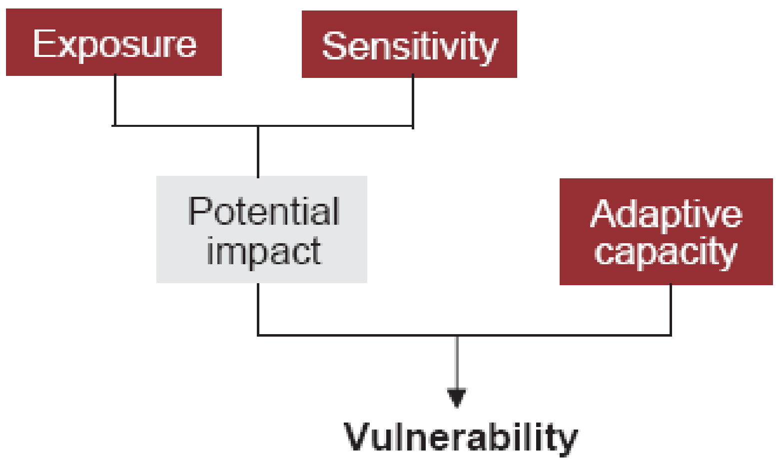

Fig. 4 Vulnerability to climate change is a function of exposure and sensitivity, and adaptive capacity (Allen Consulting Group, 2005).

2.4 Supplementary information

In order to provide workshop participants with sufficient information to evaluate the relative vulnerability of PICs, the following information was presented at the workshop: (a) details of climate-related thresholds for a range of crop and forest plantation species, and livestock and associated forage species particularly important to subsistence, cash and commercial producers in the Pacific region (Appendix 1), and, (b)climate change projections for the Pacific (Christensen et al, 2007).

2.4.1 Crop, forestry and livestock thresholds

For each crop and livestock species identified as important to rural livelihoods in the Pacific (Appendix 1), summary information was provided on key climate-related physiological, system (or value-chain) thresholds; vulnerability to extreme events such as intense storms, inundation and sea level rise; known response to an elevated concentration of carbon dioxide (CO_2) in the atmosphere, and a brief assessment of the likelihood of climate change breaching the noted thresholds by the year 2050.

In many cases the threshold information was drawn from research relating to production in developed nations, particularly Australia. As the biophysical conditions in sub-tropical and tropical regions of Australia are similar to those across the Pacific, this information is deemed an adequate starting point from which to consider climate-related crop physiological and system thresholds in the absence of more cultivar-specific information. Further assessment is required to determine if thresholds for key crops and cultivars grown in the Pacific warrant investment of further research.

2.4.2 Climate change projections

IPCC Fourth Assessment climate change projections for North and South Pacific (Christensen et al, 2007) have been used in this study to consider impacts, adaptive capacity and vulnerability. These include projections for relative change in temperature (°C), precipitation (%) and extreme seasons (%) for the period 2080 to 2099 using a baseline period of 1980 to 1999 (Tables 3, 4). The shaded blue areas show instances where the middle half (25 to 75%) of the distribution of output from all 21 global models used to produce the mean response projections for precipitation, indicate an increase. This agreement amongst the models suggests increased confidence in the direction of precipitation change. However, it is important to stress that these projections are not forecasts, but rather are based on the A1B scenario of future changes in energy and greenhouse gases and the possible implications of these on the climate. The techniques for producing these scenarios of change are imprecise, particularly at the scale of small islands. These ranges are subject to both scientific uncertainties and to the range of future greenhouse gas emission scenarios. Further details, including projections of sea level rise and the frequency and extent of tropical cyclones (Meehl et al, 2007) was also presented.

Table 3 IPCC Fourth Assessment Report regional climate projections (Christensen et al, 2007): regional averages of temperature (°C), precipitation (%) and extreme events (%) for the North Pacific Ocean from a set of 21 global models in the multi-model dataset for the A1B scenario.

		Temperature Response (°C)						Precipitation Response (%)						Extreme Seasons (%)		
Region[a]	Season	Min	25	50	75	Max	T yrs	Min	25	50	75	Max	T yrs	Warm	Wet	Dry
NPA	DJF	1.5	1.9	2.4	2.5	3.6	10	-5	1	3	6	17	>100	100	20	2
	MAM	1.4	1.9	2.3	2.5	3.5	10	-17	-1	1	3	17		100	14	
0,150E	JJA	1.4	1.9	2.3	2.7	3.9	10	1	5	8	14	25	55	100	43	1
to	SON	1.6	1.9	2.4	2.9	3.9	10	1	5	6	13	22	50	100	31	1
40N,120W	Annual	1.5	1.9	2.3	2.6	3.7	10	0	3	5	10	19	60	100	35	1

Table 4 IPCC Fourth Assessment Report regional climate projections (Christensen et al, 2007): regional averages of temperature (°C), precipitation (%) and extreme events (%) for the South Pacific Ocean from a set of 21 global models in the multi-model dataset for the A1B scenario.

		Temperature Response (°C)						Precipitation Response (%)						Extreme Seasons (%)		
Region[a]	Season	Min	25	50	75	Max	T yrs	Min	25	50	75	Max	T yrs	Warm	Wet	Dry
SPA	DJF	1.4	1.7	1.8	2.1	3.2	10	-6	1	4	7	15	80	100	19	4
	MAM	1.4	1.8	1.9	2.1	3.2	10	-3	3	6	8	17	35	100	35	1
55S,150E	JJA	1.4	1.7	1.8	2.0	3.1	10	-2	1	3	5	12	70	100	27	3
to	SON	1.4	1.6	1.8	2.0	3.0	10	-8	-2	2	4	5		100		
0,80W	Annual	1.4	1.7	1.8	2.0	3.1	10	-4	3	3	6	11	40	100	40	3

3.0 Indices of vulnerability

To assist workshop participants in forming their opinions of relative vulnerability of PICs, a selection of commonly used indices were considered. Indices have been used widely in studies of vulnerability to identify populations most likely to experience negative effects from social, economic or political events. The following indices were provided as reference material to workshop participants to assist their assessment of the vulnerability of rural livelihoods in the Pacific to climate change:

- Human Development Index (HDI)
- Human Poverty Index for Developing Countries (HPI-1)
- Environmental Sustainability Index (ESI)/Environmental Performance Index (EPI)
- Environmental Vulnerability Index (EVI);
- Water Poverty Index (WPI);
- Gross National Income (GNI);
- Human Assets Index (HAI);
- Economic Vulnerability Index (EVI*)[1].

A brief summary of the HDI, HPI-1, ESI, EPI, EVI, WPI, GNI, HAI and EVI* indices is provided in Appendix 2. A number of criticisms have been levelled at the composition and usefulness of the indices listed above. Some of the criticisms include:

- A limited number of datasets are generally used to produce composite indices, resulting in a restricted measure of vulnerability that may differ according to the data and indicators used. Indices are further constrained by a lack of readily available and reliable data, particularly for remote and sparsely populated countries. Consequently, the data used may not adequately represent the processes that determine vulnerability (Eriksen and Kelly 2007);
- Composite indices may add little to the value of the individual measures that compose them and are frequently derived from arbitrary weightings and incommensurable datasets;
- Average national-level values fail to reflect the spatial variability necessary to provide an understanding of the processes that shape vulnerability (Eriksen and Kelly, 2007). The coarse resolution may further fail to capture the scale at which decisions are made in rural livelihoods.
- Static measures fail to recognise temporal changes and trends. Where index values for a subject (i.e. country) are ranked relative to other countries, comparison of performance over time is particularly difficult as a single country's performance is dependent on the relative performance of other countries;
- A lack of transparency in the assumptions embedded in an index makes it difficult for users to unravel calculations, assumptions and meanings.

Despite the above limitations, index measures may provide a useful, relatively inexpensive means of characterising a limited aspect of the vulnerability of countries. Table 5 shows the index values for Pacific countries included in this study.

[1] *The Economic Vulnerability Index is abbreviated to EVI, similar to the Environmental Vulnerability Index (EVI). In order to differentiate the two indices in this report, an astrix has been inserted in the Economic Vulnerability Index abbreviation (EVI*).

3.1 Environmental Vulnerability Index

One of the most comprehensive indices in terms of the data used to compose it and geographic application is the EVI. In brief, the EVI is based on 50 estimated indicators of environmental vulnerability of a country to future damage and degradation. However, it does not explicitly address the vulnerability associated with social, cultural or economic drivers. The 50 indicators are combined by simple averaging and reported simultaneously as a single index, a range of policy-relevant thematic sub-indices and as a profile showing the results for each indicator.

One of the sub-indices derived from the EVI relates to environmental risks likely to result from climate change (Fig. 5). The signals used to compute the climate change sub-index relate to periods of extreme high winds, dryness, wetness and heat; changes in sea surface temperature; total land area and its dispersion; vertical relief; proportion of low-lying land; the amount of natural vegetation cover remaining; availability of renewable water; human population density, and the density of people living in coastal settlements. These signals are described briefly in Appendix 3. Tables 6 and 7 show the climate change sub-index values for volcanic and atoll and coral PICs included in this study, respectively. On the basis of the EVI climate change sub-index values, the following indicates the relative vulnerability of PICs included in this study:

Volcanic PICs (from most to least vulnerable):

> **FSM > Tonga > Samoa > Fiji > Vanuatu > Palau > East Timor > PNG > Solomon Islands.**

Atoll and coral PICs (from most to least vulnerable):

> **Nauru > FSM > Tuvalu > Marshall Islands > Kiribati > Cook Islands > Tokelau > Niue > Fiji > Palau > East Timor.**

Although the above ranking indicates a hierarchy of vulnerability between the PICs, Figure 5 shows that in there is little difference between the values assigned to each country and that adaptive capacity in all countries is insufficient to address the challenges of climate change (maximum value of adaptive capacity is 7). In general, the EVI climate change sub-index indicates that atoll and coral islands are generally more vulnerable than volcanic islands. This is due to a greater incidence of (a) flooding, cyclones, extreme wet periods, and the resulting stress to land surfaces and ecosystems, (b) highly fragmented and ‘thin’ land areas with limited refugia and ecosystem types to provide breaks and resilience to damage from natural disasters and human impacts, and (c) the presence of lowlands and associated pollution, ecosystem disturbance, flooding and coastal vulnerability. In addition, relatively lower vulnerability in volcanic islands is attributed to fewer extreme high temperature events and associated stress on water resources; a large vertical relief range supporting a wide variety of ecosystems and habitat types; and the retention of a high percentage of natural and regrowth vegetation cover to support biodiversity and ecosystem structure and functioning.

Table 5 Performance indices for a selection of PICs. The EVI vulnerability classifications (Vuln. Class.) are: Ext vuln = extremely vulnerable; High vuln = highly vulnerable; Vuln = vulnerable. Bold, italic text indicates the worst/lowest performance/situation within each index.

	Human Development Index (HDI)[1]		Human Poverty Index (HPI-1)[2]		Environmental Performance Index (EPI)[3]		Environmental Vulnerability Index (EVI)[4]		Water Poverty Index (WPI)[5]		Per capita gross national income (GNI)[6]		Human Assets Index (HAI)[7]	Economic Vulnerability Index (EVI*)[8]	
	Value	Rank (classification)	Value	Rank	Value	Rank	Value	Data% and Vuln. Class.	Value	Rank	US $	Value	Rank	Value	Rank
Cook Islands							383	82 (Ext vuln)							
East Timor	*0.514*	150 (medium)	*41.8*	95	66.2*	102*	316*	98* (High vuln)	64.9*	33*	*467*	55.3	84	65.2	123
FSM							392	74 (Ext vuln)							
Fiji	0.762	92 (medium)	21.2	50	69.7	93	333	92 (High vuln)	61.9	45	2,337**	89.8	23	51.2	92
Kiribati							395	82 (Ext vuln)			917	90.5	20	84.3	129
Marshall Islands							348	80 (High vuln)							
Nauru							*421*	76 (Ext vuln)							
Niue							309	68 (Vuln)							
Palau							338	78 (High vuln)							
PNG	0.530	145 (medium)	40.3	90	64.8	109	251	94 (At risk)	*54.5*	89	527	*54.1*	85	44.2	68
Samoa	0.785	77 (medium)					328	78 (High vuln)			1,597	90.4	21	64.7	122
Solomon Islands	0.602	129 (medium)	22.4	53	*52.3*	137	281	86 (Vuln)			557	70.6	66	56.9	105
Tokelau							328	58 (High vuln)							
Tonga	0.819	55 (medium)					392	74 (Ext vuln)			1,590**	97.9	5	76.1	128
Tuvalu							367	78 (Ext vuln)			1,267	89.7	25	*91.9*	130
Vanuatu	0.674	120 (medium)	24.6	56			285	80 (Vuln)			1,187	66.0	72	64.3	121

*Data for Indonesia used.

1 Human Development Report 2007 / 08 (http://hdr.undp.org/en/media/hdr_20072008_en_complete.pdf)
2 Human Development Report 2007 / 08 (http://hdr.undp.org/en/media/hdr_20072008_en_complete.pdf)
3 Environmental Performance Index 2008 (http://www.yale.edu/epi/files/2008EPI_Text.pdf)
4 Environmental Vulnerability Index 2005 (http://www.vulnerabilityindex.net/EVI_Country_Profiles.htm)
5 Water Poverty Index (http://www.keele.ac.uk/depts/ec/wpapers/kerp0219.pdf)
6 GNI (http://www.un.org/esa/policy/devplan/cdppublications/2006cdpreport.pdf); **Fiji and Tonga GNI (hhttp://webapps01.un.org/cdp/dataquery/selectCountries.action)
7 Human Assets Index (http://www.un.org/esa/policy/devplan/cdppublications/2006cdpreport.pdf)
8 Economic Vulnerability Index (http://www.un.org/esa/policy/devplan/cdppublications/2006cdpreport.pdf)

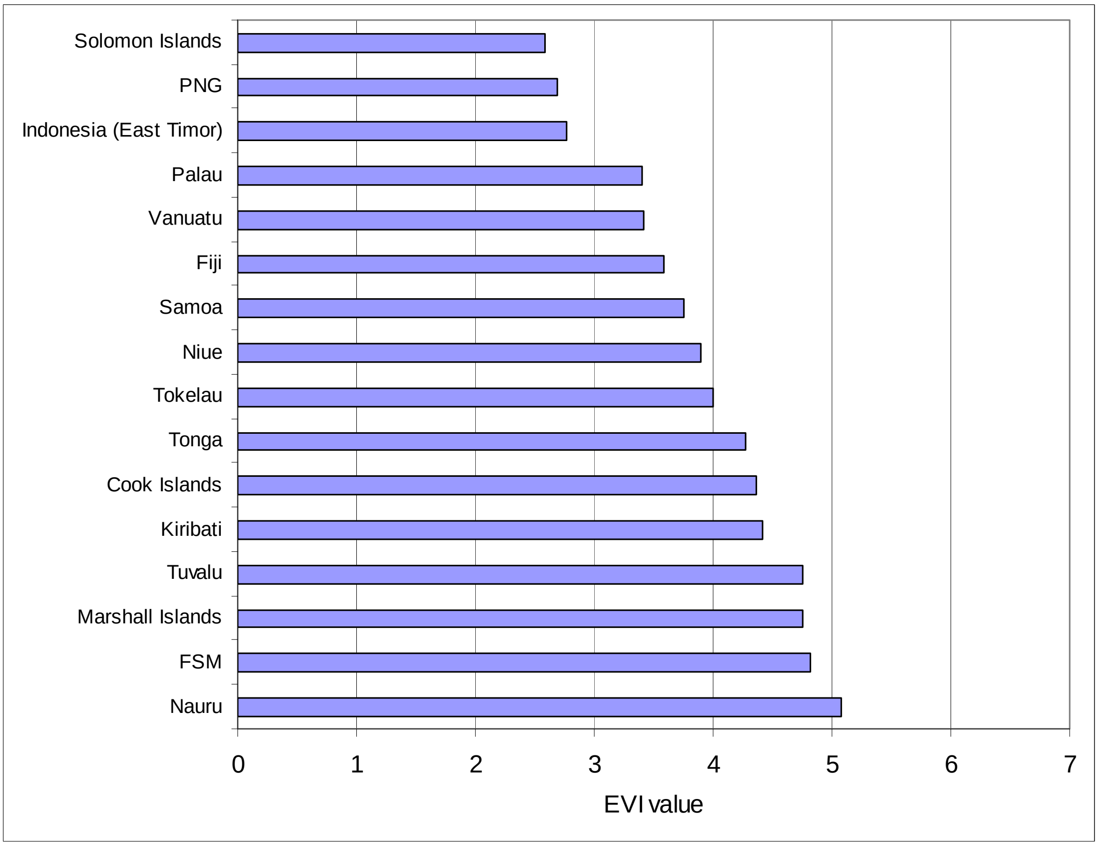

Fig. 5 Environmental Vulnerability Index climate change sub-index values for all PICs.

Table 6 Environmental Vulnerability Index (EVI) climate change sub-index values for volcanic PICs. Ranking indicates the country with the most (1) and least (16) vulnerability to climate change.

Volcanic PICs	Value	Data%	Overall ranking
FSM	4.82	85	2
Tonga	4.27	85	7
Samoa	3.75	92	10
Fiji	3.58	92	11
Vanuatu	3.42	92	12
Palau	3.40	77	13
East Timor	2.77	100	14
PNG	2.69	100	15
Solomon Islands	2.58	92	16

Table 7 Environmental Vulnerability Index (EVI) climate change sub-index values for atoll and coral PICs. Ranking indicates the country with the most (1) and least (16) vulnerability to climate change.

Atoll and coral PICs	Value	Data%	Overall ranking
Nauru	5.08	92	1
FSM	4.82	85	2
Tuvalu	4.75	92	3
Marshall Islands	4.75	92	4
Kiribati	4.42	92	5
Cook Islands	4.36	85	6
Tokelau	4.00	85	8
Niue	3.90	77	9
Fiji	3.58	92	11
Palau	3.40	77	13
East Timor	2.77	100	14

4.0 Sustainable livelihoods

Whilst the EVI climate change sub-index provides an assessment of environmental vulnerability, it fails to take into account adaptive capacity and the broad range of economic and social capitals and interactions in livelihood strategies in response to managing climate variability and change. We have utilised the SL framework as a research and policy tool to recognise the complex and multidimensional relationships between the social and physical environments within which decisions regarding livelihood strategies in rural areas of the Pacific are made (Fig. 6).

In the context of this study, the SL framework is used to emphasise the vulnerability context (i.e. the environment in which people exist) and factors that impact on a stakeholder's asset status and hence capacity to pursue beneficial livelihood outcomes in the face of shocks, trends and seasonal shifts. Shocks may, for example, be related to human health epidemics, natural phenomena such as extreme weather events, the economic system as exemplified by rapid changes in exchange rates and terms of trade, crop/livestock heath and civil conflict. Shocks can destroy assets directly or force people to abandon their home areas and dispose of assets (such as land) prematurely as part of a coping strategy. Trends are generally more predictable and may relate to population, resources, national and international economics, governance and politics. Seasonality may be experienced through cyclic fluctuations in prices, production, and health and employment opportunities. Seasonal shifts in prices, employment opportunities and food availability are one of the greatest and most enduring sources of hardship for poor people in developing countries (DFID, 1999).

The SLA approach seeks to gain an understanding of people's strengths (assets or capital endowments) and how they endeavour to convert these into positive livelihood outcomes. Assets are seen as either human, social, natural, physical or financial (see Box 2 for a description of each type of capital).

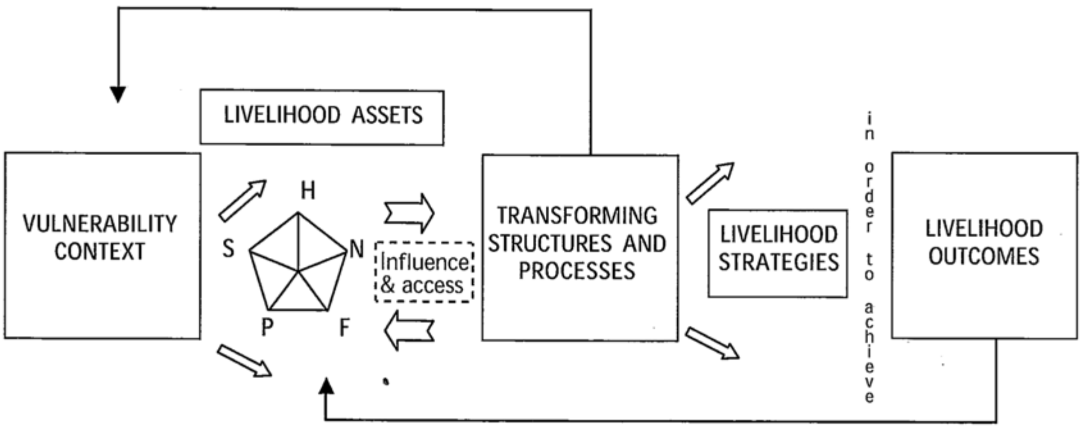

Fig. 6 Livelihood conceptual framework (DFID, 1999). Livelihood assets are divided into human (H), natural (N), financial (F), physical (P) and social (S).

Box 2 Sustainable Livelihoods capitals (DFID, 1999).

Human capital represents the skills, knowledge, availability of labour and good health that together enable people to pursue different livelihood strategies and achieve their livelihood objectives. At a household level human capital is a factor of the amount and quality of labour available; this varies according to household size, skill levels, leadership potential, health status, etc.

Social capital refers to the resources people draw upon in pursuit of livelihood objectives. Social capital is developed through: networks and connectedness; membership of more formalised groups (governed by mutually-agreed or commonly accepted rules, norms and sanctions); and informal safety nets based upon relationships of trust, reciprocity and exchange.

Natural capital is the term used to describe the natural resource stocks from which resource flows and services (e.g. nutrient cycling, erosion protection) useful for livelihoods, are derived. There is a wide variation in the resources that make up natural capital, from intangible public goods such as the atmosphere and biodiversity to divisible assets used directly for production (trees, land, etc). Within the SL framework, the relationship between natural capital and the *Vulnerability Context* is particularly close. Many of the shocks that devastate the livelihoods of the poor are themselves natural processes that either destroy natural capital (e.g. fires that destroy forests, floods and earthquakes that destroy agricultural land) or result from seasonality (resulting in changes in the value or productivity of natural capital over the year).

Physical capital comprises the basic infrastructure and producer goods needed to support livelihoods. Infrastructure consists of changes to the physical environment that help people to meet their basic needs and to be more productive; producer goods are the tools and equipment that people use to function more productively. The following components of infrastructure are usually essential for sustainable livelihoods: affordable transport; secure shelter and buildings; adequate water supply and sanitation; clean, affordable energy; and access to information (communications). Infrastructure is commonly a public good that is used without direct payment. Exceptions include shelter, which is often privately owned, and some other infrastructure that is accessed for a fee related to usage (e.g. toll roads and energy supplies). Producer goods may be owned on an individual or group basis or accessed through rental or 'fee for service' markets, the latter being common with more sophisticated equipment.

Financial capital denotes the financial resources that people use to achieve their livelihood objectives. There are two main sources of financial capital which contribute to consumption and production: available stocks and regular flows of money. The notion of financial capital has been included in livelihood analysis to reflect the importance of the availability of cash or equivalent in enabling people to adopt different livelihood strategies.

4.1 Sustainable Livelihood Analysis methodology

Sustainable Livelihood Analysis (SLA) (Carney 1998; Ellis 2000) was used to assess the vulnerability of rural livelihoods across the Pacific to climate change. This approach was adopted as it provides a method for rapidly assessing a rural communities' access to the multiple capitals (human, social, natural, physical, financial) underpinning food security and sustainable development (Hammill et al, 2005). Importantly, the livelihood analysis approach enabled the information previously presented by the project team on climate change projections and key crop, forestry and livestock system thresholds, to be contextualised within each participant's knowledge and experience of rural livelihoods in PICs.

Whilst this study was predominantly focused on the vulnerability of rural livelihoods to climate change, the systems perspective afforded by the SL approach enabled the multiple drivers impacting decision-making at the livelihood scale, to be simultaneously taken into account. This facilitated the capture of the workshop participants' perception of not only the economic, environmental and social aspects of rural livelihoods, but also the multiple drivers, interactions and feedback loops that are likely to determine exposure, sensitivity (collectively referred to as potential impact) and adaptive capacity, and hence vulnerability into the future (see Fig. 6).

The workshop participants were presented with an overview of the SL conceptual framework and examples of each of the five capitals in the context of assessing vulnerability to climate change (Table 8). A number of examples of attributes that may be used to reflect access to an individual capital were also presented. The workshop participants were then allocated to either the "volcanic" or "atoll and coral" breakout group, depending upon their level of knowledge on each of the PICs in the study (as indicated on previously submitted bibliographic information).

Table 8 Examples of each of the five capitals in the context of assessing vulnerability to climate change.

Capital	Description	Indicator (example only)
Human	Education, skills, health	• Farm management & innovation • Specific NRM skills & training • Proximity to health care
Social	Social networks & associations (claims & obligations)	• Family & local support • Peer groups • Government programs and support
Natural	Land, water, trees – yields, products	• Rainfall (annual, seasonality) • Productivity (crop yields & carrying capacity) • Native veg
Physical	Goods derived from economic production	• Dams, fences, buildings, machinery • Crop & herd improvements (new varieties & breeds)
Financial	$$, access to credit	• Average income from all activities • Off-farm employment opportunities

Within the two breakout groups, participants were asked to nominate indicators of a country's endowment of each of the 5 capitals. Once 3 or 4 indicators had been agreed upon for each capital, all participants were asked to rank individual PICs against the chosen indicators. For example, the atoll and coral breakout group chose communication infrastructure (including intranet) as an indicator of social capital. Those countries rated 5 by the breakout group members were considered to have sufficient access to communication infrastructure to enable sustainable adaptation to climate change projected for the year 2050. In contrast, countries rated 0 were considered to have relatively poor access and were therefore highly vulnerable to climate change. Countries rated 2 to 3 were considered to have partially sufficient adaptive capacity. Participants were asked to integrate potential transferability between capitals (e.g. the use of financial credit to pay for attendance on a technical course to increase knowledge and skills) into the scores they attributed to each country and capital.

By systematically assessing the adaptive capacity of each indicator for all of the PICs, we were able to capture the relative vulnerability of rural livelihoods to climate change across the breadth of the Pacific as perceived by the workshop participants.

Importantly, we were also able to gain an understanding of why the indicators were considered important to reducing climate change vulnerability and why individual PICs were considered either vulnerable or well endowed with adaptive capacity, from the discussions held between the participants.

The breakout groups decided upon the most appropriate process by which to determine indicators and rating scores. Slightly different approaches were adopted by the two groups. Those discussing volcanic PICs chose an open discussion forum incorporating all members to reach a consensus of opinion. The atolls and coral group participants opted for a more structured allocation of individual PICs, designating individual group members to countries based on their relative levels of knowledge. Neither of the approaches is considered superior, rather a reflection of the skills and knowledge within the breakout group members and SLA facilitators. The different approaches therefore means that the relative ranking of the countries must only be considered within island types, i.e. atoll and coral, or volcanic, and not extended across the whole range of PICs included in the study.

Information collected from the SLA workshop has been synthesized with secondary data on climate-related crop and system thresholds, information obtained from the literature review and EVI climate change sub-index values to provide a broad assessment of the vulnerability of rural livelihood stakeholders in the Pacific to climate change.

4.2 SLA results

Tables 9 and 10 list the indicators used in the SLA and provide a short explanation for why each one was chosen by the workshop participants. Summary graphs of the results are shown for volcanic islands (Fig. 7) and atoll and coral islands (Fig. 8). The pentagraphs provide a snapshot of the relative asset endowment of rural livelihoods in each PIC as perceived by the workshop participants. In general, the smaller the area within the pentagon, the greater the vulnerability of the country to climate change. However, some capitals may be transferrable and used to substitute or provide access to other capitals, impacting overall adaptive capacity and the level of vulnerability. For example, overseas relatives may use remittances to supply agricultural technologies not generally available to community group members residing in the Pacific. An individual pentagraph is shown for each volcanic (Fig. 9) and atoll and coral (Fig. 10) PIC and mean ranking values provided in Tables 11 and 12.

Table 9 Indicators used to consider the vulnerability of volcanic PICs to climate change.

Capital	Indicator	Rationale
Human	Health; nutrition	Health and nutrition provides a good indication of the ability to cope with further challenges posed by climate change.
	Population growth and density	Population pressures impact substantially on the condition and management of agricultural and natural resources posing threats to continued human well-being. This measure provides an insight into the requirement for supporting infrastructure and links with the urban/rural migration indicator (below).
	Migration (urbanisation and migration outside the county)	Migration was considered to capture the balance between rural and urban populations as well as the proportion of family members living outside the Pacific. These combined measures provided an indication of the ability of an island population to provide agricultural products, as well as their ability to access support outside the country. It must be remembered however, that whilst young people may leave an island/region, they may send remittances back to their community.
Social	Access to information e.g. newspapers, internet, radio, telephone	Access to information was used to indicate the ability of rural populations to take onboard new information to facilitate adaptation, e.g. exposure to information that examines new cultivars, management practises. Access to information affects ones ability to change and adapt.
	Crime rate	Crime rate is an indictor of the general stability of the population and the integrity of social networks that may aid adaptation. A high crime rate would indicate low stability and poor social networks and hence is likely to negatively impact the potential of stakeholders to adapt to climate change.
	Social networks e.g. religious and social groups	Support from social networks can facilitate change and adaptive capacity.
	Traditional governance (e.g. land tenure records)	Traditional governance reflects the importance of tradition in the Pacific and indicates how well the traditional governance structures are operating within a country. Locations with good traditional support structures are considered to be more likely to be able to cope with the negative impacts of climate change.
Natural	Biodiversity, including agro-ecological, terrestrial and marine resources (in terms of both quality and extent)	High biodiversity is associated with high resilience within an ecosystem.
	Biodiversity (marine only)	Marine biodiversity highlights the importance of fisheries to the livelihoods of stakeholders in rural communities.
	Proportion of low lying land	The proportion of land that is low-lying highlights the vulnerability of infrastructure and production to increases in sea level and more extreme events.
	Access to water(taking into account quality and quantity)	Sufficient quantities and quality of water are fundamental to existence and are a key limiting factor in the sustainability of rural livelihoods.
Physical	Access to energy sources	This indicator includes all types of energy, i.e. renewable and non-renewable and captures how effective energy production is, as well as the diversity of its production.
	Water storage and transfer infrastructure	The storage and transportation of water is necessary for existence and poor infrastructure is a key limiting factor for developing sustainable rural livelihoods.
	Infrastructure in low lying areas (proportion there of)	The existence of infrastructure in low-lying areas indicates vulnerability to future climate and sea level changes.

	Utilities e.g. drainage and effluent disposal; power supplies	Captures the effectiveness of current infrastructure to resolve drainage, waste and effluent problems. This is linked to health issues that may be impacted by future climate and sea level changes.
Physical	Access to energy sources	This indicator includes all types of energy, i.e. renewable and non-renewable and captures how effective energy production is, as well as the diversity of its production.
	Water storage and transfer infrastructure	The storage and transportation of water is necessary for existence and poor infrastructure is a key limiting factor for developing sustainable rural livelihoods.
	Infrastructure in low lying areas (proportion there of)	The existence of infrastructure in low-lying areas indicates vulnerability to future climate and sea level changes.
	Utilities e.g. drainage and effluent disposal; power supplies	Captures the effectiveness of current infrastructure to resolve drainage, waste and effluent problems. This is linked to health issues that may be impacted by future climate and sea level changes.
Financial	Ability to generate income (including per capita income)	A stakeholder's income will affect their ability to change and adapt to climate and sea level changes.
	Remittances	Remittances received from overseas or distant livelihood members offers diversity in the sources of income that a rural livelihood stakeholders can access. This income provides some resilience to change, especially when it is not dependent on tourism or agriculture. Income from remittances can help facilitate changes to climate and sea level rise.
	Access to development assistance	The ability of a country to access aid or credit is positively correlated with the degree to which new infrastructure can be developed. Infrastructure, in turn, facilitates adaptation to climate and sea level changes.

Table 10 Indicators used to consider the vulnerability of atoll and coral islands PICs to climate change.

Capital	Indicator	Rationale
Human	Population growth, density and age structure; preparedness to migrate	Captures a number of issues: greater numbers of people increase the capacity to work together; migration has potentially positive and negative impacts on the ability to adapt to climate and sea level changes; population demography affects the willingness to change.
	Personal productivity	More productive people have a greater ability to produce food and engage effectively in adaptation measures.
	Skill levels; formal education levels; access to education; understanding and communication capacity of agricultural research and extension; existence of traditional knowledge	Greater skills and knowledge (i.e. formal training, practical experience and indigenous knowledge) provide the capacity to use resources effectively and generate new ideas to cope with challenges.
	Health status, disease burden	Health status and disease burden is positively correlated to a person's capacity to implement changes in response to climate and sea level change. Stakeholders pre-occupied with basic survival may not be willing or able to adapt.
	Risk profile; knowledge of and access to climate change information	Stakeholders with existing awareness and access to programs dealing with climate change will already have a base upon which to develop and implement response strategies.

Social	Strength of community groups and traditional governance; community-level planning; mechanisms for sharing information; communication	Active community groups provide a ready access point for engagement, group learning and the spread of effective new ideas that may offer adaptation to climate and sea level changes.
	Ability to access education; education systems; traditional knowledge	A positive correlation exists between access to formal and informal learning institutions and the spread of effective adaptation options.
	Gender roles and gender based knowledge	Women can play a valuable role in reducing livelihood vulnerability - in some cultures the contribution of women is suppressed, whilst on other islands traditional societies are matriarchal and enhance the role of women.
	Access to support groups; supporting institutions; emergency management	Institutional support from governments and NGOs facilitates the spread of improved resource management practices and assists in coping with challenges such as climate and sea level change.
	Decision-making structures from community to national level (including religious and gender institutions); type of government; national level planning; civil society; international relations; land tenure systems; effective markets	Effective government and community decision-making bodies can facilitate efforts to cope with climate change. Non-effective bodies are likely to impede adaption to climate and sea level changes.
Natural	Availability of terrestrial and marine resources e.g. forestry, marine, fisheries, good soil; arable land and soil type; proportion of suitable land that is unutilised; condition of agricultural land; proximity to sustainable potential	The availability of good quality natural resources will improve the range of options available to rural livelihood stakeholders when developing and implementing adaptation strategies to address climate and sea level changes.
	Elevation; geology; geomorphology; landscape stability; erodibility	Accessibility to good quality land reduces the risk of hazards faced by rural livelihood stakeholders. Access to good quality land increases the range of options available to stakeholders to adapt.
	Climate and weather patterns; potential for renewable energy	Reflects the present and future potential risks faced by rural livelihood stakeholders due to climate change and the potential for climate and weather patterns to provide alternative options for renewable energy.
	Conservation areas	Acknowledgment of the fundamental dependence of human existence on the environment and the need to manage and protect it. Conservation areas can positively impact on the recovery rate of an area following disturbance (i.e. extreme events related to climate and sea level change).
	Access to fresh water and resource type	Reflects the current baseline of availability and access to fresh water and its source, together with the potential for climate change to impact on this.
Physical	Communication infrastructure (including internet)	Better communication infrastructure improves the communication of adaptation options and the information upon which stakeholders can base changes in behaviour and their response to risk.
	Climate protection infrastructure; preparedness of infrastructure; monitoring facilities for climate, sea level rise, groundwater contamination etc	Reflects the degree to which present infrastructure is capable of buffering impacts resulting from a change in climate or sea level.

	Crop varieties; animal breeds; R&D infrastructure	A greater range of adaptation options will be available to those stakeholders who can access technological options such as climate-ready crop varieties.
	Water resources (including irrigation) and transport infrastructure	More flexible water resources and transport infrastructure provide greater capacity for rural livelihood stakeholders to effectively adapt to climate and sea level change.
	Proportion of population that has access to agricultural machinery; the amount of processing plants, health and education infrastructure and waste management facilities	Rural livelihood stakeholders will be better able to alter their vulnerability to climate and sea level change if they have access to technology and infrastructure.
Financial	Credit schemes (household and national); trust funds	Increased access to credit and money more readily facilitates transitions to new livelihood options and more generally provides a buffer to climate and sea level change impacts.
	Overseas aid (including agreements for these)	Access to overseas aid increases the amount of resources that can be accessed during time of stress.
	Regular access to cash income; remittances flow	Regular access to a cash income or remittances will smooth out fluctuations in income and provide financial security with which to consider adaptation options.
	Debt/equity at local to national scales; balance of trade; currency value	High debt and inequity of wealth during periods of disturbance increases stress on limited resources and constrains the development of alternative adaptation options.

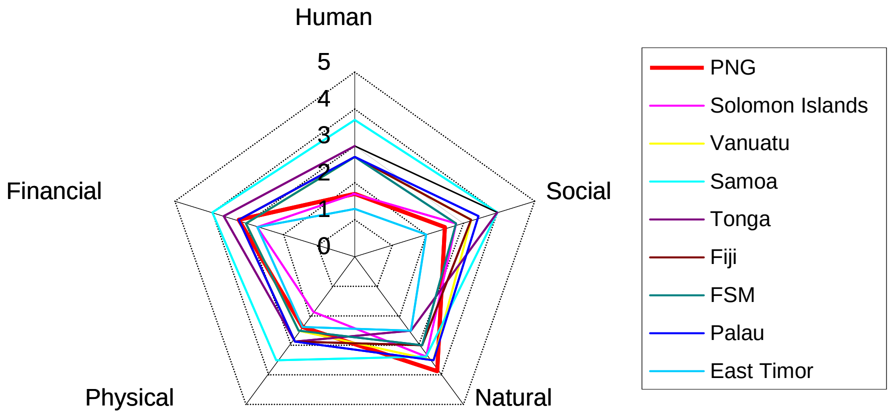

Fig. 7 Livelihood analysis summary graph for volcanic PICs. Adaptive capacity to climate change projections for the year 2050 is considered to be adequate for capitals rated 5, partially adequate for those rated 2 to 3 and insufficient for those rated 0.

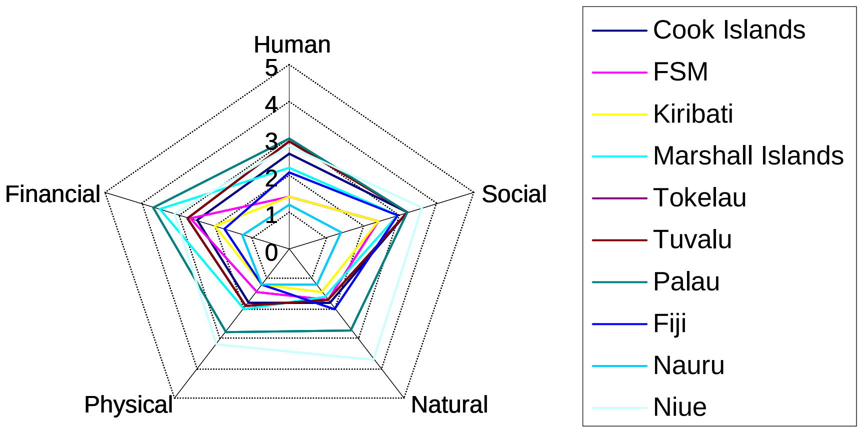

Fig. 8 Livelihood analysis summary graph for atoll and coral PICs. Adaptive capacity to climate change projections for the year 2050 is considered to be adequate for capitals rated 5, partially adequate for those rated 2 to 3 and insufficient for those rated 0.

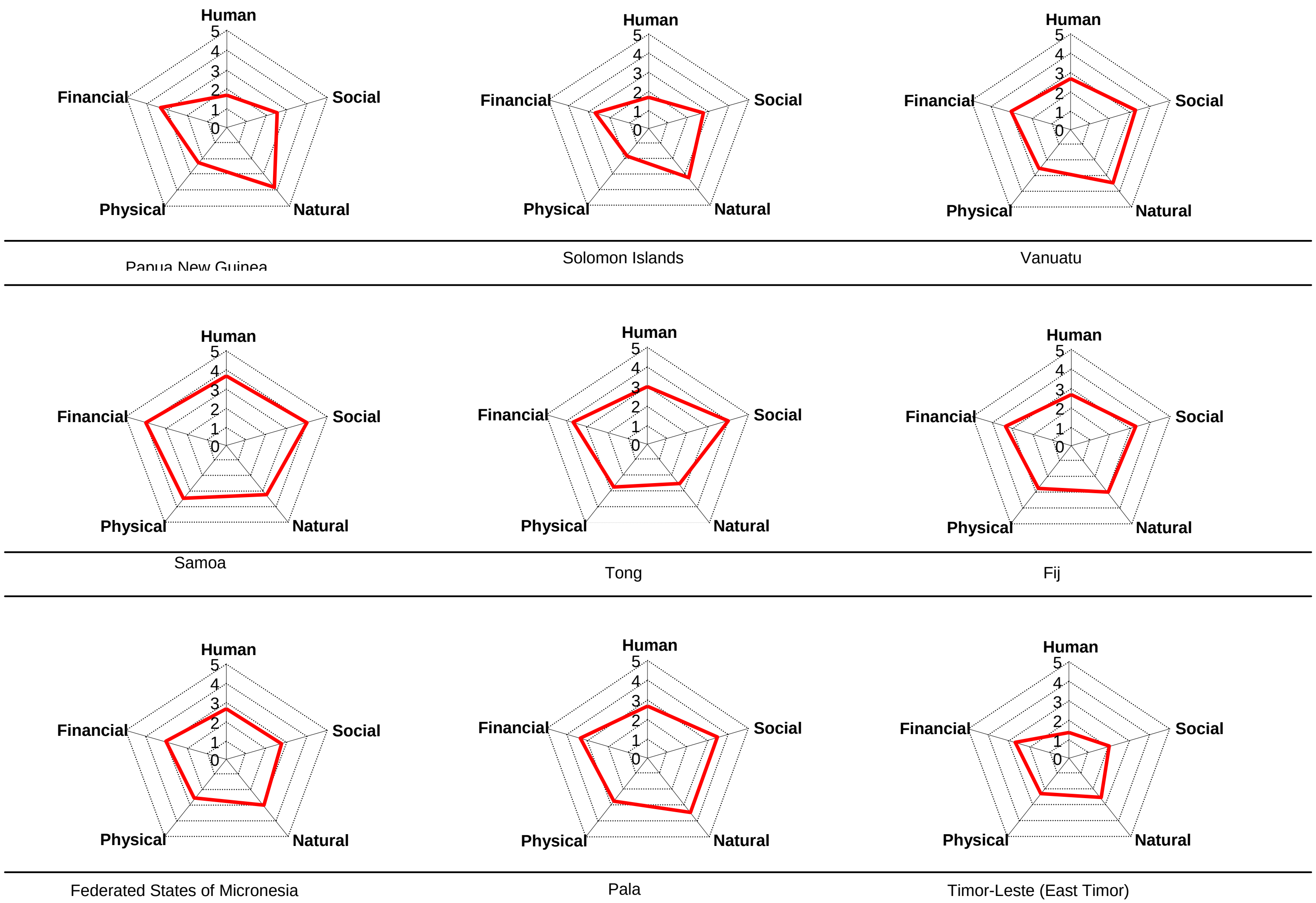

Fig. 9 Livelihood analysis summary graphs for volcanic PICs. Adaptive capacity to climate change projections for the year 2050 is considered to be adequate for capitals rated 5, partially adequate for those rated 2 to 3 and insufficient for those rated 0.

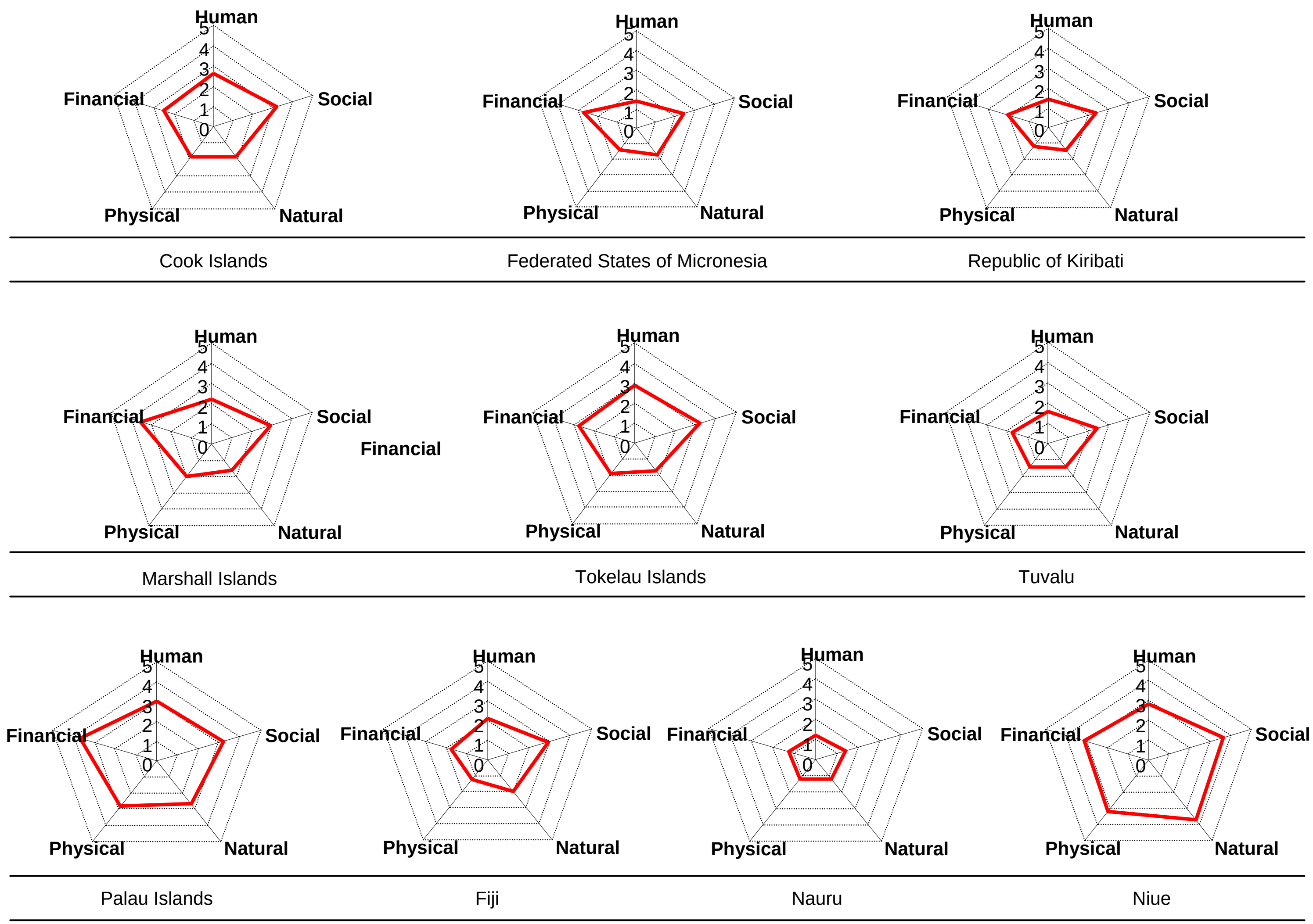

Fig. 10 Livelihood analysis summary graphs for atoll and coral PICs. Adaptive capacity to climate change projections for the year 2050 is considered to be adequate for capitals rated 5, partially adequate for those rated 2 to 3 and insufficient for those rated 0.

Table 11 Livelihood analysis mean values for all Pacific volcanic island countries included in the study.

Country	Island type	Capitals					Mean
		Human	Social	Natural	Physical	Financial	
PNG	Volcanic	1.7	2.5	3.8	2.3	3.3	2.70
Solomon	Volcanic	1.7	2.8	3.3	1.8	2.7	2.42
Vanuatu	Volcanic	2.7	3.3	3.5	2.5	3.0	2.98
Samoa	Volcanic	3.7	4.0	3.3	3.5	4.0	3.68
Tonga	Volcanic	3.0	4.0	2.5	2.8	3.7	3.18
Fiji	Volcanic	2.7	3.3	3.0	2.8	3.3	3.00
FSM	Volcanic	2.7	2.8	3.0	2.5	3.0	2.78
Palau	Volcanic	2.7	3.5	3.5	2.8	3.3	3.15
East Timor	Volcanic	1.3	2.0	2.5	2.3	2.7	2.15

Table 12 Livelihood analysis mean values for all Pacific atoll and coral island countries included in the study.

Country	Island type	Capitals					Mean
		Human	Social	Natural	Physical	Financial	
Cook Is	Atoll	2.6	3.2	1.8	1.8	2.5	2.38
FSM	Atoll	1.4	2.4	1.7	1.4	2.7	1.91
Kiribati	Atoll	1.4	2.4	1.4	1.2	2.0	1.68
Marshall Is	Atoll	2.2	2.9	1.6	2.0	3.5	2.44
Tokelau	Atoll	2.9	3.2	1.7	1.9	2.8	2.49
Tuvalu	Atoll	1.6	2.4	1.4	1.4	1.8	1.71
Palau	Coral	3.0	3.2	2.7	2.8	3.7	3.07
Fiji	Coral	2.1	2.9	2.0	1.2	1.8	1.99
Nauru	Coral	1.2	1.4	1.2	1.2	1.3	1.25
Niue	Coral	2.8	3.6	3.7	3.2	3.1	3.29

4.2.1 Key attributes of vulnerability across the Pacific

Although the SLA was conducted independently by two groups at the workshop in Fiji, a number of the vulnerability indicators chosen by the participants were found to be common to both volcanic and atoll and coral PIC breakout groups. In terms of human capital all participants agreed that population demographics and the ability of rural stakeholders to undertake productive activities were major determinants of vulnerability. There was some variability in the scoring of individual countries for population demographics, with the general thrust of the participants' argument being that population pressures would negatively impact on agricultural and the natural resource base, forcing many to consider migration as an adaptive livelihood strategy. Personal productivity was seen to reflect the health and nutritional status of rural stakeholders, which was generally considered to be poor across the Pacific. Rising food prices are only likely to increase currently high levels of food deprivation and further reduce the health and nutritional status of the poorest in rural societies (FAO, 2008*a*; Rogers, 2008).

The importance of social networks and traditional governance was the only social indicator common to both volcanic and atoll and coral PIC breakout groups. This indicator was generally scored high by the participants, reflecting not only the present existence and effective functioning of these institutions, but also their importance in future strategies aimed at reducing vulnerability.

The indicators of vulnerability used to consider natural capital within the volcanic and atoll and coral breakout groups corresponded closely, with both groups independently considering the availability and conservation of natural resources and biodiversity, island geomorphology and in particular the extent of low lying land, and access to good quality water as being important. There was strong sentiment expressed by the participants about the need to protect managed and natural resources to avoid further increasing vulnerability to climate change. Some rural stakeholders were thought to manage their natural resources considerably better than others. The generally low scores given to all PICs in regard to geomorphology reflected the importance of protecting low lying areas found throughout the Pacific region, regardless of island type. Low lying areas and costal environments generally contain fertile ecosystems that attract settlement by many rural populations. Clearly, access to sufficient quantities of good quality water is a basic necessity for all rural stakeholders in the Pacific and the range of scores given by the participants reflected the disparity in, and importance of, this natural capital across the region.

Closely tied to the access and availability of water is the availability of physical infrastructure (capital) for the transportation of water. Both breakout groups considered this to be a key indicator of vulnerability and generally ranked all PICs in the Pacific as being poorly endowed.

Financial capital common to both breakout groups was focussed on the importance of accessing credit, either through domestic institutions or from overseas via remittances or aid agencies. In general, domestic credit opportunities were considered limited, with many rural stakeholders basing adaptive livelihood strategies on financial capital sourced from outside their country.

4.2.2 Volcanic

The workshop participants rated volcanic PICs from most to least vulnerable as follows:

> **East Timor > Solomon > PNG > FSM > Vanuatu > Fiji > Palau > Tonga > Samoa**

This ranking is based on the mean value of the five capitals (Table 11). In general, volcanic PICs have relatively better access to social and natural capital, than human, physical and financial capital, with the exception of Tonga and Fiji which both have relatively more access to financial, compared to natural capital.

Volcanic - social capital

The indicators deemed by the workshop participants to reflect social capital in the volcanic PICs included access to information, crime rate, social networks and traditional governance (Table 9). The extensive radio and newspaper coverage on islands in Fiji, Tonga, Samoa and Palau suggest that the amounts of social capital that rural livelihood stakeholders have access to is both high and widespread in these countries and can therefore help facilitate the spread and uptake of new information. Having access to information such as new cultivars and alternative management practices will positively influence the ability of stakeholders to adapt to climate change. The geographic spread of islands in countries like FSM however, is a major challenge to developing effective information networks and media coverage, but the strong social networks that operate in some countries may offer an alternative means of information exchange.

Crime rate and the maintenance of traditional governance structures were identified by the workshop participants as additional indicators of social capital likely to influence the capacity of rural livelihood stakeholders to adapt to climate change. The extent and frequency of crime across the volcanic PICs appears to vary greatly and was noted to have changed in recent years. Vanuatu was considered to have one of the lowest crime rates across the Pacific and recent improvements were noted in the Solomon Islands, but the high rate of crime and unemployed youths in East Timor and the inter-racial conflicts in Fiji are examples of major impediments to the development and implementation of effective enabling strategies aimed at reducing vulnerability. Reliance on traditional governance structures to address such issues may not be possible where these have been weakened by external factors, as seen with the American influence in FSM and Palau. The ranking of the volcanic countries by the workshop participants revealed a generally negative relationship between the presence of strong social networks and traditional governance structures, and the rate of crime in a country.

Volcanic - natural capital

Natural capital in volcanic islands was assessed using indicators of terrestrial and marine biodiversity, the amount of low-lying land and access to good quality water (Table 9). The observed gradient across the Pacific region from west to east of decreasing biodiversity was reflected in the participants' rating of volcanic countries, with PNG scoring high due to its extremely high levels of both terrestrial and marine species and a central source of diversity for many major tropical crops. High biodiversity was seen by the workshop participants as underpinning the environment upon which rural livelihoods are developed and is therefore essential in providing resilience to changes in climate. Encouragingly, the vulnerability of biodiversity in PNG is rated lowest in the EVI biodiversity sub-index.

The most vulnerable countries in terms of terrestrial biodiversity were seen as Tonga and East Timor. The high vulnerability of biodiversity in Tonga is also reflected in the EVI biodiversity sub-index. Marine diversity was considered generally good across all Pacific countries and important in terms of an alternative food supply and hence, food security.

Despite the steep relief found on many volcanic islands, there are areas of low lying land and highly productive deltas and plains. Occupation of these areas by rural communities renders all of the volcanic islands in the Pacific vulnerable to sea level rise to some degree and the related impacts from climate change (e.g. increased frequency and extent of storm surges). Samoa and Tonga were considered particularly vulnerable, although the higher altitudes found in countries like East Timor are likely to make them less sensitive to sea level rise. The high vulnerability shown by the relief indicator in the EVI for PNG most probably relates to the expanse of low lying area in the west of West Papua.

Present access to good quality water is periodically insufficient in many volcanic countries in the Pacific. For example, the Western Province of PNG, East Timor and the Fijian islands regularly experience water shortages during the dry season, and water quality may be particularly poor in PNG. Less vulnerable countries include Vanuatu and Samoa, where there is a good supply of high quality surface water. Importantly, water transportation infrastructure is good in both of these countries and has kept up with increasing demand. Whilst the Solomon Islands have very few really dry areas, they too were considered vulnerable by the workshop participants. Out of the islands defined as volcanic in this study, the EVI water sub-index (captures water vulnerability issues) shows Fiji, Tonga, and FSM water resources to presently be particularly vulnerable.

Volcanic - human capital

The indicators selected by the workshop participants for human capital were health and nutrition, population growth and density, and migration (Table 9). Health and nutrition was generally considered to be low across all volcanic PICs, rendering residents with a generally low capacity to adapt to the challenges of climate change. Samoa was considered to be the least vulnerable country due to its ability to access external resources.

The ranking given by the workshop participants suggests that the rapid population growth seen in many volcanic Pacific countries (e.g. PNG, Solomon Islands), increasing urbanisation and poor health and nutrition status are all related and negatively impact capacity to adapt to climate change. In some cases, overseas migration has reduced population growth, for example in Fiji, however the high concentration of citizens remaining in urban areas means there is continued pressure on limited resources. Migration from rural areas into the cities and major centres is generally considered to have a negative impact on food security, whereas migration to destinations outside of the Pacific offers access to a wider pool of resources and reduced vulnerability to shocks, trends and seasonality.

Volcanic - physical capital

The indicators selected by the workshop participants for physical capital were access to energy, water storage and transfer infrastructure, infrastructure in low lying areas and provision of utilities such as drainage and effluent disposal (Table 9). Access to energy was considered in terms of present usage and supply, as in general, rural stakeholders across the Pacific are not highly dependent on external energy so are unlikely to consider themselves very sensitive to shortages or price rises. East Timor is one example where there are plentiful energy resources within the country (e.g. natural gas), but it is questionable whether these are available to rural stakeholders.

Where there is demand for external energy sources in rural areas, those countries that have widely dispersed islands such as Palau, may find that the energy supplied on outer lying locations with few alternative energy options are highly sensitive to climate change impacts. Some non-fossil fuel sources are either in operation or are planned for various locations across the Pacific, including hydro-electricity in Fiji, co-generation of electricity from bagasse from sugarcane milling in Fiji, and various biofuels (e.g. coconut). However, Fiji is typical of many islands where increasing energy demand has meant that the present supply (e.g. from hydro sources) is insufficient. Development of climate change adaptive and transformative response strategies must therefore take future energy requirements into consideration.

Islands such as Samoa, which have suitable biophysical conditions for growing coconut, have the potential to utilise the oil as a fuel source, but less suitable areas (e.g. Palau) will be exposed to external supply fluctuations. With a limited tolerance of sea water inundation and high winds and an optimal mean temperature requirement of 27°C and narrow diurnal variation of only 6-7°C, future changes in climate may alter current production areas for coconut with implications for future sources of biofuel.

Increases in crop and animal production resulting from projections of increased rainfall across the Pacific will only be realised if effective water storage and transfer infrastructure is available. The workshop participants considered the infrastructure and widespread use of water tanks on houses in Samoa, reduced vulnerability to changes in rainfall. Moreover, good infrastructure connections between the islands of Savai'i and Upolu extend this capacity across much of the country. However, in other countries water and waste disposal infrastructure is either insufficient (e.g. PNG, Fiji, FSM) or poorly maintained (e.g. East Timor), resulting in a low capacity to adapt.

With projections of rising sea levels, future provision of water and other infrastructure must be located sufficiently above sea level to avoid inundation. The infrastructure in many Pacific volcanic countries is highly vulnerable. For example, PNG and Samoa has extensive areas of infrastructure situated in coastal and low lying areas. In the case of Tonga, the concentration of buildings on the lower side of the island renders them particularly vulnerable to sea level rise. At present the EVI lowlands indicator shows the percentage of land area less than or equal to 50m above sea level and indicates that between 60 and 75% of land on volcanic islands is low lying. Future update of the EVI lowland indicator will refine the measure to 10m above sea level and provide more informative information relating to the vulnerability of low lying areas.

Present activities to reclaim land (e.g. in Fiji, Samoa) will be highly vulnerable to continuing sea level rise if sufficient defences are not developed. Increased vulnerability of key transport infrastructure, such as airports and roads, presently located at or just above sea level (e.g. in Samoa and Fiji), will constrain the future movement of people and resources and therefore their capacity to adapt.

Volcanic - financial capital

The indicators selected by the workshop participants for financial capital were ability to generate income, remittances and access to development assistance (Table 9). Fiji was considered to have the greatest capacity to generate income due to its participation in many domestic and international activities and markets. Countries like Vanuatu and Palau were also seen as having income generating capacity due to tourism and fisheries activities.

More sensitive countries include the Solomon Islands, FSM and East Timor as present incomes in all three countries are low. Further issues include a heavy dependency on imported goods in FSM and past civil conflict in East Timor leaving stakeholders with a low capacity to generate income.

Low capacity to generate income can be supplemented with overseas remittances. These are a particularly important supply of financial capital as they diversify income sources and improved resilience of rural livelihoods to shocks, trends and seasonality, especially when generated from non-tourism or agricultural production activities. A key factor influencing the ability to generate remittances is bilateral employment agreements between PICs and neighbours such as Australia and New Zealand. For example, Samoan, Tongan, and Vanuatu citizens currently work in New Zealand, America offers employment to a citizens from FSM, and the three-year pilot Pacific Island guest worker scheme started in Australia in 2008, will offer 2,500 visas to workers from Kiribati, Tonga, Vanuatu and Papua New Guinea. The visas will offer employment potential for up to seven months in any given year. The focus of this scheme is on the Australian horticulture industry, not only providing a source of financial remittances, but the development of knowledge and skills in commercial fruit and vegetable production.

Development assistance in the form of financial aid and credit from external countries was also considered vital by the workshop participants for fostering an environment conducive to the development and implementation of effective climate change adaptation strategies. Countries, such as the Solomon Islands rely heavily on aid from Australia as most of their foodstuffs, consumer goods, machinery, transport materials and petroleum products must be imported. PNG and East Timor were thought to be the main recipients of aid presently from Australia, reducing their perceived vulnerability in the eyes of the workshop participants. However, development assistance may be only a temporary form of financial capital as shown in the case of Samoa where future foreign aid is being reduced considerably due to demonstrable improvements in the country's development status (and as reflected in the relatively lower vulnerability perceived by the workshop participants during the livelihood analysis as shown in Figure 9). Similarly, political and civil unrest, as seen in the Solomon Islands and Fiji, has the potential to result in a cessation of assistance from outside donors and an increase in vulnerability.

4.2.3 Atoll and coral

The workshop participants ranked atoll and coral PICs from most to least vulnerable as follows:

> **Nauru > Kiribati > Tuvalu > FSM > Fiji > Cook Islands > Marshall Islands > Tokelau > Palau > Niue**

This ranking was based on the mean value of the 5 capitals (Table 12). In general, atoll and coral PICs have relatively better access to social and financial capitals than natural, physical and human capital. Physical capital is the most inadequate capital for atoll and coral countries reflecting in particular, their exposure to sea level rise.

Atoll and coral - social capital

The indicators considered by the workshop participants to reflect social capital in the atoll and coral PICs were the existence of community groups and traditional governance networks, education and traditional knowledge, gender-based knowledge and roles, supporting structures and institutions, and governance and decision making structures (Table 10). Community groups and traditional governance networks were considered by the workshop participants to provide a ready access point for engagement, group learning and the spread of ideas to aid adaptation to climate and sea level changes. Groups and networks were considered to be strong and operational in almost all of the atoll and coral islands, as exemplified by the strong community groups and information sharing seen in Tuvalu, strong traditional decision-making structures in FSM, and traditional groupings operating in Kiribati.

Education and traditional knowledge was also considered important to developing adaptive capacity in rural stakeholders. The ratings given to atoll and coral countries for this attribute correlated strongly with the scoring for community groups and traditional governance networks. Interestingly, in Niue the concentration of relatively low populations of rural stakeholders was considered to facilitate communication, whilst in Palau access to USA affiliated schools enables the transfer of information and skills to aid adaptation to the changing climate. As both countries were rated equally by the workshop participants, this suggests that the two methods of knowledge sharing were seen as similarly effective and to some degree, may be substitutive. Consultation with individual participants after the workshop suggests that the relationship between Tokelau and New Zealand is also likely to increase the education of rural stakeholders in Tokelau.

The traditional role of women in rural communities varies across the Pacific and in general it was considered by the workshop participants that where women had more active participation in decision making and climate change adaptation activities, the livelihood strategies in operation contained greater adaptive capacity than those where women played a passive role. Palau was considered to have a relatively strong adaptive potential, in part due to its matriarchal society.

Access to support groups, supporting institutions and emergency management was seen as facilitating the spread of improved resource management practices and coping strategies. Niue was considered to have relatively greater capacity in this respect than the other atoll and coral countries. In contrast, FSM, Kiribati and Nauru were seen as being particularly poorly endowed due in part to issues relating to isolation, corruption and poor governance. Again assistance from the Pacific's major bilateral partners (Australia, New Zealand, Taiwan and Japan) offer support and emergency management resources that reduce vulnerability (Rogers, 2008).

The operation of effective structures linked to governance and decision making was also selected as an indicator of social capital. All islands were seen to have insufficient structures and/or non-effective bodies likely to impede adaptation to climate and sea level change. Geographic dispersal of islands was considered to impact negatively on the operation of such structures, as exemplified by FSM, but the presence of a relatively stable government, as found in the Marshall Islands, was thought to be a positive feature in reducing vulnerability. Again bilateral agreements between Pacific and non-Pacific countries is likely to improve governance and decision making processes in PICs.

Atoll and coral - natural capital

The indicators considered by the workshop participants to reflect natural capital in the atoll and coral islands were terrestrial and marine resources, physical land attributes, climate and weather patterns and their impact on the potential for generating renewable energy, conservation areas, and sources and access to fresh water (Table 10). Availability of sustainable terrestrial and marine resources positively impacts on the range of future livelihood strategies available to rural stakeholders in addressing climate and sea level change. As noted by the workshop participants in the volcanic PICs breakout group, marine resources across the Pacific are generally plentiful, but terrestrial resources vary considerably with a general gradient of decreasing biodiversity running from west to east across the Pacific. The high levels of tourism and awareness-raising in Palau has resulted in extensive conservation efforts and the protection of much of the biodiversity that underpins rural livelihood strategies in the country and builds ecological resilience.

More widely, in 2006 the Micronesia Challenge was adopted by five Micronesia government entities (FSM, Republic of Palau, Republic of the Marshall Islands, Guam and the Commonwealth of the Northern Mariana Islands). The aim was to "effectively conserve at least 30% of the near-shore marine and 20% of the forest resources across Micronesia by 2020" (http://www.gefcountrysupport.org/docs/14.doc). The Challenge is looking to communities and traditional resource owners to take a significant role in addressing resource management. However, the biggest challenges include lack of financial and human resources to undertake travel to isolated islands within FSM for capacity building. Internet e-mailing and sharing of documents through networks established over many years are being utilised to address this constraint, but it is recognised that this limits communication to State centres. The workshop participants considered the current status of conservation of resources in Palau to be good (quoting areas of 34% and 18%), but very poor generally across FSM, with the exception of Yap.

Physical land attributes, such as elevation, geology, geomorphology, landscape stability and erodibility impacts the vulnerability context in which rural stakeholders operate by increasing their sensitivity to climate change impacts and reducing the range of potential adaptation options available to them. The low-lying nature of all atolls and coral islands render them particularly vulnerable to inundation with further increases in sea level. The EVI lowlands indicator shows many of the coral and atoll islands in the Pacific have up to 75% of land area below 50m. Tuvalu was considered particularly vulnerable having no capacity to adapt, whilst Niue was again considered notable for having extensive capacity to adapt to climate and sea level changes up to the year 2050. This is largely due to the island of Niue rising to an elevation of approximately 70m, with continued slow uplifting resulting from tectonic plate flexure. There is only a small platform around the island which is vulnerable to sea level rise, but this is around 100m wide at the most and unlikely to impact the settlements on higher ground. Although cliff erosion is likely to increase with rising sea levels and an increase in extreme events, the majority of the island is at a sufficient elevation to render it markedly less vulnerability than other atoll and coral islands in the Pacific.

Future climate and weather patterns will influence the potential for developing renewable energy sources, and thereby alter the impact, sensitivity and adaptive capacity of rural livelihoods to climate change. All atoll and coral islands were considered to have little potential for developing these technologies sufficiently to reduce their vulnerability. Most of the countries in the Pacific region are currently heavily dependent on imported fossil fuel, and fluctuations in global oil price have already prompted many to explore alternative sources of energy. In the case of the Marshall Islands a substantial alternative energy push over the past three years has led to nearly half of the remote outer atoll homes receiving donor-funded solar units. However, a state of emergency called in July 2008 resulted in a redirection of alternative energy efforts to the two urban centers to help reduce the use of costly electricity supplied by the government's diesel-fired power plants. This highlights one of the issues surrounding continuity of supply in rural areas. Another issue is noted in a feasibility study conducted prior to the implementation of the solar energy facility in the Marshall Islands and suggests that "…village owned, government owned schemes and individually owned solar units have not worked generally because of inadequate maintenance…." (as cited in Yokwe Online, 2006).

The fifth attribute considered by the workshop participants under the heading of natural capital was sources and access to fresh water (Table 10). This was considered relative to current status as all atoll and coral islands experience water stress. All islands are considered to be negatively impacted with changes in climate despite projections of an increase in rainfall in most seasons in the North and South Pacific by the period 2080 to 2099 (Tables 3 and 4). Niue is considered the least vulnerable due to its present relatively high levels of annual rainfall and abundant groundwater supplies. Whilst the Cook Islands were considered to have "some spare freshwater around" and Fiji is noted for generally receiving abundant rainfall, countries such as FSM, where present water supplies cannot be consumed, will undoubtedly face increasing vulnerability if any increases in rainfall cannot negate the negative impacts of inundation as sea levels continue to rise. The EVI water sub-index shows water resources are vulnerable on all atoll and coral islands, with particular concern for Niue, Solomon Islands, PNG, Tokelau and Vanuatu.

Atoll and coral - human capital

The indicators considered by the workshop participants to reflect human capital in the atoll and coral islands were population, personal productivity, skill and education of research and extension and traditional knowledge, health, and risk profile (Table 10). Features of the population, such as growth rate, density, age structure, and preparedness to migrate, were considered to affect stakeholders' willingness to change their livelihood strategies. Nauru, Tuvalu and Kiribati were considered vulnerable. In the case of Tuvalu, limited land area is a major constraint to the ability of stakeholders to migrate within the country. Consultation with individual participants after the workshop suggests that the relationship between Tokelau and New Zealand is likely to increase the potential for migration and hence reduce the vulnerability of Tokelau to climate change.

High levels of personal productivity were considered by the workshop participants to enable the production of food and engagement in effective climate change adaptation activities. Health and disease status is clearly correlated with personal productivity. Although both indicators were scored independently by the participants, the atoll and coral island countries were ranked similarly, with FSM, Kiribati and Tuvalu were all considered particularly vulnerable.

Skill and knowledge, as reflected by access to and level of education, together with knowledge of traditional practices and an ability to understand agricultural research and extension information, was considered important for effective use of resources and the generation of ideas and technologies to address the challenges of climate change on rural livelihood strategies. Nauru was considered particularly vulnerable due to a combination of economic difficulties, due limited resources, and poor administration. These have meant that education focussed on technology and innovation is not well established. Indeed, one workshop participant noted that student enrolment statistics from the Nauru Department of Education for the period 2000 to 2007 showed a reduction of over 50% of primary school students subsequently entering secondary education. Aside from this, Nauru was also considered to have a weak economy unable to support skilled capacity. The poor health, resulting from limited dietary options, may also contribute to a lack of motivation in Nauru. Highly dispersed populations in countries such as Kiribati was thought to constrain opportunities to migrate overseas. Where there are bilateral relationships with non-Pacific neighbours, such as Tokelau and New Zealand, this will improve the ability to migrate. Knowledge of traditional practices, however, may also negate these limitations and reduce vulnerability.

Existing awareness of potential climate change impacts and exposure to adaptation programs were considered to reduce the general risk profile of rural stakeholders in atoll and coral PICs, with those having prior knowledge being more capable of understanding and acting upon issues. The strong conservation sector in Palau offers a source of information for rural stakeholders, contributing to the development of an enabling environment for adaptation and reduced vulnerability. Similarly, government-run programs in Tuvalu reduce the risk profile of rural stakeholders in that country. However, the dissemination of information poses a particular challenge to countries with high geographic dispersal, as exemplified by the remote residents of the low-lying atolls of the Marshall Islands. Consultation with individual participants after the workshop suggests that the relationship between Tokelau and New Zealand is likely to increase awareness-raising in that country.

Atoll and coral - physical capital

The indicators considered by the workshop participants to reflect physical capital in the atoll and coral islands were communication infrastructure, climate protection infrastructure, climate ready crop and animal varieties and R&D infrastructure, and access to agricultural, health, education and waste management machinery and infrastructure (Table 10). Extensive and effective communication infrastructure was considered by the workshop participants to positively impact the adaptation options and information available to stakeholders to address risks such as climate change.

There is considerable diversity in communication infrastructure across the atoll and coral PICs. The relative affluence of Palau is reflected in it, and Niue, having good communication facilities. Similarly, the reliable power grid and internet access available on the Marshall Islands means that the participants rated the country relatively high in terms of communication infrastructure. In contrast, countries like Kiribati and Tuvalu have little or no internet facilities and poor telephone infrastructure and hence were considered to have low capacity to develop and implement adaptation strategies. Purely providing infrastructure was not considered to be an effective way to address this vulnerability, as skills to maintain communication technologies are also required. Bilateral agreements between Pacific and neighbouring countries are also considered to improve communication infrastructure, as exemplified by Tokelau.

Abundance of physical capital aimed at reducing the impact of climate change (i.e. infrastructure), and consideration of its preparedness for extreme events, together with activities aimed at monitoring potential impact (e.g. through ground water, sea level and climate data collection) were collectively considered by the workshop participants as indicators of a country's capacity to buffer climate and sea level change impacts. All low lying atoll and coral islands were considered generally very vulnerable due to proximity to sea level. Being an uplifted island, Niue is the least vulnerable in this respect, but was still considered to have insufficient adaptive capacity to adapt to the projected changes for 2050. The extent of vulnerability seen amongst the other countries is marginal and based on their perceived ability to implement infrastructure (seen as poor in FSM), rigorousness of building codes (considered relatively good in the Cook Islands) and geographic dispersal (the outlying island of Fiji are relatively more vulnerable than the two main islands).

Access to technological options such as climate-ready crop and animal varieties, and R&D infrastructure was considered to aid the development of adaptation options. All atoll and coral PICs were seen as being particularly poorly endowed and hence highly vulnerable to changes in climate and sea level. The notable exception again being Niue, largely due to relatively lower vulnerability of communities and their physical capital on the high elevations of the island. In other countries, such as Fiji, where there is presently a program of research being undertaken to identify and develop climate ready crops, the geographic dispersal of the country means that outer lying atoll and coral islands may still be poorly serviced. Distribution of climate adaptation technologies must therefore aim to reach those most vulnerable.

The extent of water and water transport infrastructure is positively correlated with the ability of rural livelihood stakeholders to effectively adapt to climate and sea level change. All Pacific atoll and coral island were considered by the workshop participants to be poorly endowed with water resources and the necessary infrastructure to transport it to rural areas. Kiribati, Tokelau, Fiji and Nauru were all thought to be particularly vulnerable. Rural livelihoods in Kiribati, for example, presently rely on well water and limited water transport infrastructure. Again, the geographic dispersal of islands has resulted in increased and island-specific vulnerabilities, as seen in FSM. The relative affluence in Palau is reflected in the good water treatment facilities on the island. Niue is also considered to one of the less vulnerable countries in terms of water treatment.

Rural livelihood stakeholders were considered to be better able to alter their vulnerability to shocks, trends and seasonality with increased access to agricultural, health, education and waste management technologies and infrastructure. All PICswere again considered particularly vulnerable, with FSM deemed to have almost no capacity to adapt to the climate change projections for the year 2050 as waste and health infrastructure continues to deteriorate. The relative affluence of Palau is more likely to provide some, yet still insufficient, adaptive capacity to climate change.

Niue is similarly, less vulnerable than most atoll and coral islands in terms of essential infrastructure. The existence of bilateral agreements between Pacific and neighbouring countries has the potential to provide access to these technologies and infrastructure.

Atoll and coral - financial capital

The indicators considered by the workshop participants to reflect financial capital in the atoll and coral PICs were the availability of credit schemes and trust funds, recipients of overseas aid, access to cash income and the amount of debt in the population and equity of wealth (Table 10). The workshop participants considered access to financial funds facilitated the transition to new livelihood options and more generally provided a buffer to climate and sea level change impacts. The level of access to credit schemes and trust funds was not known for the Marshall Islands or Kiribati, but rural stakeholders in all other countries were considered to have little or no access to credit. One example of a community-run trust fund was noted for Tuvalu, where the local community group takes decisions regarding the distribution of money to members.

Overseas aid is important for providing access to resources during times of stress. Historical ties are reflected in many of the associations between aid donor countries and atoll and coral island PICs. For example, the Cook Islands, Tokelau and Niue all receive assistance and have favourable links with New Zealand, whereas the Marshall Islands receive assistance from the USA. Political and civil unrest in Fiji has resulted in sanctions being imposed on Fiji’s military regime by both New Zealand and Australia, resulting in aid only being supplied to the Fiji Red Cross and non-governmental relief organisations.

Similarly, remittances received from abroad by rural stakeholders help to smooth out fluctuations in income and offer greater financial security with which to consider adaption of livelihood strategies. The workshop participants considered that all atoll and coral islands rural stakeholders received insufficient remittances to enable adequate adaptation to climate change projections for the year 2050. Bilateral agreements with non-Pacific neighbouring countries facilitate overseas employment opportunities for countries like Tokelau. The many US armed forces personnel visiting Palau provide a substantial contribution to the local economy, and most likely foreign exchange earnings.

The workshop participants considered that lack of debt and greater equity of wealth across all levels of society (i.e. individual rural stakeholders, communities, local, regional and national governments), was likely to reduce stress on already limited resources and facilitate the development of alternative adaptive strategies during periods of disturbance. The debt burden and equity of wealth in all atoll and coral PICs is likely to exacerbate stress on resources and constrain adaptation. The less vulnerable countries are likely to be Palau and Niue due their relative affluence.

4.2.4 Summary

The above text, together with Tables 9, 10, 11 and 12 and Figures 7, 8, 9 and 10, detail the relative accessibility of capital resources by rural stakeholders and hence their likely vulnerability to a change in climate and sea level by the year 2050, as perceived by the workshop participants. Vulnerability in this context has been considered by the workshop participants as a function of the impact of climate related hazards on rural livelihoods in each country, their relative sensitivity and the potential adaptive capacity resulting from access to human, social, natural, physical and financial capital.

The SLA indicates that rural livelihoods in all PICs have insufficient access to human, social, natural, physical and financial capital to adequately adapt to climate change and are therefore vulnerable. Whilst this conclusion has previously been identified in many individual country and regional studies, further knowledge and analysis appears to be needed to better understand the nature, causes and dynamics of vulnerability within individual countries and the potential transferability of livelihood strategies that confer adaptive capacity (e.g. FAO, 2008*b*).

This study addresses this shortcoming by taking a country level perspective of the relative vulnerability of PICs and considers stakeholder access to the five key capitals upon which livelihoods strategies are developed and outcomes achieved. From this analysis it is possible to consider why rural stakeholders in some countries operate in a context of high vulnerability, whilst others have relatively greater adaptive capacity and hence are less vulnerable to external drivers such as climate change. These findings may be used to determine the attributes most likely to foster enabling environments for those stakeholders most vulnerable to climate change by enhancing their capacity to improve food security in a changing climate.

The high vulnerability of rural livelihoods to climate-related hazards in the Pacific is largely due to their heavy reliance on access to natural capital, generally inadequate or poorly maintained physical capital (e.g. sewage infrastructure), the weakening of traditional social networks inadequately compensated for by the social capital developed through closer relationships with external agents, (e.g. aid agencies), and scarce human and financial capital. In particular, degradation of the natural resources upon which rural livelihood strategies are based, are likely to negatively impact desirable livelihood outcomes such as increased income and the sustainable use of the natural resource base. Sustainable natural resource use underpins food security for the vast majority of rural livelihood stakeholders (Hammill et al, 2005).

Although the SLA did not explicitly compare the vulnerability of volcanic to atoll and coral PICs, the workshop output suggests that the generally reduced exposure and sensitivity of high volcanic islands to climate-related hazards, has enabled their accumulation of capital assets, continued development of adaptive capacity and hence generally lower levels of vulnerability compared to atoll and coral islands. The importance of favourable natural assets on agricultural development is well recognised (Diamond, 2005).

The workshop participants ranked volcanic PICs from most to least vulnerable as follows:

> **East Timor > Solomon > PNG > FSM > Vanuatu > Fiji > Palau > Tonga > Samoa**

The workshop participants ranked Pacific atoll and coral islands from most to least vulnerable as follows:

> **Nauru > Kiribati > Tuvalu > FSM > Fiji > Cook Islands > Marshall Islands > Tokelau > Palau > Niue**

In contrast to the EVI climate change sub-index analysis, the SLA ranking above shows East Timor to be relatively highly vulnerable to climate change. It is considered that this difference is largely due to the use of data for Indonesia as a proxy indicator for East Timor, and it is considered in this instance that the Indonesian data is inadequate to capture the particular vulnerability found in East Timor. The least vulnerable of the volcanic PICs to climate change was considered by the workshop participants to be the Samoa.

In terms of atoll and coral islands, both the EVI climate change sub-index and the SLA suggest that Nauru is the most vulnerable of the atoll and coral PICs. This is in part due to its frequency and mix of dry spells and excessive rainfall events, low provision of land area or habitat types and diversity, together with widely dispersed land areas and predominantly low lying topography. In addition, high densities of human population per unit of land area, particularly in coastal regions, has resulted in the loss of native vegetation and stress on coastal ecosystems.

Using the EVI Palau features as one of the least vulnerable atoll and coral PICs in terms of both environmental attributes (i.e. using the EVI climate change sub-index) and when taking wider economic and social considerations into account (i.e. using the SLA). Comparison of EVI climate change sub-index ranking results with the SLA findings, particularly for East Timor, highlighting the importance of obtaining a holistic understanding of all key drivers impacting rural livelihoods, in addition to climate change and environmental factors.

In summary, the EVI offers a limited assessment of vulnerability in contrast to the SLA assessment which provides an understanding of the vulnerability context within which rural stakeholders are operating and the factors determining why one country is more vulnerable than another. Knowing why exposure, sensitivity and adaptive capacity varies with access to capital assets, is useful in informing the allocation of limited development, and more specifically, climate change adaptation resources.

4.3 Critique of SLA methodology

Like all qualitative PRA research techniques, SLA can be critiqued on the basis of being prone to bias because of reliance on interpretation; based on only a small sample size of respondents, and time consuming (DFID, undated). In this scoping study we have tried to address biases and self-interest being expressed by respondents seeking to attract R&D investment in their country by inflating its perceived vulnerability. In the case of the volcanic breakout group, this was done through an informal mediating process initiated by the participants during lively debates on relative scoring. This mediating process was less integrated into the scoring process undertaken by the atoll and coral breakout group, as individual participants took responsibility for determining the relative scoring of all countries across a single indicator. The relatively reduced amount of group debate taking place in the atoll and coral breakout group was therefore supplemented with a more formal mediating activity that took place after the workshop. This consisted of individual stakeholders from the volcanic breakout group, who showed no obvious bias, being asked to comment on the relative ratings determined by the atoll and coral breakout group. Changes to ratings were made as a result of this subsequent mediating activity, but this was due to the mediator’s relatively greater knowledge of some individual atoll and coral PICs than that collectively contained in the atoll and coral breakout group. Formal mediating sessions could have been conducted by the breakout groups themselves on their own ratings, but time did not permit this to happen on the day of the workshop.

It is acknowledged that the small size of the breakout groups (8 or 9 people in each group) resulted in some skills and knowledge of climate change impacts, sensitivity and adaptive capacity not being represented. Whilst this may have been addressed in part by a larger number of participants being included in the participatory process and/or repeated SLA workshops being undertaken with different stakeholders, both approaches required resources beyond the means of this scoping study. We therefore sought to broaden the skills and knowledge represented by the participants in the workshop to cover multiple disciplines and knowledge of PICs (see Appendix 4 for a list of workshop participants, and Appendix 5 for analysis of their experience in the field of climate change.

The SL framework is considered to be a PRA tool and as such did not require an extensive investment of time by either the workshop participants or the project team undertaking this study. It is recognised that qualitative PRA tools are likely to fall short of providing the quantitative evidence preferred by funding agencies and policy makers keen to demonstrate impacts from funded activities. A clear trade-off exists between qualitative tools that provide contextual detail (e.g. SLA), and qualitative measures determined using simple, reductionist tools (e.g. the EVI). By being able to incorporate quantitative data, SLA offers a means of combining both data sources. By using the SLA in this study, we were able to collate a substantial amount of contextually relevant information, from which it was possible to infer a picture of the relative vulnerability of 16 PICs and more importantly, an understanding of the nature, causes and dynamics of vulnerability within individual countries. This information and analysis is presented as a broad scoping study to inform further qualitative and quantitative analysis. Indeed, evidence suggests that a combination of both qualitative and quantitative methodologies may yield the most informative and effective impacts in poverty alleviation (Farrington et al, 1999).

A further feature of the SLA, like all tools of a similar nature, is that it fails to convey changes over time or evolving circumstances (Ellis, 2000). We have partially addressed this by asking the workshop participants when estimating vulnerability to consider climate change projections for the year 2050 and likely access to livelihood assets at that time given the current situation.

On a more conceptual level, the SL framework has also received critiques regarding three main concerns: the principles underlying the approach appear to lack a unifying purpose, an omission of essential components in SLA, and incompatibility with other approaches (see Carney (2002) for detailed responses to these claims).

The SL framework does not provide a set of recipes for solving problems. Rather it can be used to identify ways of formulating policies to overcome constraints and allow assets to be utilised productively (Ellis, 2000). However, the utility of the framework is subject to the application to which it is being applied, and the skill of the practitioners using it and their ability to firstly, courier participants through the analyses, and secondly, interpret the data that has been collected.

From this brief review of the utility of the SL framework, it is evident that, as with any tool, its usefulness must be determined within recognised limits. As it has been used in this study, the SL approach has provided a conceptual framework that allows integration of the consideration of both the impacts of climate change and adaptive capacity as a function of human, social, natural, physical and financial capital (Nelson et al, submitted). Conducting a SLA provided not only a holistic measure of vulnerability, but more importantly, a greater understanding of the nature of the factors contributing to vulnerability. The SLA also emphasised a number of core principles of good development practice, such as being people-centred, responsive and engendering stakeholder participation; providing a cross-sectoral focus on multiple levels (local, sectoral and regional, and national), and embracing a dynamic and sustainable approach (Ashley and Carney, 1999).

5.0 Research and development opportunities

This section of the report offers recommendations for future research opportunities in the area of climate change adaptation for rural livelihood stakeholders in PICs. The methodology used to construct these recommendations includes consideration of (a) the broad scope of key knowledge gaps identified during the course of this study, (b) public values elicited from workshop participant contributions to the Fiji workshop, and (c) knowledge and experience of science R&D technologies currently available (Fig. 11). As indicated by the two way arrows shown in Figure 11, the analysis of recommendations has been conducted as an iterative process involving feedback and input from the workshop participants and AusAID representatives.

Public values (Boseman and Sarawitz 2005) are considered in this context as desirable outcomes for rural communities resulting from R&D in climate change adaptation, as generally agreed and expressed by representatives living and working in the Pacific. The SLA indicators in Tables 9 and 10 have been used as a proxy for defining the public values necessary to reduce vulnerability to climate change in Pacific rural communities (Table 13). Due to the commonality found in many of the indicators used by both the volcanic and atoll and coral workshop breakout groups, public values have been amalgamated across both island types. The public values have also been categorised into the 5 capitals used in the SLA for consistency.

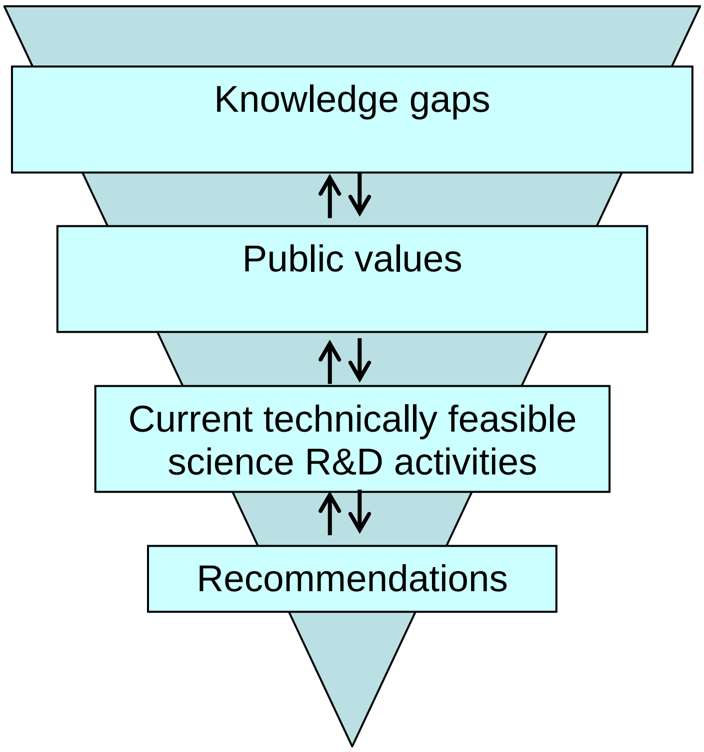

Fig. 11 Method used to narrow R&D investment decision-making from the identification of knowledge gaps, to common public values and desirable outcomes from R&D elicited from workshop participants' contributions. These have been filtered down to those public values that can be addressed with currently available technologies to produce recommendations for science R&D aimed at reducing the vulnerability of rural livelihood stakeholders.

Considering climate vulnerability investment in the Pacific in terms of knowledge gaps, public values and current science R&D technologies, enables a narrowing of focus from a broad appraisal of what is currently unknown on the issue, to knowledge gaps that need to be addressed in order to result in desirable outcomes for rural livelihood stakeholders, and finally to science R&D activities aimed at reducing vulnerability to climate change that can feasibly be undertaken with currently available technologies. This approach has been adopted in response to the need to strengthen AusAID's evidence-based approach to aid programs and investment decision-making and the need to take immediate action to reduce vulnerability in rural livelihoods in the Pacific.

Explicit statement of these public values at the outset of investment policy development and strategic planning may avoid duplication of R&D investment in areas already addressed by other agencies and encourage contextually relevant and useful outcomes that are well aligned with strategic objectives. It will also provide a means to monitor and evaluate project outcomes against objectives to ensure R&D investment strategies are effectively reducing the vulnerability of rural livelihood stakeholders to climate change.

All of the public values in Table 13 fall within the four interlinked themes around which the AusAID program is organised; namely generating shared and sustainable economic growth; fostering functioning states; investing in people and regional stability. The overarching principle of gender equality is also reflected in the public values elicited from the contributions made by the workshop participants.

It is interesting to note that nearly two-thirds of the public values elicited from the workshop participants do not explicitly relate to climate, but focus more generally on enabling capacity within rural livelihoods to sustain and adapt to a range of external drivers, including climate change. For example, there is a necessity for good land tenure systems as a foundation for sustainable agricultural practices. In other words, climate change is only one of many drivers influencing broader desirable development outcomes. This supports the call for the mainstreaming of climate change across all national sustainable development policies in the Pacific (SPREP, 2009).

The nine public values relating explicitly to climate change can be described as human, social or physical capital within the sustainable livelihoods framework and relate to greater knowledge of population demographics on livelihood strategies; improvements in skills and knowledge, the exchange of information, social networks, governance structures and institutional support; identification and protection of productive land and infrastructure, and access to adaptation technologies such as climate-ready crop and animal species, and machinery.

The following R&D opportunities aimed at reducing the vulnerability of rural livelihood stakeholders in PICs to climate change take into account public values with both direct and indirect relevance to climate change. The recommendations have been categorised into four thematic areas:

- Building adaptive capacity;
- Diversification;
- Managing climate risk, and
- System constraints/barriers to adoption.

Table 13 Public values elicited from the workshop participants as desirable for reducing vulnerability to climate change in Pacific rural communities. The focus of the public values is described as either indirect (providing a general improvement in development), or direct (focused explicitly on reducing vulnerability to climate change).

Capital	Public value	Focus on climate change
Human	Improvement in health and nutrition to enable an increase in personal productivity and coping ability.	Indirect
	Increased understanding of the impacts of population demographics on the natural resource base and the development and outcomes from livelihood strategies aimed at reducing vulnerability to climate change.	Direct
	Improvement in skill and knowledge levels to enable better uptake and application of climate change and adaptation information.	Direct
Social	Improvement in access to and exchange of information (e.g. through newspapers, internet, radio, telephone, community groups) related to climate change.	Direct
	Improvement in the stability of the rural population and the integrity of social networks through a reduction in crime.	Indirect
	Improvement in support from social networks (e.g. religious and social groups) and decision-making structures and institutions (e.g. governments and NGOs) related to climate change.	Direct
	Strengthening of traditional governance structures, particularly related to the management of climate variability.	Direct
	Improvement in access to education.	Indirect
	Enhancement of the role of women in decision-making activities related to livelihood strategies.	Indirect
Natural	Improvement of long-term access to good quality land for production and the retention and management of conservation areas.	Indirect
	Improvement in the extent and quality of biodiversity through more sustainable management of terrestrial and marine resources.	Indirect
	Reduction in the amount of productive land that is low lying and vulnerable to sea level rise and extreme events.	Direct
	Improvement in the quantity and quality of water available for rural communities.	Indirect
Physical	Improvement in access to renewable and non-renewable energy sources.	Indirect
	Improvement in water storage and transfer infrastructure.	Indirect
	Reduction in the amount of infrastructure sited in low lying areas.	Indirect
	Improvement in utilities – e.g. drainage and effluent disposal, and power.	Indirect
	Improvement in communication infrastructure.	Indirect
	Improvement in climate protection infrastructure (e.g. seawalls).	Direct
	Improvement in the capacity and flexibility of water resources and water transport infrastructure.	Indirect
	Increased access to adaptation technologies such as climate-ready crop and animal varieties, and machinery (e.g. tractors, processing plants, health and education infrastructure, waste management facilities).	Direct
Financial	Increased ability to generate and sustain diverse sources of income (including remittances, credit schemes, trust funds, development assistance).	Indirect
	Increased access to development assistance and financial credit to promote infrastructure development.	Indirect
	Reduction in wealth inequity.	Indirect

5.1 Theme 1 - Building adaptive capacity

Workshop participants provided details of the rural livelihood strategies across the Pacific that have developed over time to manage the challenges wrought by climate-exposed environmental, social and economic systems. They also provided evidence of ongoing autonomous and project-assisted adaptations with respect to climate change. However, projections of climate change for the Pacific (Christensen et al, 2007) suggest further adaptation will be required in the future as more severe climate changes unfold. Climate change impact is likely to exacerbate those agro-ecological, social and economic environments that are already considered insufficiently buffered to cope with the many current shocks, trends and seasonal shifts.

A better understanding of the sensitivity of individual strategies and aspects of rural livelihoods, together with potential exposure to climate change and capacity to adapt, will help prioritise areas for future R&D intervention. This would necessitate more focused and intensive analyses than those undertaken in this broad scoping study, and in particular greater emphasis on the transferability of different capitals to increasing adaptive capacity. Importantly, future research requires additional consideration of the broad range of fishery-related activities included in rural livelihoods.

Uncertainty regarding greenhouse emissions, regional climate change impacts and triple-bottom-line outcomes renders the development of appropriate and effective adaptation actions fraught with difficulty. In the absence of increased precision of climate change projections and improved quantification of climate impact, an alternative approach to developing response strategies that does not require precise measures of climate change or response analyses, focuses on improving the general capacity of livelihood units to withstand shocks from a range of key drivers impacting rural livelihoods. These key drivers may include climate, but are not necessarily confined to it. The R&D challenge is therefore is to consider actions that will increase long-term adaptive capacity through the enhanced resilience of environmental, social and economic systems. Promotion of long-term resilience in agricultural systems and livelihood strategies in general is a common theme running through many adaptation response recommendation from previous studies conducted in the Pacific (Mimura, et al, 2007; Hay et al, 2003; Aalbersberg et al, 1993; FAO, 2008*b*).

The notion of enhancement is central to increasing adaptive capacity as this focuses attention on current practices, which not only provides contextualisation of adaptive options but also recognises the value of indigenous knowledge in assessing these. Importantly, it is the synthesis of indigenous knowledge with external ideas and information that enables new and innovative practices to be assessed by stakeholders within their specific context. Finding ways to bring these bodies of information together will pose a particular problem for R&D methodologies that do not embrace participatory methods and actions.

One example of a new and innovative practice is the introduction of different crop species not previously grown in a region, but increasingly suitable due to the changing climate. Diversification of crop species and livelihood activities is seen as a key strategy in increasing resilience and adaptive capacity (dealt with in more detail in Theme 2). Future R&D opportunities lie in combining modelling tools and participatory assessments to effectively match both the biophysical and socio-economic requirements of crop production.

Also central to building adaptive capacity is the identification of appropriate adaptive responses and importantly, the uptake of technologies and actions by stakeholders. Opportunities exist for designing R&D methodologies that enable stakeholders to participate from the outset of the research process, preferably at project conception, through to implementation of adaptive strategies and iterative cycles of performance evaluation and refinement.

One of the largest R&D challenges will be the identification of the livelihood capitals and strategies that confer high adaptive capacity in a region. Opportunities exist for further developing the use of SLA to rank the relative vulnerability of PICs and further identify the livelihood capitals and strategies that confer high adaptive capacity in a specific context. Gaining a better understanding of region-specific livelihood strategies and their vulnerability context, may provide practical models for communities, project managers, donors and governments to simultaneously visualise and assess for potential application and modification to the local context of other regions.

Focus at the livelihoods level is most appropriate for building adaptive capacity in rural populations as it focuses on the levels at which decisions are made. However R&D activities must be linked across regional and national sectoral research programmes and infrastructure to avoid maladaptation or constraints to adoption, as well as being considered in terms of their broader contribution to sustainable development regardless of the magnitude or direction of future changes in climate. Opportunities exist for addressed these questions using software tools developed to support the assessment and enhancement of project impacts on local adaptive capacity to climate variability and climate change at the livelihood scale.

Identifying, building upon and consolidating past and present livelihood-level adaptation projects in the Pacific is a challenge as many organisations have appeared to undertake projects largely independent of each other. Opportunities exist for developing a more co-ordinated and strategic approach that offers the potential to value-add to research outcomes and consider the appropriateness of transferring technologies between countries, islands and regional communities.

5.2 Theme 2 – Diversification

As stated in Theme 1, a key strategy for improving adaptive capacity at the livelihood scale is the diversification of activities, not least because it enhances the resilience of livelihoods by spreading risk and increasing the potential for substituting between coping and adaptive strategies (Ellis, 2000). In turn, diversity may address more specific issues, such as micronutrient deficiencies experienced by Pacific islanders with restricted access to healthy foods (Barnett, 2007). Diversification operates at a number of levels. More obviously, diversification can be applied to the range of field and tree crop and animal species included in livelihood activities. Less apparent is genetic diversity within crop and animal species, for example, as manifest in dry bean varieties that produce a harvestable yield at different times of the year, or express differing levels of drought tolerance and water use efficiency. Although not covered explicitly in this study, fishery activities offer a further steam of diversification options that need to be considered in future studies of rural livelihoods in the Pacific (Bell et al, 2009). Regardless of the way in which diversity manifests, it is a key tenet in the current drive by organisations such as the FAO to “relaunch” agriculture in the developing world as a means to address food insecurity (FAO, 2008*b*).

One particular R&D challenge will be to consider genetic (G) diversity in terms of its 3-way interaction with the environment (E) and management practices (M), whereby expression of diversity is a culmination of G*E*M. This interaction renders the improvement of crop and animal diversity both complex and challenging, but as demonstrated by a study of the Australian Sugarcane Breeding Program, it also “offers the best potential for improving productivity and combating losses from diseases and some insect pests” (Park et al, 2007) – major challenges to future food security in the Pacific. Closely aligning research in this area with that already being undertaken in more developed countries (e.g. Australia), offers the potential to make substantial and effectives gains in understanding the G*E*M interaction in terms of diversifying crop and animal production.

Genetic improvement can be achieved through two main routes: direct manipulation of genetic material referred to as genetic modification (GM) or engineering, and traditional crop breeding methodologies that operate at the whole of organism level. Genetically modified technologies have to date generally been used to improve agronomic traits that enable reduced input requirements, e.g. herbicides and pesticides, and to a lesser extent quality characteristics. Traditional breeding methods have focused on increased production and quality.

Whilst GM promises the potential to substantially reduce the time from development to market release of new varieties, the side effects in terms of potentially adverse impacts on the environment and human health are unknown. More traditional breeding programs focus on population improvement through (i) the selection of parental germplasm, including the introduction of new germplasm from foreign breeding programs, and (ii) the creation of genetic variability through cross pollination. An important sub-set of the latter, are the less formal crop and animal selection and breeding activities based on the expression of phenotypic performance undertaken by livelihood stakeholders to improve productivity and performance. Active creation of genetic variability through informal stakeholder 'experiments' reported to already be undertaken in areas of the Pacific, highlights an opportunity to engage with local stakeholders to progress and enhance diversification strategies.

There is a present lack of information and general hostility towards GM in the Pacific (pers comm. workshop participant), suggesting emphasis should be directed towards traditional methods of selection, breeding and preserving indigenous diversity. Regardless of the method used, crop improvement is a dynamic operation that requires germplasm collections well sourced, maintained, documented and evaluated. Characterisation of parental clones is necessary if existing genetic variation is to be exploited (a) to identify optimal responses to future increased temperatures and concentrations of CO_2 and altered rainfall patterns, as well as identifying physiological and system thresholds (i.e. sensitivity), (b) identify plant traits with potential to confer opportunities for alternative food or fuel production systems, (c) to evaluate performance under differing environmental and management conditions, and (d) distribution of existing germplasm based on phenotypic performance to new locations. Opportunities exist for drawing upon similar research being conducted in Australia on crop species important to some PICs (e.g. sugarcane).

Crop suitability studies conducted in participation with landholders on former sugarcane lands in Australia have demonstrated the usefulness of a model-based approach (e.g. PlantGro (Hackett, 1991; Hackett, et al, undated)) in matching suitable crop species to biophysical and climatic conditions (McDonald et al, 2006). In this study, the inclusion of landowners in the process of selecting alternative crop species was considered key to identifying new opportunities for diversification that were context specific and incorporated stakeholder knowledge of both biophysical and socio-economic constraints. The general willingness shown by rural stakeholders in the Pacific to explore options for diversification in their production systems and participate with external agencies, suggests opportunities exist to use more collaborative and developed methodologies to advance crop suitability studies. Building on present efforts being undertaken by one of the workshop participants to embrace Participatory Varietal Selection and Participatory Plant Breeding activities offers clear opportunities to synthesize indigenous knowledge with more formal science R&D.

Opportunities exist to value-add to an existing germplasm collection based in Suva, Fiji, that has been derived from key crop species grown and potentially suitable for wider production in the Pacific. Combining a model-based approach to matching crop species in this collect to the biophysical conditions around the Pacific, together with on-farm evaluation trials, offers potential for suitable crop species to be effectively incorporated into wider livelihood strategies aimed at addressing changes in climate and sea level.

Diversification of crop species offers the potential to not only address the domestic food security issues already entrenched in PICs, through increasing annual productivity and reduced rural poverty, but also the promotion of trade and generation of export revenue (FAO, 2008*a)*. However, improvements in domestic food security will only occur if increases in food production are accompanied by the widespread availability of food, the ability to access food and the capacity to utilise food sufficiently to extract the necessary calories, protein and micronutrients it contains. In terms of generating export income from higher and more diverse productivity, the FAO (2008*a*:38) notes that today's high food prices "offer opportunities to intensify production of some staple crops and agricultural commodities that might formerly have been available only for higher-value export crops". The ability to compete in global trade is however, likely to be constrained by a general lack of quality R&D able to inform production practices and international quality requirements (pers comm. workshop participant). Examples, such as the EU-funded Facilitating Agricultural Commodity Trade (FACT) is a typical example of where climate change adaptation expertise would be beneficial.

5.3 Theme 3 - Managing climate risk

Extreme climate events are a major impediment to sustainable development (Hay et al, 2003) and discussions with the workshop participants suggested current practices aimed at managing climate variability in many Pacific countries, are already insufficient to cope with the present frequency and extent of extreme events. As projections of climate change for the Pacific indicate a likely increase in extreme weather events (Christensen et al, 2007), R&D opportunities exist for current climate risk management strategies to be reviewed for their potential to cope with the likely climate challenges that lie ahead.

Decisions made about the implementation of climate risk management strategies are taken at the livelihood scale. Conducting participatory research with the livelihood unit will therefore enable knowledge and experience of past climate and actions to be built upon, again centring climate risk management R&D around current practices and indigenous knowledge. This approach will enable enhancing strategies to be both context-specific and reflect historic and future risks, delivering actions that would be taken even in the absence of climate change, due to their positive contribution to sustainable development and food security.

Climate change risk management in agricultural production in Australia is currently being enhanced through the use of downscaled projections focussed on specific climate change variables tailored to key production decisions; scenario and sensitivity analysis; cost benefit analysis, and iterative management that includes monitoring and evaluation. From the review of published literature on climate change research conducted in the Pacific and discussions with workshop participants, there appears to be considerable potential for using many of these tools for managing present and future climate change risk at the livelihood level in the Pacific.

Current methods for downscaling General Circulation Model (GCM) projections to Pacific countries or islands, is insufficiently advanced to offer adequate confidence in model output and hence the assessment of exposure to climate change. Whilst further research on meteorology and the monitoring of climate variables and sea level would clearly inform this, investment in this area is both costly and unlikely to deliver meaningful data for a considerable period of time. This renders current opportunities to reduce vulnerability to climate change in the near future through increased precision of climate change projections, somewhat questionable. In contrast, climate related decisions are, and need to be, made by livelihood stakeholders today. Moreover these decisions are being made with the clear realisation that they are based on imperfect knowledge in many cases. Regardless of a lack of data, it is recognised that acting now is one of the most effective ways to prepare for future climate change (Hay et al, 2003).

The International Climate Change Adaptation Initiative (ICCAI) managed by the Australian Government Department of Climate Change (DCC) and AusAID has recently been set up with the aim of improving the climate science needed in the Pacific to support more integrated assessments of vulnerability and the development of adaptive strategies. In particular, the initiative is looking to develop fine-resolution climate change projections for each island nation and tailored products to help inform future vulnerability and adaptation activities. This has the potential to move vulnerability assessment outputs from broad, qualitative statements, to quantitative estimates of impact. In combination with participatory research, there is also the opportunity to tailor downscaled output to deliver key climate change variables identified by stakeholders as being useful to decision making at the livelihood scale. The focussing of climate change information on stakeholder's demands, rather than supply-driven science, offers the opportunity for more informed decision-making at all levels.

However, the accumulation of uncertainty arising from future levels of greenhouse gas emissions, global projections and statistical downscaling, will necessitate stakeholders have a clear understanding of any information generated, its utility, and importantly, its limitations. Opportunities exist for scenario and sensitivity analyses to be used to address uncertainty by providing a means to answer "what if" questions and enable best bet strategies to be identified given current levels of knowledge and certainty. This can be further informed by the use of cost-benefit analyses to estimate the costs of adaptation options relative to the likely costs of impacts if no action is taken. Clearly, including an assessment of greenhouse gas output and mitigation strategies will avoid maladaptive options being implemented and offer a valuable contribution to safeguard longer-term food security and sustainable development in the Pacific (Hay et al, 2003; Mimura et al, 2007).

It is recognised that within-system adaptation will be constrained by biophysical and socio-economic limits, that once breeched require more extensive transformational change to be considered. Opportunities exist to apply R&D methodologies to determine when thresholds are likely to be reached and the extent of residual vulnerability to assist stakeholders in better managing future climate risk.

The delivery of information is only one link in promoting an increase in adaptive capacity and enhancing food security. Ensuring that stakeholders can understand and interpret information correctly, use it to inform decision making within their own specific livelihood context, and implement risk management actions, must all be addressed if stakeholders are to be self-reliant and adaption is to be sustainable into the future. "The absence of application of these techniques in the study of climate change vulnerability in the Pacific is notable …" (Mimura et al, 2007). Opportunities exist for building capacity and skills in the area of managing climate variability and must be considered a priority for generating shared and sustainable economic growth in rural areas.

5.4 Theme 4 - System constraints/barriers to adoption

A review of past research conducted on climate change adaptation in the Pacific highlights deficiencies in operationalising adaptation strategies at the livelihood scale, with a few notable exceptions (e.g. Nakalevu 2006). Adaptation strategies appear to be discussed without explicit consideration of potential impediments to implementation. Discussion with R&D practitioners from the participatory workshop held in Fiji suggests that the constraints and barriers to adoption experienced in the Pacific are likely to be similar to those in other developing countries around the world and include insecurity of land tenure (see Boydell 2001 for an overview of this issue), poor governance institutions, under-resourced and poorly informed extension services, and resistance by rural stakeholders to consider alternative technologies and practices promoted from external sources.

Central to recognising and addressing these issues is the necessity for stakeholders to be included in the project process (from conception to implementation, evaluation and monitoring) to ensure "ownership", applicability and uptake of project outcomes. As recognised by the workshop participants, rural stakeholders in the Pacific are continuously assessing new crop species and practices using informal and small scale experimental methodologies. Opportunities therefore exist for these activities to be built upon by introducing a wider array of technologies and more rigorous methods of assessment. Stakeholder participation will explicitly incorporate context-specific knowledge on potential impediments to implementation into the development of adoption technologies and pathways for their incorporation into livelihood strategies. Opportunities exist for methodologies developed to support industrial agricultural producers in developed countries transform their agri-businesses in the face of multiple and complex external drivers, to be modified and used to consider contextually relevant adoption and transformational pathways for rural livelihood stakeholders in the Pacific.

Impediments to implementation may be of either an environmental, social, economic or institutional nature, producing complex interactions that are not readily apparent to external observers such as R&D practitioners. Opportunities exist for obtaining detailed knowledge of the systems within which rural livelihoods operate and interact with climate, to provide a greater appreciation of potential constraints and barriers to implementation of adaptation and transformation strategies.

Creating an enabling environment that provides technical options, adaptive and transformative pathways and supporting institutional frameworks is therefore necessary to reduce climate change vulnerability in a way that is compatible with broader development goals. Mainstreaming climate change throughout the policy environment will integrate consideration of vulnerability within all national policies, strategies and programmes (FAO, 2008*b*). Creating an enabling environment may similarly be enhanced by identifying gaps in current knowledge and technologies considered core enabling platforms for adaptation. Using participatory methodologies will enhance the potential for limited research resources to be targeted to demand and credible high-impact outcomes. The coordination of climate change research activities at a national and regional level with broader strategic development priorities, in line with initiatives such as the Paris Declaration on Aid Effectiveness (OECD, 2005), will also provides the greatest opportunity for effective deployment of limited resources. See Rogers (2008) for a comprehensive review of bilateral and multilateral partners active in the Pacific and their areas of intervention).

There is a recognised need to raise awareness and understanding of climate change and its potential impacts on food production and food security beyond the environment departments and NGOs that have previously been at the forefront of climate change discussions. A key recommendation repeated in many studies is the integration of strategies that address climate change impacts within the context of broader sustainable development (Hay et al, 2003; Koshy, 2005; Nakalevu et al, 2006; FAO 2008*a*). Opportunities exist to identify and consider the outcomes from using tools such as legislation and policy adjustments relating to food sources and social and environmental protection, on the environment in which rural stakeholders operate. However, opportunities must be taken to address both national and regional enabling environments if vulnerability to climate change for PICs is to be effectively reduced.

5.5 Summary discussion

Whilst the four research opportunity themes are discussed independently, there is considerable overlap across them. For example, for all themes research opportunities may best be addressed using stakeholder participation methodologies that promote adaptive management frameworks and the co-production of knowledge that includes both scientific and indigenous understanding. This will enable the contextualisation of impacts to be better understood, constraints and barriers to adaptation built into the development of pathways to adoption and enabling environments, R&D activities to be outcome focused, and the development of appropriate response strategies that offer a greater likelihood of implementation and enhanced adaptive capacity and food security.

Another common feature of the R&D opportunities detailed above is the advocacy of analysis at the livelihood scale. Focusing on the livelihood unit essentially places the level of analysis at the scale at which many of the decisions regarding livelihood investment and actions are made. In doing this the livelihood unit is explicitly context specific. By necessity, focusing at the livelihood level also necessitates a multidisciplinary perspective of climate change adaptation. In order to ensure effective outcomes from climate change adaptation R&D, it is therefore important to identify where, and by whom, decisions are made regarding daily existence, with the aim of developing activities that inform and support the appropriate stakeholders. Using the livelihood scale as the unit of analysis does not however exclude consideration of decision-makers at larger scales, i.e. local and national government. The interaction and impact of these larger-scale decision-makers and drivers are considered in terms of their impact on the socio-economic environment in which the livelihood unit operates.

The R&D opportunity themes cover the need to both obtain further understanding and about the vulnerability context in which rural stakeholders in the Pacific operate, and also the need to generate more information merely to understand the complexity of the problems they face. The broad scoping nature of this project has resulted in the identification of R&D opportunities broadly applicable across the range of PICs considered. However, these opportunities may only be realised if constraints and barriers to the adoption of strategies for reducing vulnerability are addressed. As perceived by the workshop participants, key constraints and barriers across the Pacific include insecurity of land tenure (Boydell 2001), poor governance institutions, under-resourced and poorly informed extension services and an inherent conservatism from farmers resistant to trying alternative technologies and practices promoted from external sources.

Effective implementation of R&D will necessitate further assessment is conducted at individual country and community levels. Individual research proposals have been developed under each of the four themes to address these more targeted R&D requirements (not included in this report).

Many of the knowledge gaps identified for rural livelihoods in the Pacific are echoed in reviews of key environmental management issues in other countries, such as Australia (Morton et al, 2009) and the United Kingdom (Sutherland et al, 2006). Whilst the relationships between production systems, land capacity and climate in more developed nations are relatively better understood than those of the Pacific, many of the ecological, economic and sociological learnings may be similarly applied to production units in PICs. A pragmatic response for decision-makers may therefore be to use current knowledge, skills and methodologies, as appropriate, to tactically address the most pressing and immediate issues for rural stakeholders, whilst simultaneously and strategically tackling more context specific long-term research objectives and critical unanswered questions. As noted by previous studies, a key constraint is limited information and in-depth analysis of climate change impacts on PICs (FAO, 2008*b*).

5.6 Evidence based policy development

This report has highlighted key attributes of vulnerability across the Pacific, the public values of a small sample of stakeholders living in and around the Pacific and working in the area of climate change, and identified opportunities for future R&D to reduce the vulnerability of rural stakeholders. As recommendations for changes to existing policy are outside the scope of this project, we have sought to support policy-makers in the development of evidence-based policies and governance by providing information produced using a defensible and scientifically rigorous methodology.

By using SLA we have provided a broad snapshot of the asset status of rural livelihood stakeholders across the Pacific and the key transforming structures and processes (as defined in the SL conceptual framework) that influence the vulnerability context in which they operate. This benchmark can be used to consider future opportunities and evaluate progress. The public values provide a clear picture of the policy outcomes considered desirable by the workshop participants.

The combination of participatory rural appraisal (PRA) methodologies, a contextual understanding of vulnerability and an integrated approach to vulnerability assessment, enabled the production of policy relevant project outputs. As a result, perceived needs and demand for research became evident. It is considered that the participation of AusAID representatives at the workshop and in the subsequent analysis, has contributed to the production of outputs that are not only policy relevant, but useful to decision-making processes for R&D investment strategies aimed at reducing vulnerability of rural stakeholders and improving broader sustainable development.

The challenge now lies in developing policies that draw upon the identified knowledge gaps and R&D opportunities to achieve a reduction in the vulnerability of rural stakeholders throughout the Pacific to changes in climate, and more broadly enhance sustainable development and food security. Given the limited resources available, one of the key decisions that policy makers will face is where to finance adaptation. It is the hope of the authors and contributors to this report that the information contained here will compliment other initiatives being undertaken in the Pacific in informing decision makers at all levels regarding climate change adaptation and wider sustainable development.

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Appendix 1 – Crop, forestry and livestock thresholds

Important agricultural crop species (and groups) for PICs considered in this study (indicated by the shaded boxes).

Commodity	Cook Islands	East Timor	FSM	Fiji	Kiribati	Marshall Islands	Nauru	Niue	Palau	PNG	Samoa	Solomon Islands	Tokelau	Tonga	Tuvalu	Vanuatu
Avocado (*Persea americana*)											■					
Banana (*Musa acuminata*)	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■
Beans, Dry		■														
Berries										■						
Breadfruit (*Artocarpus altilis*)	■				■	■						■	■		■	
Cantaloupes & other Melons												■		■		
Cassava (*Manihot esculenta*)	■	■	■	■					■	■		■		■		
Citrus fruit (*Citrus* sp.)											■			■		
Cocoa bean (*Theobroma cacao*)		■	■			■				■	■	■				■
Coconut (*Cocos nucifera*)	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Coffee (*Coffea arabica*)		■								■						■
Fruit Fresh	■		■	■	■			■		■	■	■		■		■
Ginger				■												
Groundnuts		■														■
Maize (*Zea mays*)		■	■							■						■
Mangoes		■									■					
Nuts					■					■		■				
Oil palm (*Elaeis guineensis*)										■		■				
Papayas	■										■		■			
Pepper White/Long/Black	■			■												
Pineapples				■							■					
Plantains			■											■		
Pulses		■		■								■				
Pumpkins, Squash, Gourds														■		
Rice, Paddy		■	■	■								■				
Roots and tubers	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■
Sorghum			■													
Spices	■	■										■		■		■

Commodity	Cook Islands	Timor -Leste	FS of Micronesia	Fiji	Kiribati	Marshall Islands	Nauru	Niue	Palau	PNG	Samoa	Solomon Islands	Tokelau	Tonga	Tuvalu	Vanuatu
Sugarcane (*Saccharum officinarum*)				■						■						
Sweet potato (*Ipomoea batatas*)	■	■	■	■					■	■		■		■		
Taro (*Colocasia esculenta*)	■		■	■	■	■		■		■	■	■	■	■	■	
Tea										■						
Tobacco (*Nicotiana tabacum*)											■	■		■		
Vanilla (*Vanilla tahitensis*)										■				■		
Vegetables (fresh)	■	■	■	■	■			■		■	■	■		■		■
Yam (*Dioscorea sp*)	■			■				■		■	■	■		■		
Swietenia macrophylla			■								■					
Casuarina equisetifolia					■											
Swietenia macrophylla				■					■							
Acacia auriculiformis				■					■						■	
Pinus caribaea var. hondurensis	■			■										■		■
Campnosperma brevipetiolata												■				
Terminalia brassii												■				
Swietenia macrophylla								■				■				
Campnosperma brevipetiolata										■						
Acacia mangium										■						
Tectona grandis										■						
Gmelina arborea										■						
Eucalyptus delgupta										■						
Cordia alliodora																■
Endospermum medullosum																■
Santalum austrocaledonicum	■															■
Toona australis								■						■		
Morinda citrifolia								■								
Flueggea flexuosa											■					
Terminalia richii											■					

Appendix 2 – Summary of indices of vulnerability

Human Development Index

The HDI offers a standard measure of human development at the country scale. The index was developed in 1990 and has been used since by UNDP in its annual Human Development Report. The HDI combines three basic dimensions:

- Life expectancy at birth, as an index of population health and longevity
- Knowledge and education, as measured by the adult literacy rate (two-thirds weighting) and the combined primary, secondary, and tertiary gross enrollment ratio (one-third weighting).
- Standard of living as measured by the natural logarithm of gross domestic product (GDP) per capita at purchasing power parity in United States dollars.

High HDI values indicate increased development. All countries included in the HDI are classified into one of three clusters of achievement in human development: high human development (with a HDI of 0.800 or above), medium human development (HDI of 0.500–0.799) and low human development (HDI of less than 0.500) (Human Development Report 2007/2008).

Human Poverty Index for Developing Countries

The HPI-1 was similarly developed by the UNDP and provides an indication of the standard of living in a country. It attempts to bring together in a composite index the different features of deprivation in the quality of life to arrive at an aggregate judgment on the extent of poverty in a community. Whilst the HPI-1 uses the same three components as the HDI, i.e. longevity, knowledge and standard of living, it does so from a human deprivation perspective, i.e.:

- Proportion of the population not expected to survive to the age of 40 years.
- Knowledge as measured by the adult illiteracy rate.
- Standard of living as measured by the proportion of the population without access to clean water, health services, and the proportion of children under the age of 5 years who are underweight.

Whilst the HDI is a measure of development, the HPI-1 is a measure of the extent to which people in a country are not benefitting from development due to poverty of choices and opportunities. Rather than measure poverty by income, the HPI-1 uses indicators of the most basic dimensions of deprivation: a short life, lack of basic education and lack of access to public and private resources. The HDI and HPI-1 are often used in conjunction to establish a country's level of development and standard of living.

The HPI value indicates the percentage of the population affected by the three key deprivations in their lives – showing how widespread human poverty is (Human Development Report 1997). For example, Chad has the lowest ranking (108) in the 2007/2008 Human Development Report, with an HPI-1 value of 56.9, implying that more than half (~57%) of the population suffers human poverty. High HPI values indicate increased human poverty.

Environmental Sustainability Index / Environmental Performance Index

The ESI is a composite index consisting of 21 elements of environmental sustainability covering natural resource endowments, past and present pollution levels, environmental management efforts, contributions to protection of the global commons and a society's capacity to improve its environmental performance over time. The index is produced at the country scale. It was developed by Yale University's Centre for Environmental Law and Policy in collaboration with Columbia University's Center for International Earth Science Information Network (CIESIN), and the World Economic Forum to evaluate environmental sustainability relative to the paths of other countries.

The ESI was aimed at gauging a country's overall progress towards environmental sustainability. Four ESI reports were published between 1999 and 2005.

Papua New Guinea is the only Pacific Country from Table 1 that is listed in the 2005 ESI report (ESI=55.2, rank=35). The higher the score, the better positioned the country is to maintain favourable environmental conditions into the future. (Finland ranked 1, scored 75.1; Australia ranked 8, scored 61.0; North Korea ranked 146, scored 29.2).

However, the developers of the index found that a commonly accepted and measurable definition of environmental *sustainability* could not be agreed upon and in 2006 they shifted their focus more towards environmental *performance*. Environmental performance was aimed at measuring the ability of a country to actively manage and protect their environmental systems and shield their citizens from harmful environmental pollution. The Environmental Performance Index (EPI) is an outcome-oriented indicator calculated at the country-scale and considered more easily used by policy makers, environmental scientists, advocates and the general public.

The 2008 EPI has 2 key objectives: capturing environmental health and ecosystem vitality and uses 25 indictors to measure 6 categories: environmental health, air quality, water resources, biodiversity and habitat, productive natural resources, and climate change (2008 Environmental Performance Index).

The EPI ranges from 0 to 100, where 100 corresponds to the target (based on international treaties and agreements, environmental and public health standards developed by international organizations and national governments, scientific literature and expert opinion from around the world), and 0 is the worst observed performance (2008 Environmental Performance Index).

Environmental Vulnerability Index

The EVI is a country level index of vulnerability focused on the natural environment. It was developed by the South Pacific Applied Geoscience Commission (SOPAC), the United Nations Environment Programme (UNEP) and their partners. The index was designed to be used with economic and social vulnerability indices to provide insights into the processes that can negatively influence the sustainable development of countries.

Emphasis is given to the environment on the grounds that it is the life-support system for all human systems and therefore an integral part of the developmental success of countries. The index is orientated towards sustainability and is used to identify ways to build resilience through the optimisation of an individual country's unique situations and development goals. It is argued that the focus of the EVI at the national scale is most appropriate given that major decisions affecting the environment in terms of policies, economics and social and cultural behaviours, are made at the country scale.

The EVI is based on 50 estimated indicators of environmental vulnerability of a country to future damage and degradation. It does not address the vulnerability of the social, cultural or economic environment of a country. The 50 indicators are combined by simple averaging and reported simultaneously as a single index, a range of policy-relevant thematic sub-indices and as a profile showing the results for each indicator. The indicators are considered 'smart' or 'end-point' indicators, selected to represent a wide variety of conditions and processes that must be operating well if that measure is favourable in terms of environmental vulnerability. This approach negates the need to measure many hundreds of indicators that could individually lead to losses.

Vulnerability is considered in three distinct aspects; the risks associated with hazards coming into play, and resistance and acquired vulnerability (damage), the latter two reflecting the environments ability to withstand the effects of hazards. The underlying assumption is that the more degraded the ecosystems of a country (as a result of past natural and anthropogenic hazards), the more vulnerable it is likely to be to future hazards. There are 32 indicators of hazards, 8 of resistance and 10 that measure damage. For most indicators, signals are based on average levels observed over the past 5 years, but may include data for much longer periods for geological events.

High EVI values indicate increased vulnerability. EVI scores place countries into one of 5 vulnerability classifications: extreme vulnerability (365+), highly vulnerable (315+), vulnerable (265+), at risk (215+), resilient (<215).

There are still data gaps in the EVI, a problem found in all international reporting, but a tolerance has been built into the index which requires a minimum of 80% of data returns over the 50 indicators for a valid EVI evaluation. Countries with less than 80% data are reported as "EVI trends for countries that are data deficient". Eight of the Pacific countries included in Table 1 are data deficient.

Water Poverty Index

The Water Poverty Index (WPI) was developed to quantify "water poverty" and capture a comprehensive picture of the challenge of managing water (see Alexander et al, (2008) for a review of the WPI). Water poverty has been defined as the ability to access adequate or efficient water supplies and takes into account "the relationship between the physical availability of water, its ease of abstraction, and the level of welfare of the population" (Alexander et al, 2008). The WPI incorporates both "physical and social sciences to understand the physical, economic and social drivers linking water and poverty". The WPI is applicable to national, basin, catchment and community scales.

Water Poverty Index values range from 0 to 100. The highest ranking country (Finland) in the 2002 Water Poverty Index: An International Comparison report scored 78, whilst Haiti was the lowest of the 147 countries measured at a value of 35.1.

Gross National Income, Human Asset Index, Economic vulnerability Index

Every three years the United Nations Committee for Development Policy reviews their list of least developed countries. Three dimensions of a country's state of development are used to define "least developed", namely (a) its income level, measured by gross national income (GNI) per capita; (b) its stock of human assets, measured by a Human Assets Index (HAI); and (c) its economic vulnerability, measured by an economic vulnerability index (EVI*).

The thresholds for inclusion in the list of least developed countries are per capita GNI less than $745; HAI less than 58; and EVI* greater than 42. PNG was recently admitted and Samoa, Kiribati, Tuvalu and Vanuatu are being considered for graduation from the list (even though they have very high EVI*).

Human Assets Index

The Human Assets Index (HAI) is a combination of four indicators, two for health and nutrition and two for education: (a) the percentage of population undernourished; (b) the mortality rate for children aged five years or under; (c) the gross secondary school enrolment ratio; and (d) the adult literacy rate.

The HAI ranges from 0 to 100, higher values indicate better human assets. Seven of the PICs in Table 1 were considered least developed in 2006.

Economic Vulnerability Index

The Economic Vulnerability Index (EVI*) is a combination of seven indicators: (a) population size; (b) remoteness; (c) merchandise export concentration; (d) share of agriculture, forestry and fisheries in gross domestic product; (e) homelessness owing to natural disasters; (f) instability of agricultural production; and (g) instability of exports of goods and services.

The EVI* ranges from 0 to 100, higher values of EVI* indicate the presence of increased vulnerability. Six of the PICs in Table 1 are included in the 10 most vulnerable developing countries in the world.

Appendix 3 – Summary details of indicators included in the EVI climate change sub-index

(Kaly et al, 2004)

1. High winds	
Indicator text:	Average annual excess wind over the last five years (summing speeds on days during which the maximum recorded wind speed is greater than 20% higher than the 30 year average maximum wind speed for that month) averaged over all reference climate stations.
Signals captured:	Vulnerability to cyclones, tornadoes, storms, erosion, habitat damage, disturbance. This indicator captures the likelihood of damage from frequent and severe wind that can affect forests, fan fires, create storm surges, dry soils, spread air pollution, and interact with other stressors. Because this indicator is expressed in relation to the 30 year monthly means, a high score could indicate shifts in weather patterns and climate, and could negatively affect a country's resilience to other hazards. The signal generated captures not only the frequency of high winds, but also their strength.

2. Dry periods	
Indicator text:	Average annual rainfall deficit (mm) over the past 5 years for all months with >20% lower rainfall than the 30 year monthly average, averaged over all reference climate stations.
Signals captured:	Vulnerability to drought, dry spells, stress on surface water resources. This indicator captures not only the number of months with significantly lower rainfall, but also the strength of the deficit. Two countries could have the same average number of months over the past 5 years with less than 20% lower than the monthly average rainfall, with one only having a small deficit, while another a very large one. This indicator ensures that the amount of rain 'missed' is captured. Frequent and severe drought months could indicate shifts in weather patterns and climate, and could negatively affect a country's resilience to other hazards (e.g. fires, water movements, ability of ecosystems to attenuate pollution).

3. Wet periods	
Indicator text:	Average annual excess rainfall (mm) over the past 5 years for all months with >20% higher rainfall than the 30 year monthly average, averaged over all reference climate stations.
Signals captured:	Vulnerability to floods, cyclones, wet periods, stress on land surfaces and ecosystems subject to flooding and disturbance. This indicator captures not only the number of months with significantly higher rainfall, but also the amount of the excess. Two countries could have the same number of months of the past 60 (5 years) with more than 20% higher rainfall than the monthly average, with one only having a small excess, while another a very large one. The modification to this indicator ensures that the amount of rain 'in excess' is captured. Frequent and severe wet months could indicate shifts in weather patterns and climate, and could negatively affect a country's resilience to other hazards (e.g. water movements, the spread of and ability of ecosystems to attenuate pollution).

4. Hot periods

Indicator text:	Average annual excess heat over the past 5 years for all days more than 5°C hotter than the 30 year mean monthly maximum, averaged over all reference climate stations.
Signals captured:	Vulnerability to heat waves, desertification, water resources, temperature stress, bleaching. This indicator is designed to capture stress on land surfaces and near-shore or shallow aquatic environments to periods of high temperatures that can affect productivity, oxygen levels, pollution, reproduction and symbiotic relationships and lead to mass mortality. On land, periods of high temperatures can also lead to interactive effects such as fires. This indicator captures not only the number of days with significantly higher temperatures, but also the amount of the excess. Two countries could have the same number of days with more than 5ºC higher temperatures than the monthly average, with one only having a small excess, while another has a very large one. Frequent and severe hot days could also indicate shifts in weather patterns and climate, and could negatively affect a country's resilience to other hazards (e.g. ability of forests to regenerate if disturbed).

6. Sea surface temperatures	
Indicator text:	Average annual deviation in Sea Surface Temperatures (SST) in the last 5 years in relation to the 30 year monthly means (1961-1990).
Signals captured:	This indicator captures vulnerability to fluctuations in productivity, fisheries, currents, eddies, ENSO, cyclones & storms, blooms and coral bleaching. The indicator captures the total amount of the anomalies in SST, either as excess or deficit (using absolute values). Frequent and severe deviations from the 30 year moving average could herald shifts in currents, upwelling, weather patterns and climate, and could negatively affect a country's resilience to other hazards (e.g. for water movements, the spread of and ability of ecosystems to attenuate pollution). Effects would be especially important when other stresses have already driven populations to low levels.

11. Land area	
Indicator text:	Total land area (km^2).
Signals captured:	This indicator captures the richness of habitat types and diversity, availability of refugia if damage is sustained or for protection, and species and habitat redundancy. It is generally considered that larger countries will have more options and the 'critical mass' required for ecological sys terms to persist and re-seed each other in the face of ecosystem stressors. There will also be more options for the human populations to allow areas that have been damaged to recover.

12. Country dispersion	
Indicator text:	Ratio of length of borders (land and maritime) to total land area.
Signals captured:	This indicator captures the degree to which a country's land area is fragmented and 'thin'. Countries which are highly fragmented, comprised of many islands, or which have many peninsulas or land areas in thin strips are likely to be prone to more trans-boundary effects. The land areas may also be more exposed to damage from natural disasters and human impacts (e.g. cyclones, fires, effects of war) in such areas, because the presence of refugia and ecosystem types that may form breaks are likely to be limited. Although fragmentation may also bring with it the possibility that damage could be limited by intervening areas of land or sea, there are likely to be higher risks that ecosystems and species (particularly if many are endemic) will not persist. This could be especially true if there are interactions with on-going human impacts. Larger countries with fragmentation are likely to be less at risk from

	this stressor than small ones and this indicator would need to be examined in tandem with Indicator 10 on country size.

14. Vertical relief	
Indicator text:	Altitude range (highest point subtracted from the lowest point in country).
Signals captured:	Biodiversity of habitat & species, potential for habitat disturbance through movements of water and slides. A country with a large altitude range is likely to have a greater variety of ecosystems, which in very high altitude areas, or very low ones (e.g. the Black Sea) leads to the formation of "endemic habitat types". These can be an integral part of the character of a country, and if lost, the same arguments as for endemic species applies.

15. Lowlands	
Indicator text:	1. Percentage of land area ≤50m above sea level; 2. Percentage of land area ≤10m above sea level. 1. Although this indicator was originally defined in relation to land areas ≤10 above sea level, data were difficult to obtain. Although maps are available locally in some countries that could be used to calculate area of land at or below this level, coverage was generally poor. It was necessary to redefine the indicator to include all land areas ≤50m which is shown on global maps. 2. We consider the use of ≤50m a proxy for this indicator. The indicator will be more valuable when data for land area ≤10m become generally available.
Signals captured:	This indicator focuses on the presence of lowlands in a country with implied impacts associated with pollution, ecosystem disturbance, flooding and coastal vulnerability. Areas of lowlands are those that will tend to be the first to flood, will tend to accumulate pollution that is mobilised by surface run-off, provide an important entry point (and extraction point) for ground waters and if on the coasts of the sea or lakes may be subject to storm surges, tsunamis or sea level rise. They tend to be areas of high biodiversity and/or form critical habitats. They may also be critical areas for productivity, soil formation, erosion, natural resources and pollution attenuation. A country's resilience to future hazards will be related to risks on lowland areas. This would be especially important if there are many sensitive ecosystems susceptible to the loss of keystone species and interactions with on-going human impacts.

24. Natural vegetation cover remaining	
Indicator text:	Percentage of natural and regrowth vegetation cover remaining (include forests, wetlands, prairies, tundra, desert and alpine associations).
Signals captured:	This indicator focuses on the loss of natural vegetation cover in a country with implied impacts on biodiversity and ecosystem integrity. The loss of natural vegetation has resulted in a loss of biodiversity, and may also have resulted in impacts on ecosystem structure and function through complex ecological interactions. Areas of natural vegetation are viewed as refugia for threatened species, those unknown to science, or those which may act as a future resource (e.g. for biochemical applications). Natural forests and vegetated areas are also likely to be important areas for groundwater intake, soil production, CO_2 – oxygen relationships and attenuating air and water pollution. A country's resilience to future

	hazards will be related to the rate and total loss of naturally vegetated areas. This would be especially important if there are many sensitive ecosystems susceptible to the loss of keystone species and interactions with on-going human impacts.

36. Renewable water	
Indicator text:	1. Average annual water usage as percentage of renewable water resources over the last 5 years; 2. Average annual percentage of water usage per year met from renewable and non-declining sources over the last 5 years. 1. This proxy indicator does not show whether the water actually used by countries comes from renewable sources or whether it is mined. It shows only whether overall withdrawals exceed the available supply of renewable water. Countries may still be making the choice to mine their water from non-renewable sources. 2. The original form of the indicator, shown as 2 above, would be a better measure because it encompasses the choice of whether needs are being met from the available renewable resources.
Signals captured:	This indicator captures the risk to terrestrial environments, aquatic ecosystems and ground waters from over-extraction of freshwater resources. It focuses on sustainable use of surface free water and groundwater and damage through salinisation, extraction of functionally non-renewable groundwater, and damage to rivers, lakes and other habitats. Renewable water is that which is caught in rain tanks and reservoirs, or collected from streams, rivers, lakes, ice or groundwater sources that are not being diminished or salinised as a result of the extraction. The effects of over-extraction would be especially important if there are many endangered species, sensitive ecosystems, and interactions with on-going human impacts.

45. Human population density	
Indicator text:	Total human population density (number per km^2 land area).
Signals captured:	This is a proxy measure for pressure on the environment resulting from the number of humans being supported per unit of land. The greater numbers of people increases pressure on the environment for resources, for the attenuation of wastes and physical disturbance of the environment.

48. Human populations - coastal settlements	
Indicator text:	Density of people living in coastal settlements (i.e. with a city centre within 100km of any maritime or lake* coast). (* To be included, lakes must have an area of at least 100 sq km).
Signals captured:	This indicator captures the focus of stress on coastal ecosystems, often the most productive living areas in a country, through pollution, eutrophication, resource depletion and habitat degradation. The adjacent water areas are capable of spreading pollution widely in aquatic habitats and will not tend to allow for attenuation over upland areas. Countries with heavy densities of human populations living on their coastal areas are likely to be damaging some of their most productive and diverse areas and negatively affecting the resilience of the country to natural disasters such as cyclones, tsunamis etc.

Appendix 4 – List of workshop participants

The following is a list of the workshop participants. For the purposes of personal privacy, names have been excluded by the details provided. This list indicates the range of professional skills, knowledge and interests in the area of climate change in the Pacific.

Position:	Theme Leader – Natural Ecosystems
Organisation:	CSIRO Climate Adaptation Flagship
Location, Country:	Canberra, Australia
Brief details of past and present interests and past activities/research in climate change impacts and vulnerability, rural livelihoods, and/or development.	More than 20 years experience of developing methods to predict where particular trees will grow and how well they will grow. I wrote my first paper on climate change in 1987 and have contributed to the work of the Intergovernmental Panel on Climate Change (IPCC). As well as Australia my work has involved studies in Africa, Latin America and particularly SE Asia. Much of this work is summarised in ACIAR Proceedings No. 63 'Matching Trees and Sites' (available free on request from Comms@aciar.gov.au) and in 'Carbon Accounting in Forests' (downloadable from www.csiro.au/resources/pf14p.html).

Position:	Climate Impacts Scientists
Organisation:	CSIRO Climate Adaptation Flagship
Location, Country:	Canberra, Australia
Brief details of past and present interests and past activities/research in climate change impacts and vulnerability, rural livelihoods, and/or development.	Over the past 12 years I have been involved in the study of both climate change and climate variability impacts on both agricultural production and Natural Resource management. This has involved research assessing the implications of climate variability and change on rangeland productivity, commercial seedling establishment, grazing animal heat stress, crop production, catchment hydrology, coastal vulnerability and the interaction between climate variability and climate change on decadal and multi-decadal timescales. I have been a contributing author and expert reviewer of the Inter-Governmental Panel on Climate Change (IPCC) Third Assessment Report on Climate Change in 2001 and continued in an expert review capacity for the IPCC fourth Assessment report released in 2007.

Position:	Senior Scientific Officer
Organisation:	The University of the South Pacific
Location, Country:	Laucala Campus, Suva, Fiji Islands
Brief details of past and present interests and past activities/research in climate change impacts and vulnerability, rural livelihoods, and/or development.	I have completed an MA in Marine Affairs and Development Studies. Over the past 4 years I have been working and facilitating the implementation of community-based natural resource management initiatives in some sites in Fiji. Also, my work involves assisting in the implementation of an AUSAID project on Climate Change Adaptation in 6 sites in Fiji. Part of this project is working with the local people on the sites to identify and implement climate change adaptation strategies. Recently, I am researching on the social and economic impacts of community-based resource management projects on the local people. The study focuses on the identification of changes in socioeconomic variables in local communities as direct results of resource management actions.

Position:	Chief Executive Officer
Organisation:	Sugar Research Institute of Fiji
Location, Country:	Fiji
Brief details of past and present interests and past activities/research in climate	Did some simple studies to look at some of the climatic factors that may be affecting the sugar production within a few mills in Fiji. Desire to study as to how the various climatic conditions like increased temp

change impacts and vulnerability, rural livelihoods, and/or development.	and decreased rainfall would affect sugar production.

Position:	MC Intern Co-Coordinator
Organisation:	Micronesia Conservation Trust
Location, Country:	Pohnpei, FSM
Brief details of past and present interests and past activities/research in climate change impacts and vulnerability, rural livelihoods, and/or development.	Spent the last year of BA degree focussing on the politics of climate change in the Pacific and the ability of PICs to negotiate at international environmental meetings. I am now working towards my MA examining changing gender roles in the face of changing economic conditions in the Pacific. Most recently, I have been working with the Micronesia Conservation Trust in Pohnpei, FSM. I was one of the Micronesia Challenge Young Champion Intern Co-Coordinators, responsible for capacity building and spreading awareness about the MC through activities carried out by young Micronesian adults.

Position:	Theme Leader, Adaptive primary industries & enterprises
Organisation:	CSIRO
Location, Country:	Canberra, Australia
Brief details of past and present interests and past activities/research in climate change impacts and vulnerability, rural livelihoods, and/or development.	Completed a Bachelor of Science with Honours in 1983 from the University of New South Wales, Sydney, Australia, having focused on ecology, climatology and soil science. A PhD in the ecology and management of tropical grasslands. I am a climate change and adaptation specialist leading CSIRO research into adapting primary industries transforming Australia's agricultural industries and regions. As a Theme Leader in the CSIRO Climate Adaptation Flagship I currently lead a national team of researchers working with community, government and industry stakeholders to develop adaptations to climate change and climate variability and the interactions of these with broader emerging economic, environmental and social influences. I have been a major contributor to the Intergovernmental Panel on Climate Change since 1994 and have been part of many other international processes dealing with climate change adaptation and mitigation.

Position:	Senior Lecturer/Geography Programme Director
Organisation:	Earth Sciences, Victoria University of Wellington
Location, Country:	Wellington, New Zealand
Brief details of past and present interests and past activities/research in climate change impacts and vulnerability, rural livelihoods, and/or development.	I have completed an Honours and PhD in coastal geomorphology specialising in the response of coastal landforms to climatic and environmental change. I specialised in the development of coral reefs and islands and their vulnerability to climate change, focussing on sea-level rise and storms. Fieldwork has been conducted in Fiji, Niue, Torres Strait, Kiribati, Samoa and New Caledonia, investigating the links between reef growth, sediment production and island stability. This research has been conducted in participation with local and industry stakeholders and has been widely published in the academic literature.

Position:	Senior Programme Officer Climate Resilience and Water Group
Organisation:	AusAID
Location, Country:	Australia
Brief details of past and present interests and past activities/research in climate change impacts and vulnerability, rural livelihoods, and/or	Doctorate in environmental physics from Nottingham, UK. Have been teaching and researching in environment and climate change issues at USP. Have also worked for SPREP as climate change negotiations officer and at UNEP as Task manager for adaptation. Lot of experience working in climate change issues in the Pacific, including developing and implementing projects.

development.	

Position:	Manager Climate Services
Organisation:	Fiji Meteorological Service
Location, Country:	Nadi, Fiji Islands
Brief details of past and present interests and past activities/research in climate change impacts and vulnerability, rural livelihoods, and/or development.	I have completed a Masters Degree in Geography, thesis on the Relationship between Precipitation-Climate Extremes and ENSO in the Fiji Islands. Over the past 8 years, I have worked as a Climatologist with the Fiji Meteorological Service. Prior to this, I spent a year with the Ministry of Environment assisting with Fiji's first National Communications and National Vulnerability and Adaptation Report.

Position:	Program Manager – Environment & Climate Change
Organisation:	AusAID
Location, Country:	Suva, Fiji
Brief details of past and present interests and past activities/research in climate change impacts and vulnerability, rural livelihoods, and/or development.	Studied Marine Affairs and Management. Have worked at SOPAC, UNDP and now AusAID. Key areas focussed on include: environmental Vulnerability, climate change, environment, renewable energy and energy efficiency. Index. Areas of work include project implementation, project management and management of relationships.

Position:	Cropping Systems Scientist
Organisation:	CSIRO
Location, Country:	Toowoomba, Australia
Brief details of past and present interests and past activities/research in climate change impacts and vulnerability, rural livelihoods, and/or development.	I have completed an Honours Degree in Development studies, a PhD in plant competition in agricultural production, and post-doctoral research in climate change impacts on agriculture in the UK. Over the past 3 years I have been researching the impacts of climate change on the sugarcane and the horticultural industries in Australia. This research has been conducted in participation with industry stakeholders and focuses on the identification of appropriate adaptation strategies. I have recently co-authored a World Bank paper entitled: Climate Change Response Strategies for Agriculture: Challenges and Opportunities for the 21st Century.

Position:	Agricultural climatologist
Organisation:	NIWA
Location, Country:	Wellington, New Zealand
Brief details of past and present interests and past activities/research in climate change impacts and vulnerability, rural livelihoods, and/or development.	Hold a Diploma of Field Technology from Lincoln University. Work includes numerous climate consultancies in New Zealand, including climate adaption in the Kiwifruit and livestock industries. Editor, Climate Update, the monthly publication of New Zealand's National Climate Centre. Have managed a dairy farm in India; installed CliCom climate database in Kiribati; currently involved in the Integrated Climate Change Adaption in Samoa (ICCAS) project design and implementation, under the National Programme of Action (National Adaptation Programme of Action, Samoa, Ministry of Natural Resources and Environment, Govt of Samoa, 2005).

Position:	Principal Research Scientist
Organisation:	Bureau of Meteorology
Location, Country:	Melbourne, Australia
Brief details of past and present interests and past activities/research in climate change impacts and vulnerability, rural livelihoods, and/or	Climate research, global warming, El Niño, climate prediction, climate projections, communicating climate science to wider community, provision of climate services. Currently involved in the development of major new Australian program called the Pacific Climate Change Science Program (PCCSP), aimed at improving our understanding of the climate system in the Pacific region and providing some of the climatic information needed by PICs

development.	to adapt to climate change (e.g. regional climate change projections). The PCCSP is part of a broader International Climate Change adaptation Initiative administered by AusAID and the Australian Department of Climate Change.

Position:	Global Environment Specialist – Climate Change
Organisation:	Sustainable Environmental Management Ltd
Location, Country:	Auckland, New Zealand
Brief details of past and present interests and past activities/research in climate change impacts and vulnerability, rural livelihoods, and/or development.	I have a PhD in Geography studying seed banks and secondary successions in temperate rainforests. Since 1991 I have worked on vulnerability and adaptation assessments as team leader, instructor/trainer,. I have worked on V&A work with many SIDS and also as Lead Author and Convening Lead Author for AR4 and TAR. I have carried out work on agricultural systems in Papua New guinea and Thailand and on climate change issues in PICs and Caribbean SIDS. I now work as a consultant on V&A issues in SIDS.

Position:	Assistant Chief Executive Officer
Organisation:	Ministry of Natural Resource and Environment (MNRE)
Location, Country:	Apia, Samoa
Brief details of past and present interests and past activities/research in climate change impacts and vulnerability, rural livelihoods, and/or development.	I have completed a Master of Engineering in Energy Planning and Policy, a Bachelor of Engineering Technology and Associate Diploma of Engineering all from Australia Institution. In 2005-2006 Energy Advice to the Minister and the CEO of the Ministry of Work, Transport and Infrastructure in all matter related in Energy. In 2007-2008 transferred to the Ministry of Natural Resource and Environment as Assistant CEO Renewable Energy responsible for climate change; climate change mitigation; project energy efficiency in transportation and wood gasification technology funded by Italian Government; project energy efficiency in the electricity sector the demand and supply and building design funded by GEF. Very interested to develop research and understanding in climate change adaptation the impact of climate change in Hearth and Agriculture sector.

Position:	Systems Ecologist
Organisation:	CSIRO
Location, Country:	Townsville, Australia
Brief details of past and present interests and past activities/research in climate change impacts and vulnerability, rural livelihoods, and/or development.	I am a systems ecologist with interests and skills in spatial data analysis, community ecology and climate change. His current work involves assessing the effects of rising levels of atmospheric carbon dioxide on savannah ecosystems, the impacts of climate change on rangelands, and assessing adaptation strategies for the pastoral industry. He also looking at ways in which pastoral properties can be structured (both the internal arrangement of paddocks, and selection of properties within multi-property enterprises) to exploit the patchy distribution of forage resources, and to mitigate risks associated with climate variability.

Position:	Regional Programme Manager
Organisation:	Foundation of the Peoples of the South Pacific International (FSPI)
Location, Country:	Suva, Fiji
Brief details of past and present interests and past activities/research in climate change impacts and vulnerability, rural livelihoods, and/or development.	Currently I am managing FSPI's Mainstreaming of Rural Development Innovations Programme, which focuses mainly on supporting sustainable livelihoods in Pacific Island Communities. At the University of the South Pacific I did researches on Labour Mobility in Small Island States. In the Government of Tuvalu, I worked various Ministries including, environment, meteorology, education and rural and outer island development.

Position:	Genetic Resources Coordinator/manager of Centre for Pacific Crops and Trees (CePaCT)
Organisation:	Land Resources Division, Secretariat of the Pacific Community

Location, Country:	Suva, Fiji
Brief details of past and present interests and past activities/research in climate change impacts and vulnerability, rural livelihoods, and/or development.	The Centre is establishing a climate ready collection of crops and varieties sourced from Pacific countries and from overseas, which are seen to have traits which will help farmers manage climate change – drought tolerance, salt tolerance etc Collection will be established in tissue culture, virus tested and distributed. Also establishing evaluation sites in the Pacific – atolls, drought-prone areas etc Interest also in pursuing a holistic approach to managing crop production within climate change – so diversity, systems, soil/compost, etc

Position:	FACT Team Leader
Organisation:	Secretariat of the Pacific Community
Location, Country:	Suva, Fiji
Brief details of past and present interests and past activities/research in climate change impacts and vulnerability, rural livelihoods, and/or development.	Presently Team Leader for a new EU-funded project assisting Pacific Islander exporters of agricultural and forestry produce. Climate change, especially increased incidence of severe cyclones and sea level rise, is likely to have major negative impacts on agricultural and forestry production, rural livelihoods and exports. Previously worked as Leader of Forest Biodiversity Research Group in Biodiversity International (Rome) and as Team leader for AusAID project SPRIG – South Pacific Regional Initiative on Forest Genetic Resources, both of which included climate change components.

Position:	Pacific Regional Environment and Climate Change
Organisation:	AusAID
Location, Country:	Canberra, Australia
Brief details of past and present interests and past activities/research in climate change impacts and vulnerability, rural livelihoods, and/or development.	Hold a degree in natural resource management and masters in applied anthropology and development. For past two years have focussed on AusAID's Pacific regional environment and climate change policy and programs.

Position:	Research Agronomist
Organisation:	CSIRO
Location, Country:	Mossman, Australia
Brief details of past and present interests and past activities/research in climate change impacts and vulnerability, rural livelihoods, and/or development.	During the preceding 18 months I have been involved in research investigating productivity, economic and water quality impacts of potential climate change on sugarcane production in the wet and dry tropics of Australia. For six years I have been involved in researching farm management practice change, investigating both farm and regional (watershed) scale financial-economic and environmental impacts, focussing on sugarcane, banana, forestry and grazing production systems.

Position:	Principal Engineer (Drainage & Irrigation)
Organisation:	LWRM Division, Ministry of Agriculture
Location, Country:	Suva, Fiji Islands
Brief details of past and present interests and past activities/research in climate change impacts and vulnerability, rural livelihoods, and/or development.	Completed Master of Civil Engineering and Post Grad. Diploma in Hydraulic Engineering (Deltaic/Lowland). Working in Fiji in the above department for the planning, management, implementation and monitoring on the development of Drainage & Irrigation infrastructures for the Agriculture. Experienced with impact of Climate change on existing and developing D&I programs. From 2005- the present, being participate in the Pacific Adaptation in the Climate Change regional project. Assist in preparation of countries papers for the PACC project proposals incorporated with the SPREP(Samoa)

Position:	Director
Organisation:	Climate Change Division, MECM

Location, Country:	Honiara, Solomon Islands
Brief details of past and present interests and past activities/research in climate change impacts and vulnerability, rural livelihoods, and/or development.	I have only attended a number of specific courses ranging from database management to climate prediction courses to climate change vulnerability and adaptation assessment program. I have been part of a team called CLIPS that made some research study on the climate and livelihoods of people on the 3 Polynesian outliers of Solomon Islands in 2006. This year, following a new merge/formation of the ministry (Environment, Conservation & Meteorology) a new division (Climate Change) was established and I was lately being appointed as the Director. Prior to that I have worked as a meteorological service officer for more than 15 years and later posted as a climate change officer within the Climate Section of the meteorological service.

Appendix 5 – Workshop evaluation

Executive Summary

An evaluation questionnaire was designed to help CSIRO and AusAID assess:

(a) How well the workshop format and the information presented was in facilitating an assessment of the relative impact of climate change on rural livelihoods in the Pacific region, and
(b) How effective the workshop was in enhancing capacity in climate change adaptation research and development in the Pacific region.

The effectiveness of the workshop was assessed via formal pre- and post workshop questionnaires. Seventeen people attended the workshop, in addition to 6 members of the CSIRO project team. A broad range of disciplines related to climate change and development were represented at the workshop and nearly half of the participants had been professionally associated with climate change research and development for over 10 years. Analysis of feedback from the participants revealed:

- Over 90% of the workshop participants considered the likely impact of climate change on the Pacific region in general to be at least substantial, with nearly 20% seeing it as extensive. This view remained largely unchanged at the end of the workshop. In contrast there was a trend towards participant's viewing the adaptive capacity in the region to be lower than previously thought as a result of the group discussions and information presented at the workshop. In general, the level of adaptive capacity was seen as being insufficient to enable the continued sustainability of rural livelihoods in the Pacific.
- Sufficient contextualised information was presented to effectively facilitate an assessment of the vulnerability of rural livelihoods in the Pacific to climate change that was commensurate with the broad scoping approach outlined in the project remit, and the time limits imposed by a one-day workshop.
- The majority of participants considered the workshop to be considerably useful in building capacity within key country, region and industry decision-makers working in the area of climate change and rural livelihoods in the Pacific. In addition to the workshop acting as an effective forum for discussion amongst participants, the bibliographic information provided by each participant also provided a key resource for networking during and after the workshop.
- Comments from a number of participants indicated that they found the day to be both informative and interesting and expressed a desire for continued involvement in the project. There was a clear indication that the participants saw value in the research and the conceptual methodology employed (i.e. assessing contextual vulnerability by considering both impact and adaptation using a participatory approach).
- Questions raised by two participants regarding the merit of the information gained during the livelihood analysis will, in part, be addressed for a limited number of countries/island types. This will be done by (a) obtaining subsequent input into the analysis from a number of key people known to have significant knowledge of Pacific countries inadequately represented at the workshop, and (b) including secondary data in the form of the Environmental Vulnerability Index. Workshop participants will be further engaged to ascertain how the information generated may inform their areas of work and provide feedback on future research opportunities.

Evaluation

The evaluation consisted of a pre-workshop and post-workshop questionnaire. The pre-workshop evaluation contained 4 multiple-choice questions and the post-workshop evaluation contained 8 (Box 1). Two of the questions appeared on both the pre- and post-workshop questionnaires and provided a means of assessing the direct impact of the workshop on the participants' perceptions of climate change vulnerability across the Pacific.

Box 1 Evaluation questions

Pre-workshop questions

1. In what sector do you work/have professional interests related to climate change?
2. How many years have you been working/had a professional interest in climate change?
3. What do you consider to be the likely general scale of impact of climate change on rural livelihoods in the Pacific region?
4. To what extent do you consider adaptation can ameliorate the impact of climate change on rural livelihoods in the Pacific region?

Post workshop questions

1. What do you consider to be the likely scale of impact of climate change on rural livelihoods in the Pacific region?
2. To what extent do you consider adaptation can ameliorate the impacts of climate change on rural livelihoods in the Pacific region in general?
3. How would you rate details presented regarding the aims of the workshop and the contribution required from you as a participant?
4. How useful was the information provided to you prior to and during the workshop in preparing you for discussions on the relative vulnerability of countries/island types in the Pacific to climate change?
5. How useful was the format of the workshop in promoting discussions between all participants?
6. How effective was the workshop in enhancing your knowledge of climate change impacts and adaptation on rural livelihoods in the Pacific region?
7. How effective was the workshop in enhancing professional networks in connection with climate change research and development for the Pacific region?
8. Are there any other comments you would like to make?

Seventeen people attended the workshop, in addition to 6 members of the CSIRO project team (Appendix 4). The range of climate change related sectors that participants worked in, or had professional interests in, is shown in Fig. 1. A number of participants had interests and experience in multiple sectors. Figure 1 shows that the participants attending the workshop covered a broad range of disciplines related to climate change and development and hence were able to provide multiple perspectives on vulnerability in the Pacific.

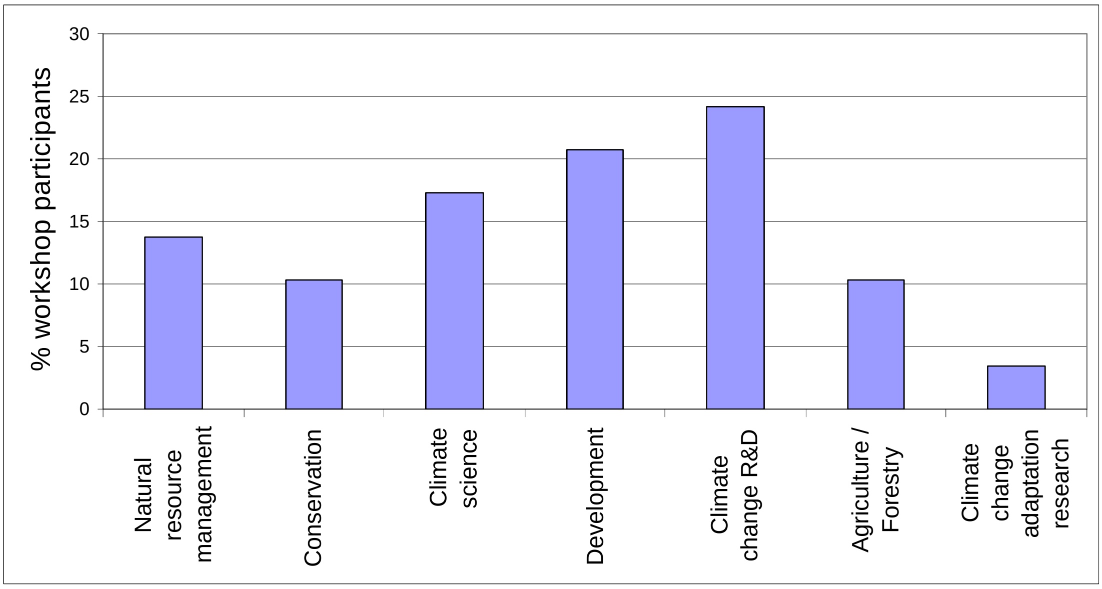

Fig. 1 Sectors that workshop participants worked in or had professional interests in related to climate change.

Figure 2 shows the number of years that participants had been working, or had a professional interest, in climate change. Nearly half of the participants had been professionally associated with climate change research and development for over 10 years. Whilst the breadth of sectors and knowledge amongst the workshop participants was broad, during the livelihood analysis it became evident that there was insufficient knowledge about a number of the countries included in the study. This will be addressed by subsequent input into the analysis being sought from a number of key people known to have significant knowledge of the individual Pacific countries inadequately represented at the workshop.

Over 90% of the workshop participants considered the likely impact of climate change on the Pacific region in general to be at least substantial, with nearly 20% seeing it as extensive (Fig. 3). There was little change in the participants' views as a result of participating in the workshop. In terms of capacity for adaptation (Fig. 4), approximately half of the participants considered this to be only moderate, and hence insufficient to enable the continuation of present levels of sustainability in rural livelihoods. As a result of the workshop, a number of participants considered adaptive capacity to be lower than they had previously thought.

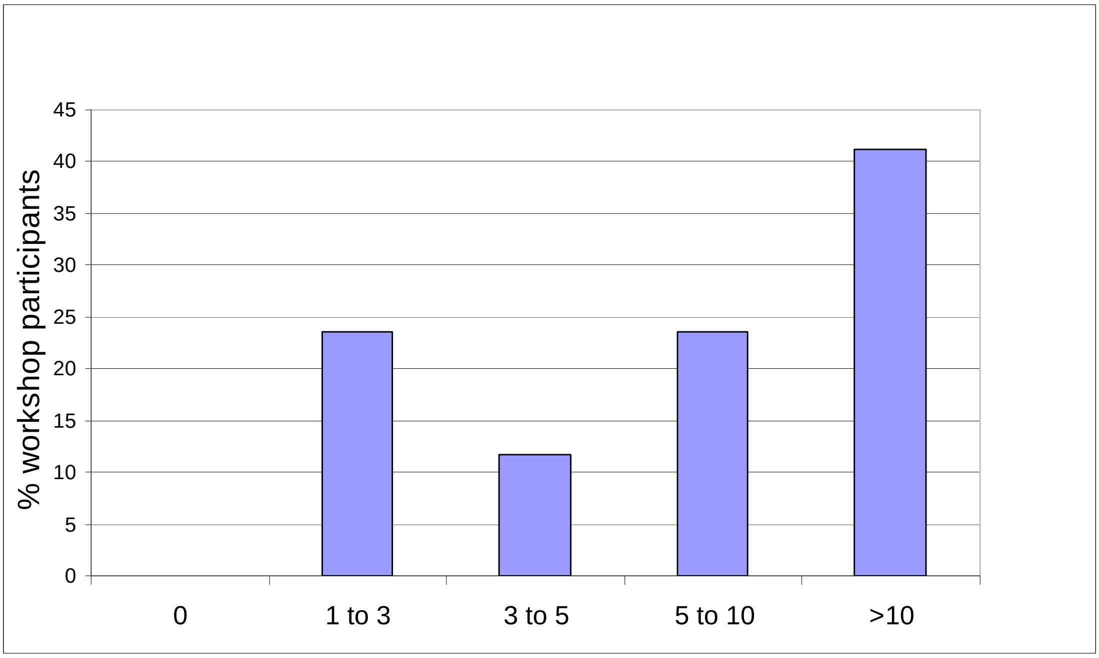

Fig. 2 The number of years that participants had been working in or had a professional interest in climate change.

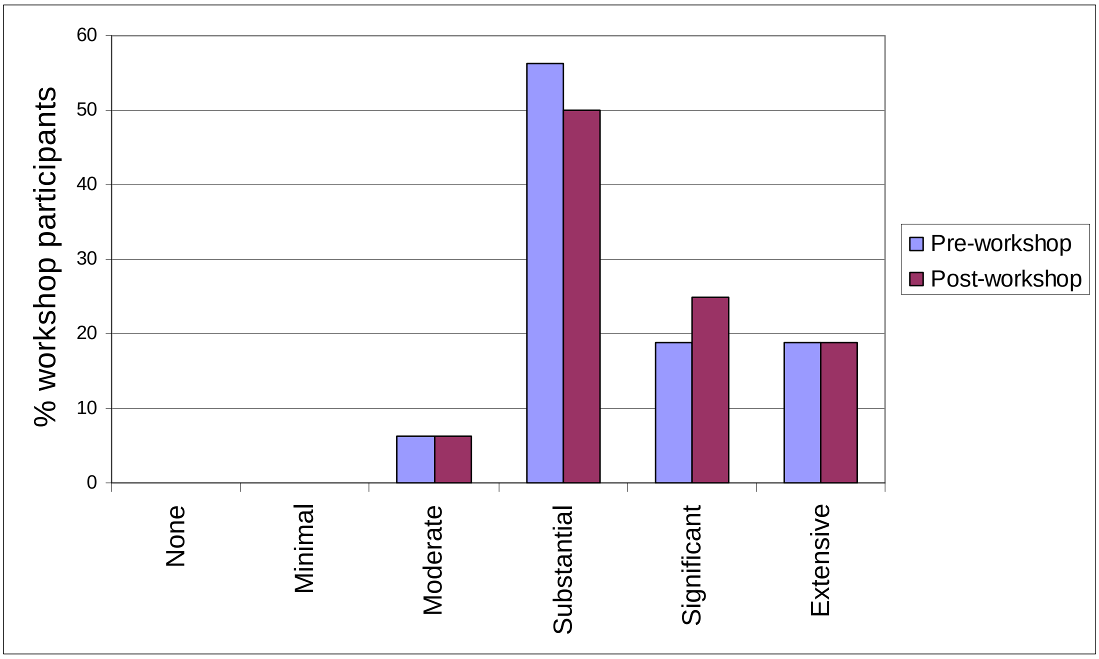

Fig. 3 Participants' pre- and post-workshop views on the likely general scale of impact of climate change on rural livelihoods in the Pacific region.

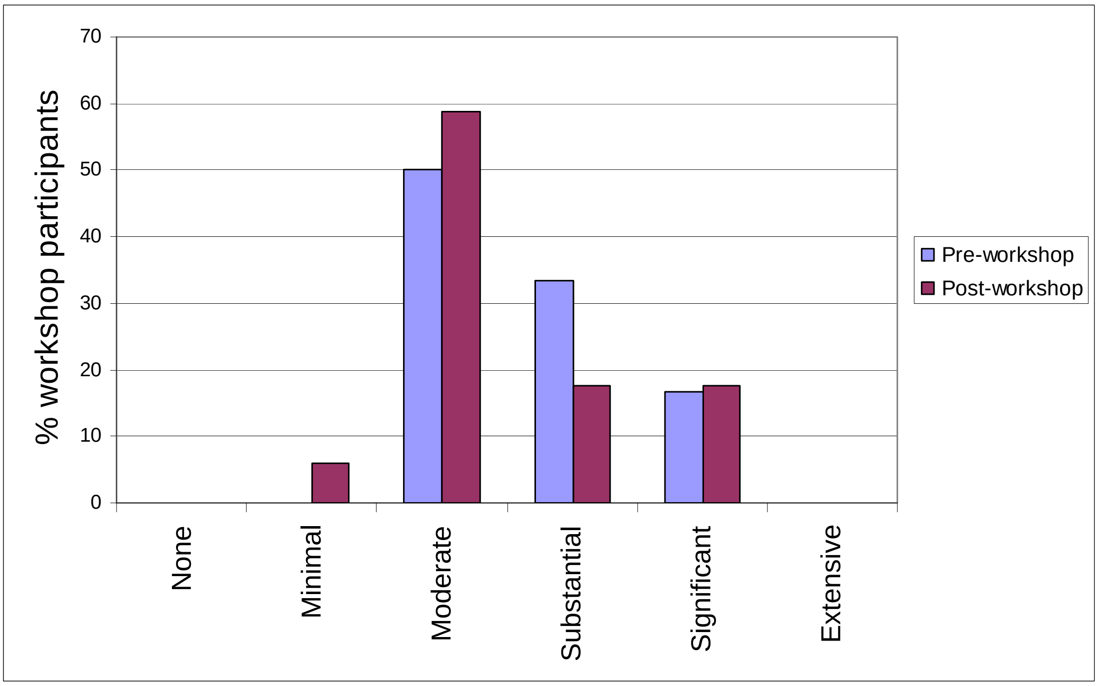

Fig. 4 Participants' pre- and post-workshop views on the extent to which adaptation can ameliorate the impact of climate change on rural livelihoods in the Pacific region.

All participants indicated that they had received at least adequate detail regarding the aims of the workshop and the contribution required from them as participants (Fig. 5). No participants rated the provision of information as poor. Nearly 90% of the participants considered the information that they had received either prior to the workshop or during it to be at least adequate in preparing them for discussions on the relative vulnerability of countries/island types already familiar to them, to climate change (Fig. 6). Over 60% of these considered the material to be considerably useful.

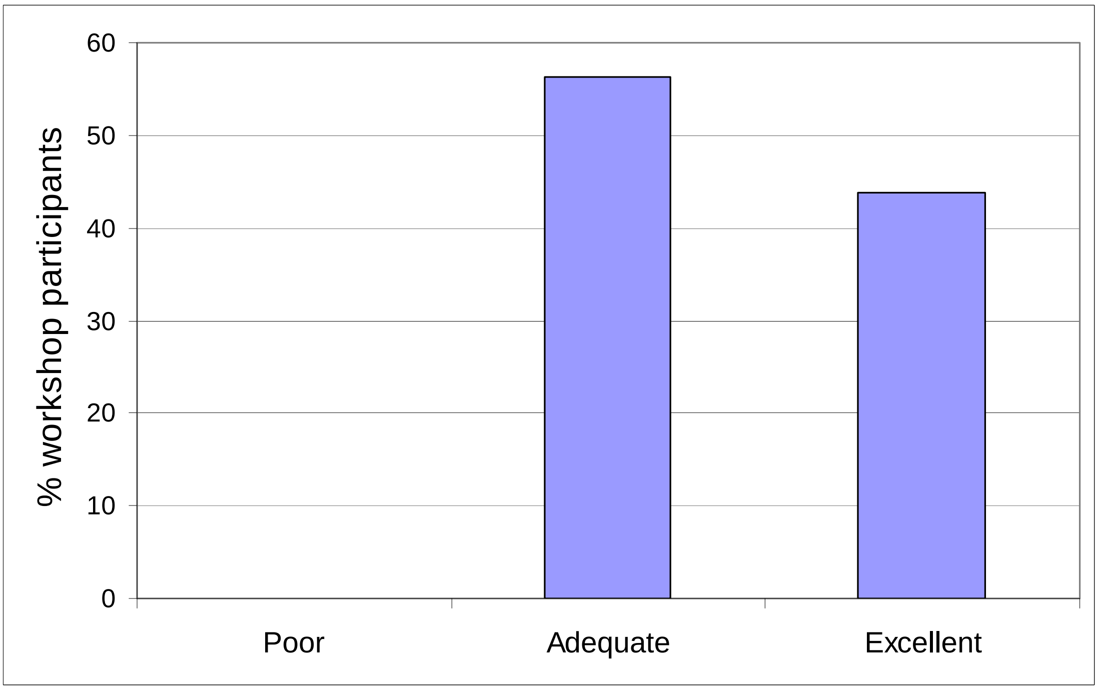

Fig. 5 Participants' rating of the details presented to them regarding the aims of the workshop and the contribution required from them.

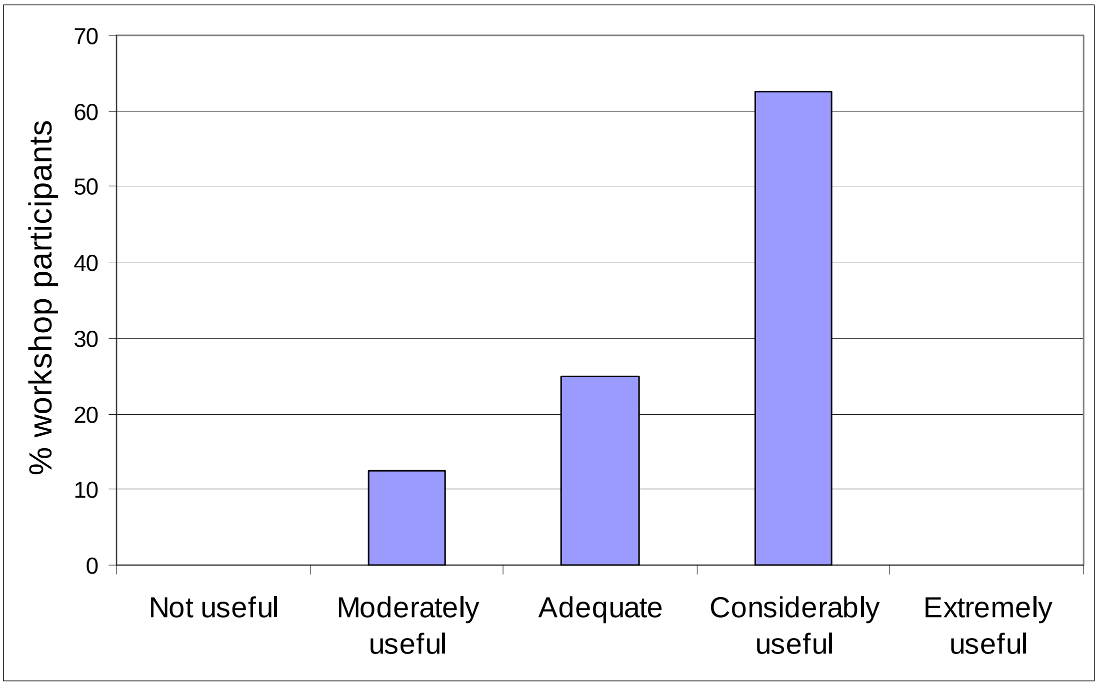

Fig. 6 Usefulness of information provide to participants prior to and during the workshop.

All participants considered the format of the workshop (consisting of presentations, whole of workshop discussions and breakout groups) to be at least moderately effective in promoting discussions between all participants (Fig. 7). Over 60% of the participants thought the format was either considerably or extremely effective.

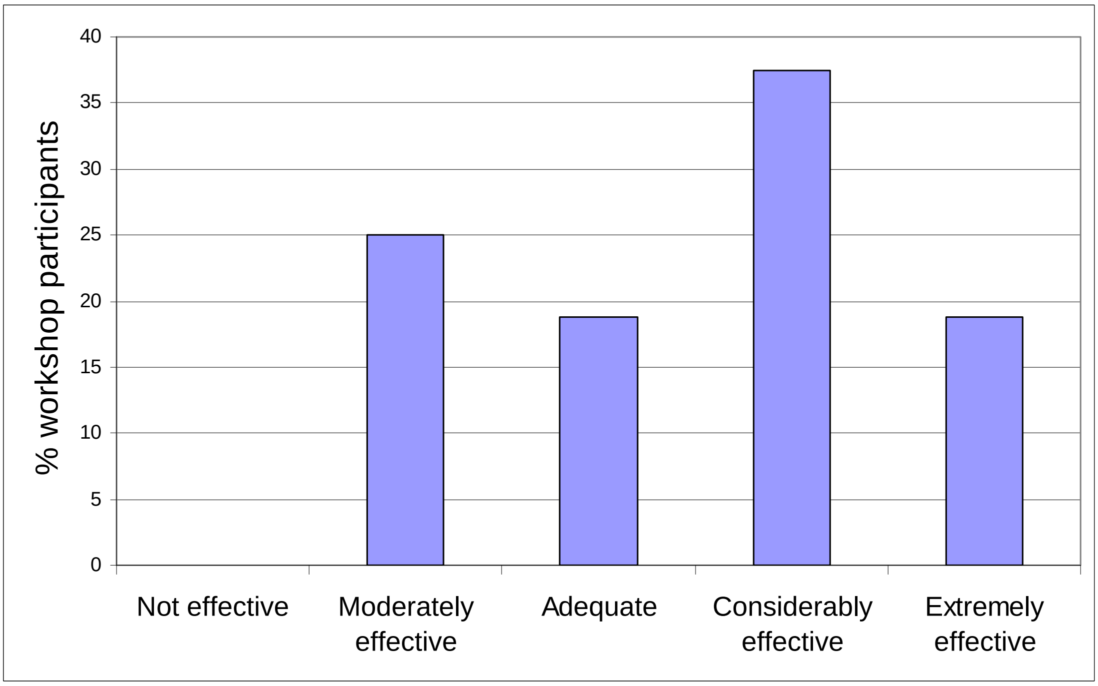

Fig. 7 Usefulness of the workshop format in promoting discussions between all participants.

One of the aims of the workshop was to build capacity within key country, region and industry decision-makers working in the area of climate change and rural livelihoods in the Pacific. The majority of participants considered the workshop to be considerably useful in enhancing this and over 90% saw the workshop as at least adequate in meeting this aim (Fig. 8). In addition to the workshop acting as an effective forum for discussion amongst participants (see Fig. 7 above), the bibliographic information submitted by each participant also provided a key resource for networking during and after the workshop. Indeed, one participant commented that it was "good to see biographies" on their evaluation questionnaire.

More general comments made on the post-workshop evaluation questionnaire were on the whole complimentary and indicated satisfaction with the information received, its delivery and the expectations of participants. These included a number of comments where participants were "looking forward to seeing results and contributing further", and more general comments about the day, such as "mix of presentations and small groups – good format"; "a satisfactory workshop" and "very interesting, informative and constructive meeting for me".

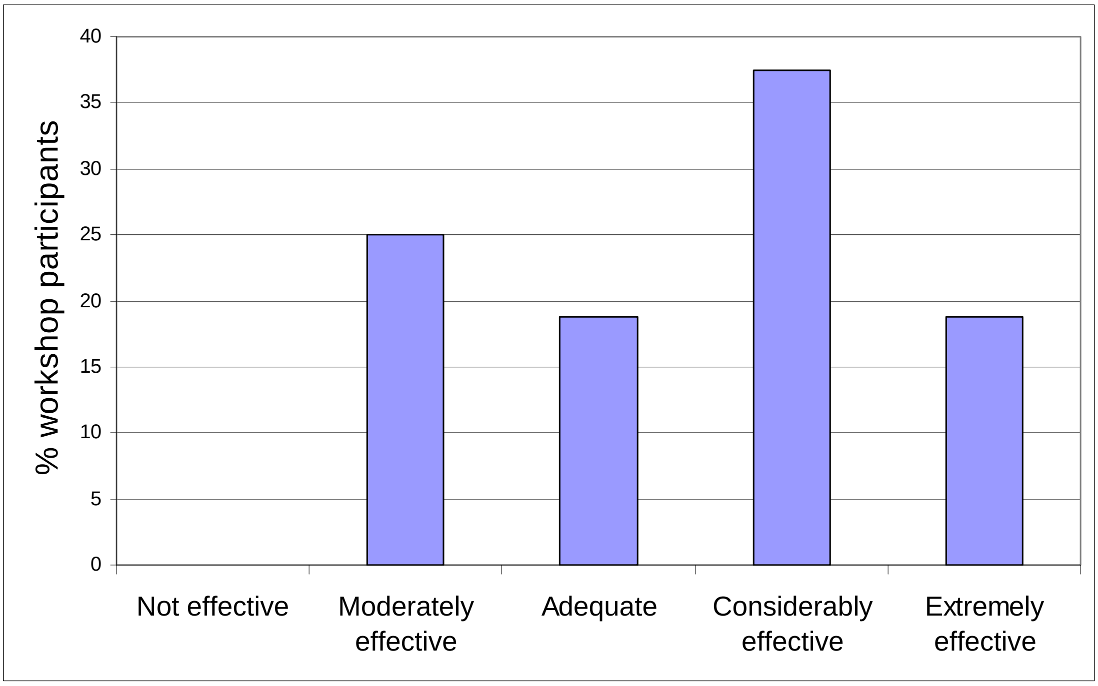

Fig. 8 Usefulness of the workshop in enhancing participants' knowledge of climate change impacts and adaptation on rural livelihoods in the Pacific region.

The use of the livelihood analysis as a method of ranking the relative vulnerability received mixed comments from participants. Whilst one participant noted "it is a new kind of approach/process for me. Interesting", two others showed concerns about the usefulness of the activity, one noting "I have some doubts about the usefulness of the group activities". They further asked if "the right people were in the room?", a question relating to the selection of participants that had attended the workshop. It is concluded that this comment more specifically related to the livelihood analysis breakout group discussing the relative vulnerability of atoll and coral islands. Two of the four participants that had failed to attend the workshop had been allocated to this breakout group and their absence may have contributed to the insufficient knowledge available for input into discussions.

The countries considered by the participants to be insufficiently represented, and hence resulting in low confidence in the data provided, were Timor-Leste (East Timor) and Tokelau. It was noted that in the 'volcanic islands' breakout group in particular, that whilst there was lively debate about the ratings of each attribute in the livelihood analysis, there was generally a high level of agreement between participants who considered themselves knowledgeable about specific countries. Whilst beyond the resources of this project, a formal test of the rigor of the data collected could involve the replication of the breakout group exercise with other participants to determine if the overall adaptive capacity values vary significantly given different participants.

More specifically, a comment was made about the process of identifying appropriate indicators of vulnerability and it was questioned if "… by 'averaging', for example, traditional knowledge and western education, this incurred a loss of important detail". This sentiment was echoed by another participant: "there are huge issues with the methodology and the reliability of information gleaned to quantify indicators". In hindsight, the selection of more specific indicators may have reduced the "loss of important detail". Whilst the livelihood analysis was aimed at providing a broad and rapid assessment of relative vulnerability as perceived by those working and living in the region (and hence not an in-depth assessment), post-workshop analysis and research, as details from other studies conducted in the region and a comparison with national indices (e.g. Environmental Vulnerability Index, (EVI)), will enable important details to be synthesized into the final analysis of relative vulnerability.

The workshop appeared to have presented sufficient information in a suitable format to effectively facilitate an assessment of the relative impacts of climate change on rural livelihoods in the Pacific commensurate with the broad scoping approach adopted in the project remit and within the time limits imposed by a one-day workshop. Comments from a number of participants indicated that they found the day to be both informative and interesting, and the general willingness to see output from the workshop and have continued involvement in the project, was a clear indication that participants saw value in the research and the conceptual methodology being employed (i.e. assessing contextual vulnerability by considering both impact and adaptation using a participatory approach). Questions raised by two participants regarding the merit of the information gained during the livelihood analysis was in part addressed during the subsequent analyses by obtaining more in depth information from secondary data including published country-level studies and the EVI.

The evaluation indicated that participants found the workshop to be an effective activity for enhancing capacity in climate change adaptation in the Pacific region through a combination of networking opportunities (i.e. group discussions and bibliographic details of participants) and the information presented.

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