Appraisal Mission:

"Managing the Impact of climate change on land resources in the Pacific"

Climate Change in the Pacific Islands: Impacts and Scope for Action

Working Paper 1

By:

Graham Sem
Sustainable Environmental Management Ltd
Auckland, New Zealand

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A. Introduction

As with other small islands developing States (SIDS), Pacific island countries (PICs) are highly vulnerable to climate change and sea level rise owing partly to their small land masses surrounded by ocean, and their location in regions prone to natural disasters. PICs are often characterized by having relatively large populations for the area they occupy with high growth rates and densities; poorly developed infrastructure and limited natural, human and economic resources, and their high dependence on marine resources for their livelihood needs. Most of their economies are reliant on a limited resource base and are vulnerable to external forces, such as changing terms of trade, trade liberalization, and migration flows. Adaptive capacity to climate change is generally low.

Changing climate regimes

The climates in the Pacific islands region are influenced by a number of factors such as trade wind regimes, the paired Hadley cells and Walker Circulation systems, seasonally varying convergence zones such as the South Pacific Convergence Zone (SPCZ), semi-permanent subtropical high-pressure belts, and zonal westerlies to the south, with the El Niño-Southern Oscillation (ENSO) as the dominant mode of year to year variability. The Madden-Julian Oscillation (MJO) is also a major mode of variability of the tropical atmosphere-ocean system of the Pacific on times scales of 30 to 70 days, while the leading mode with decadal time-scale is the Inter-decadal Pacific Oscillation (IPO). A number of studies suggest the influence of global warming could be a major factor in accentuating the current climate regimes and the changes from normal that come with ENSO events.

Recent studies in the southern Pacific region show that the annual and seasonal ocean surface and island air temperatures have increased by 0.6 to 1.0^{o}C since 1910 throughout a large part of the South Pacific, southwest of the South Pacific Convergence Zone (SPCZ) where as decadal increases of 0.3 to 0.5^{o}C in annual temperatures are only widely seen since the 1970, preceded by some cooling after the 1940, which is the beginning of the record, to the northeast of the SPCZ.

Analyses of trends in extreme daily rainfall and temperature across the South Pacific for the period 1961 to 2003 show significant increases in the annual number of hot days and warm nights, with significant decreases in the annual number of cool days and cold nights, particularly in years after the onset of El Nino, with extreme rainfall trends generally less spatially coherent than were those of extreme temperature. The maximum number of consecutive dry days is decreasing and the number of heavy rainfall events is increasing which is consistent with changes reported from global analysis of daytime and nighttime temperatures.

Variations in tropical cyclones, hurricanes, typhoons in all small islands' regions are dominated by ENSO and decadal variability which result in a redistribution of tropical storms and their tracks, so that increases in one basin are often compensated by decreases in other basins. For instance, during an El Niño event, the incidence of tropical storms typically decreases in the far western Pacific and the Australian regions, but increases in the central and eastern Pacific while during La Nina the trend reverses. The numbers and proportion of hurricanes reaching category 4 and 5 globally have increased since 1970, while total number of cyclones and cyclone days decreased slightly in most basins which is consistent with the trends observed in the Pacific islands region. Additionally, in the tropical South Pacific, the distribution of tropical storms and their tracks are dominated by ENSO and decadal variability, with small islands to the east of the dateline highly likely to receive a higher number of tropical storms during an El Nino event compared to a La Niña event and vice versa.

Long-term climate change is likely to occur in the Pacific islands region, and this is likely to increase the frequency and intensity of climate extremes such as tropical cyclones. Superimposed upon these current climate risks are additional environmental stresses caused by changes in socio-economic conditions. Thus the human systems in the Pacific region are highly sensitive to changes in water supply and demand, land use, land use practices, and demographic changes. From the sustainable development perspective; the socio-economic dimensions of climate change are probably as important as the biophysical climatic factors.

Experiencing impacts of climate change and variability

In the last couple of years and during the present decade a number of PICs had suffered great economic losses due to natural disasters particularly with the devastation and suffering caused by tropical cyclones. A few examples would illustrate the severity of these events.

a) In 2003, Fiji experienced severe flooding and losses from Cyclone Ami in key development sectors: housing, education, health, agriculture, tourism, sugar, business, infrastructure, telecommunications and power supply with an estimated cost of damage at FJ$104.4 million and over 70% of this damage was to the public sector. The cyclone also caused fourteen deaths.

b) In the Cook Islands, over a period of five weeks (from beginning of February to early March) in 2005, five tropical cyclones, four of which were category 5 (Meena 02/02/05, Nancy 10/02/05, Olaf 14/0205, Percy 25/02/05 and Rae 04/03/05) devastated the islands causing widespread damage to infrastructure and property. The cost of the damage was initially assessed at (cost of recovery) USD5, 531,200.

c) In Niue, Cyclone Heta in January 2004, caused devastation to people, properties, government and industry, infrastructure, agriculture and the economy with an estimated damage cost of more than US$60 million (or NZ$89.1 million).

d) In Tuvalu, even a short dry period of 2-3 weeks without rain can lead to water shortages. For instance in 1999, a severe drought (i.e. period without rain longer than 2-3 weeks) had forced the government to purchase a desalination plant from Japan (very expansive infrastructure) which now costs AU$30,000 per month to run given its intensive use of costly diesel fuel. This is deemed to be quite unsustainable and the long-term costs could be prohibitive.

e) In Tonga, the squash crop which had been producing 50% of the country’s exports by value was more than halved.

f) In Vanuatu, the most comprehensive assessment was conducted for Cyclone Ivy in 2004 which estimated a total cost at US$12 million. Cyclone Ivy affected 50,000 people and one fatality, 90% of water resources, 70% of roads, 60% of health infrastructure, 112 schools and over 80% of food crops were damaged.

g) In a study conducted by the World Bank (2000), Tarawa atoll in Kiribati could face average annual economic damages of US$8-US$16 million by 2050 and in years of strong storm surge up to 54% of South Tarawa could be inundated, with capital losses of up to US$430 million.

h) In Papua New Guinea, Australian government spent more than AUD$30 million delivering food aid to isolated areas of the highlands and low-lying islands affected by drought, with further losses in coffee production.

i) In FSM, crops and water were severely affected and a national disaster was declared during which time food aid and water was delivered to all affected areas.

j) In Samoa, fires sparked by unusually dry conditions destroyed large areas of forest on the island of Savai'i.

k) The World Bank has estimated that in the 1990s alone, reported natural disasters cost the Pacific islands region US$2.8 billion

Among the natural disaster being experienced in the Pacific islands region, the single most important natural disaster appears to be those of windstorms (including tropical cyclones, tidal surges and storms). From information and data on the nature and type of natural disasters that have been experienced in the Pacific Islands region between 1950 and 2004 (Bettencourt, S. et. al. 2006), it appears that droughts and floods, while fewer in number, have had a significant impact on the economies and livelihoods of Pacific islands countries with losses of US$137 million and US$95 million respectively.

In terms of the geographic distribution of natural disasters, it is evident that Melanesian region suffered the most number of natural disasters including, climate-induced droughts, floods and tropical cyclones with a loss of over US$1.6 billion while in Polynesia the losses amounted to over US$1.7 billion in 2004. In Micronesia, the total loss and the number of natural disasters is distorted by inclusion of Guam in the analysis. Thus, the impacts of climate change which are already being experienced in the PIC region can be summarized as follows:

a) Climate change will affect the physical and biological characteristics of the coastal areas, modifying their ecosystem structure and functioning. It will also affect near-shore marine and coastal areas, many wetlands and coastal forests by changes in sea level and storm surges.

b) Climate variability and intensification of hurricanes pose a significant threat to the sustainable development of Pacific island countries (PICs).

c) The sustainable development of all countries is highly dependent on their natural resource base which is being highly threatened by climate change and sea-level rise.

d) The potential economic impact of climate change on the Pacific countries is estimated at US$ 6 billion based on damage cost storms between 1990-2004.

Thus, climate change, climate variability and sea-level rise are not just environmental, but also economic, social, and political issues for Pacific island countries (PICs). The impacts, and in particular the related economic and social shocks, pose serious political and national financial management issues for Pacific island countries. Climate extreme events can adversely affect gross domestic product, balance of payments, budget deficits, foreign debt, unemployment, and living standards. Many communities and the resources they depend on for their daily livelihood and income tend to be adversely affected by the changing climate. In some situations the very survival of communities is already being seriously threatened. These concerns have reached the highest echelons of the Governments, including the Pacific Islands Forum Leaders meetings. With the Pacific's unique combination of geographical, biological, sociological and economic characteristics that can be found nowhere else in the world, the effects of climate change and extreme events are threatening the very existence of these vulnerable ecosystems and people.

Despite support from the international community in helping the PICs to understand the impacts of changes in climate both in the short and long terms, PICs have identified many critical areas where better understanding and response interventions are necessary in order to cope with and adapt to myriad changes which are likely to be exacerbated by atmospheric and oceanic changes. The reports of the regional technical meetings, activities, programmes and projects on climate change, climate variability and sea level rise in the Pacific region form a necessary point of reference since they contain a wide range of actions that are required in pursuit of sustainable development.

Previous impacts and vulnerability assessments

Reviews of previous assessments of vulnerability and adaptation to climate change, climate variability and sea-level rise in the PICs region[1] have highlighted the following:

a) Climate variability, development and social changes and the rapid population growth being experienced by most PICs are already placing pressure on sensitive environmental and human systems; and these impacts would be exacerbated if the anticipated changes in climate and sea level (including extreme events) did materialize;

b) The future health and productivity of coral reef and mangrove ecosystems will have a significant influence on the future well-being of many PICs – the anticipated detrimental effects on coral reefs arising from higher sea surface temperatures and CO_2 levels will be worsened by the degraded nature of these ecosystems;

c) Land-use changes, including settlement and use of marginal lands for agriculture, are decreasing the natural resilience of environmental systems and hence their ability to accommodate the additional stresses arising from changes in climate and sea level;

[1] Analysis of 10 V&A assessments in national communications from Cook Islands, Federated States of Micronesia, Fiji, Kiribati, Marshall Islands, Nauru, Samoa, Solomon Islands, Tuvalu and Vanuatu.

d) Given the limited area and low elevation of the inhabitable lands the most direct and severe effects of climate and sea level changes will be increasing risks of coastal erosion, flooding and inundation; these effects are exacerbated by the combination of seasonal storms, high tides and storm surges;

e) Other direct consequences of anticipated climate and sea level changes will likely include: reduction in subsistence and commercial agriculture production of crops such as taro and coconut; decreased security of potable and other water supplies; increased risk of dengue fever, malaria, cholera and diarrhoeal diseases; and decreased human comfort;

f) Groundwater resources of the lowlands of high islands and atolls may be affected by flooding and inundation from sea level rise; water catchments of smaller, low-lying islands will be at risk from any changes in the frequency of extreme events;

g) Climate and related oceanic variations already have significant impacts on fish catches, both subsistence and commercial; anticipated changes in climate and ocean conditions will reduce the security of this resource;

h) The overall impacts of changes in climate and sea level will likely be cumulative and determined by the interactions and synergies between the stresses and their effects

Given the foregoing concerns, there is a growing recognition among the PICs that climate change adaptation needs to be integrated into national development. In this context the two most relevant approaches for integration of adaptation in the Pacific region based on the experiential circumstances are those of "hazards-based approach" and "vulnerability-based approach." Hazards-based approach assesses current climate vulnerability or risk in the priority system and uses climate scenarios to estimate changes in vulnerability or risk over time and space, while the vulnerability-based approach focuses on the characterization of a priority system's vulnerability and assesses how likely critical thresholds of vulnerability are to be exceeded under climate change. Current vulnerability is seen as a reflection of both development conditions and sensitivity to current climate. The vulnerability-based approach can be used to feed into a larger climate risk assessment.

PICs have often highlighted the need to pilot climate change adaptation implementation programmes and projects at regional and national levels given that most climate change projects implemented in the region since the early nineties have largely concentrated on assessments and capacity building. Whilst these initiatives are highly commended, PICs have continued to call for urgent support for adaptation action so that planned adaptation is carried out to increase their resilience to more frequent and more intense extreme climate events. They further argued that adaptation implementation will allow for a better examination of inter-linkages between climate vulnerability, socio-economic conditions and sustainable development priorities not only in facilitating resilience-building but also contribute significantly to the achievement of sustainable development.

Past studies of adaptation options for PICs have been largely focused on adjustments to sea-level rise and storm surges associated with tropical cyclones. There was an early emphasis on protecting land through 'hard' shore-protection measures rather than on other measures such as accommodating sea-level rise or retreating from it. Vulnerability studies conducted for selected PICs show that the costs of overall infrastructure and settlement protection is a significant proportion of GDP, and well beyond their financial means. More recent studies have identified major areas of adaptation, including water resources and watershed management, reef conservation, agricultural and forest management, conservation of biodiversity, energy security, increased share of renewable energy in the energy supply, and optimized energy consumption. Proposed adaptation strategies have focused on reducing vulnerability and increasing resilience of systems and sectors to climate variability and extremes through mainstreaming adaptation.

While it is clear that implementing anticipatory adaptation strategies early on is desirable there are obstacles associated with the uncertainty of the climate change projections. This has given rise to the suggestion that a better strategy for small islands is to enhance the resilience of whole island socio-ecological systems, rather than concentrate on sectoral adaptation. The need to implement adaptation measures in PICs was highlighted in the many documents and workshops where it was suggested that risk-reduction strategies together with other sectoral policy initiatives in areas such as sustainable development planning, disaster prevention and management, integrated coastal zone management, water resources management, sustainable agriculture and food security and health care planning should be employed.

Thus an adaptation strategy for the PICs should include a strategy for precautionary adaptation since it is difficult to predict far in advance how climate change will affect a particular site, sector or community. Thus adopting a “no regrets” adaptation measures would be justified even in the absence of climate change, as this would more than likely lead to better management of natural resources and sustainable development.

B. Key Vulnerabilities to Climate Change in PICs

Climate and Climate Change

Observational records show that sea surface temperatures have been increasing by 0.1ºC per decade in the oceans where most SIDS are located. In Southeast Asia and the South Pacific significant increases have been detected in the annual number of hot days and warm nights, with significant decreases in the annual number of cool days and cold nights. Almost all observation stations have exhibited increases in the frequency of hot extremes and decreases in cold extremes, with many of these trends being statistically significant. Mean rainfall has showed an increasing trend in, and north east of, the South Pacific Convergence Zone. Extreme rainfall trends were less spatially coherent, with some stations showing increases in the proportion of annual rainfall from extreme events and some showing decrease in the number of rain days. The annual and seasonal ocean surface and island air temperatures have increased by 0.6 to 1.0ºC since 1910 throughout a large part of the South Pacific and to the northeast where decadal increases of 0.3ºC to 0.5ºC in annual temperature have been observed since 1970. The increases in surface air temperatures have been greater in the Pacific than global rates of warming.

The projections of global warming indicate a warming trend for all small island states ranging from an annual mean change of 1.98°C in the Pacific Ocean to 2.10°C by the 2050s. With respect to precipitation, the range of projections is still large, and even the direction of change is unclear. Sea surface temperatures are projected to increase by 1°C.

Tropical cyclone intensities could increase 5 to 10 per cent by about 2020 whereas the peak precipitation rates are likely to increase by 25 per cent in response to increases in maximum and mean tropical cyclone intensities. It is also estimated that, with climate change, the intensity of tropical cyclones in the Pacific may increase, thus there is a possibility that more persistent and devastating tropical cyclones may occur. The climate of PICs is strongly affected by the ENSO phenomenon; with climate change ENSO-like patterns are projected to become more frequent.

Atmosphere-ocean global circulation models (AOGCMs) have simulated well the broad scale pattern of temperature and precipitation across the major SIDS regions. However, rainfall amounts vary between models, with some underestimating or overestimating the intensity of rainfall in the high rainfall zones. AOGCMs can also represent current climate and ENSO-related climate variability reasonably well at a regional level. However, there is considerable variation in model performance at finer or island scale.

Current and future climate change impacts and vulnerabilities

Agriculture and food security

Agriculture has for a long time been the mainstay of survival and economic development in many PICs. Subsistence agriculture provides local food security, and cash crop agriculture has enabled PICs to earn export revenue and participate in world trade. Subsistence food production is vital in small islands even within those that have limited arable land. However, arable land for crop agriculture is increasingly in short supply and the likely prospect of land loss and salinisation due to climate change and sea-level rise will threaten the sustainability of both subsistence and commercial agriculture.

The occurrence of extreme weather events usually causes irreparable damage to food crops and other livelihood material on which small island populations depend. Extended droughts often cause damage to agricultural crops resulting in low exports and high imports, the latter usually resulting in a huge burden on foreign exchange earnings.

The projected impacts of climate change for agriculture include extended periods of drought and loss of soil fertility which seriously affect agriculture and food security. Much of the prime agricultural land is located on the coastal plains which are threatened by sea-level rise. Negative impacts on agriculture may lead to economic losses. However, the relative magnitude of these losses will differ among islands. For example, in the absence of adaptation on a high island such as Viti Levu in Fiji, the cost of damages could be in the range of USD 23–52 million per year by 2050 whereas in a low island such as Tarawa, Kiribati, the annual average cost of damages would be in the order of USD 8–16 million. The damage cost represents 2 to 3 per cent of Fiji's gross domestic product (GDP) in 2002 and 17 to 18 per cent of Kiribati's GDP for the same year.

Fisheries

Fisheries frequently contribute up to 10 per cent of the GDP in many PICs and therefore the socioeconomic implications of the impacts of climate change will be significant. Variations in tuna catches are especially significant during El Niño and La Nina years. For example, the El Niño of 1997/98 negatively affected skipjack tuna catches highlighting the sensitivity of fish stocks to changes in the climate. Changes in migration patterns and depth of fish stocks are the two main factors affecting the distribution and availability of tuna during such periods and it is expected that changes in climate may cause migratory shifts in tuna aggregations to other locations.

Biodiversity

As with other SIDS regions, Pacific islands region is home to an important proportion of the world's biodiversity especially because of its geographic isolation which has lead to the formation of many endemic species. The biodiversity of upland and coastal forests, including mangroves, is threatened by both global change and local factors, for example more than a quarter of small island states have a greatly reduced forest cover as a result of encroachment from infrastructure development or agriculture.

Biodiversity is also threatened by an increase in extreme events which decimate the forests in which the greatest levels of biodiversity are found. Samoa lost 92 per cent of its plantation estate in 1990 as a result of cyclones Ofa and Val, with the latter estimated to have caused damage costing over USD 300 million.

Coral reefs

Coral reefs are threatened by rises in sea surface temperatures which lead to coral bleaching. In the past 20 years, a sea surface temperature rise of approximately 1ºC above the normal maximum summer temperature has lead to bleaching events. Some studies have predicted that in the next 30 to 50 years bleaching events could occur every year in most tropical oceans. Another threat to coral reefs is that of rising CO_2 concentrations in the oceans related to rising atmospheric CO_2. Based on projected CO_2 levels it has been suggested that the calcification rate of corals could decrease by about 14 to 30 per cent by 2050.

Mangroves

Both terrestrial ecosystems on larger islands and coastal ecosystems on most islands have been subjected to increasing degradation and destruction. For example, mangroves provide a range of goods and services to local communities. Not all of these can be costed, but some efforts have been made to attribute value to many of these services. Smith (2003) provided the following values (in F$) for mangroves/ha/year for Viti Levu in each of the designated categories: subsistence fisheries (400-700), commercial fisheries (150-300), recreation (600), medicinal plants (400-700), habitat functions (150-300), and raw materials (150-500). This yields a value from these services of about F$2000-3000/ha/year (or roughly US$1000-1500/ha/year).

This valuation does not include a number of mangrove services which could not be costed, including: ornamental fish, biodiversity (other than medicinal plants) non-use (existence and bequest) values, fuel wood, non-wood products, importance to marine ecosystems, importance to marine recreation, and importance to inland groundwater. While Smith (2003) does not determine a value for coastal protection, the article cites parallel studies for other regions which imply a value of about F$3000/ha/year. This may be an overestimate for Fiji however, as the assessment of potential land lost to erosion on Viti Levu by sea level rise in World Bank study (2000) corresponds to about F$1000/ha/year. Taken together, these figures seem to imply a rough estimate of mangrove services for Viti Levu of from F$2000-5000/ha/year (US$ 1000-2,500/ha/year).

Sea level has risen in Fiji about a centimeter per decade over the last century. Coupled with a loss of mangrove protection, this has lead to significant coastline erosion in parts of Viti Levu. Coastal villages, towns, and tourist resorts have sought to protect themselves against these losses. Towns and tourist resorts have often responded by building sea walls.

Water resources

Many PICs already experience water stress at current levels of rainfall input and extraction of groundwater. Water pollution is one of the major problems facing small islands; poor water quality affects human health and the incidence of water-borne diseases. Owing to factors such as limited size, geology and topography, water resources in small islands are extremely vulnerable to changes and variations in climate, especially in rainfall, and with the rapid growth of tourism and service industries in many small islands, there is a need for both augmentation of the existing water resources and more efficient management of those resources that already exist.

Taking into account their size and topography, PICs tend to rely on any one or all of the three main natural sources of water: surface water (rivers, small lakes), rainwater and groundwater. Rainwater is the primary source of freshwater in several countries in the Pacific (e.g. Tuvalu, Kiribati and the northern atolls of the Cook Islands). Groundwater is the major source of water on many low-lying coral islands such as the Marshall Islands and raised atolls such as Nauru and Niue, where the freshwater lens can vary in thickness and quality, depending on the rates of extraction and recharge from rainfall.

This dependency on rainfall increases the vulnerability of small islands to future changes and distribution of rainfall. Low rainfall can lead to a reduction in the amount of water that can be physically harvested, a reduction in river flow, and a slower rate of recharge of the freshwater lens, which can result in prolonged droughts. Since most of the islands are dependent upon surface water catchments for their water supply, it is likely that demand cannot be met during periods of low rainfall. On the other hand, during the rainy season, lack of suitable land areas for dams and high runoff during storms (e.g. in Fiji) result in significant loss of surface and stream water to the sea.

The wet and dry cycles associated with ENSO episodes can have serious impacts on water supply and island economies, highlighting the vulnerability of water supplies to changes in the climate. For instance, the strong El Niño of 1998–2000 was responsible for acute water shortages in many islands in the Pacific ocean. In Fiji, borehole yields decreased by 40 per cent during the dry periods, and export crops including sugarcane were also severely affected. The situation was exacerbated by the lack of adequate infrastructure such as reservoirs and water distribution networks in most islands.

Recent modelling of the current and future water resources on several small islands, using a macro-scale hydrological model and the SRES scenarios found that many of these islands would be exposed to severe water stress under all SRES scenarios.

It has been estimated that a 10 per cent reduction in average rainfall by 2050 could produce a 20 per cent reduction in the size of the freshwater lens on Tarawa Atoll, Kiribati. Moreover, the thickness of the freshwater lens on atolls could be reduced by as much as 29 per cent. In addition, freshwater lenses are threatened by sea-level rise.

Coastal zones, marine areas and settlements

The concentration of large settlements (with associated economic and social activities) at or near the coast is a well-documented feature of small islands. On Pacific Ocean atolls, villages are located on the sand terrace or on the beach itself. In many small islands, continuous corridors of development now occupy practically all of the prime coastal lands. Such land is also occupied by a range of other settlements, such as fishing villages, and on many small islands government buildings and important facilities such as hospitals are frequently located close to the shore.

Roads and other infrastructure have been protected by sea walls when threatened by shoreline recession. Villages have also responded to shoreline losses by building sea walls, in part encouraged by government support for sea wall construction in the past.. Building of sea walls is now recognized as having clear costs. The walls may breach in storms and need reconstruction. They need ongoing maintenance. More troubling though is the fact that the beaches are lost when the walls are constructed. Further, the areas of coast around the sea walls seem to be more subject to erosion as a result of the walls. This observation has been reported by villages neighboring tourist resorts that have constructed sea walls, and is a source of some tension also. With the loss of beach and a physical barrier in place, the environment is not conducive to mangroves, and fisheries are also likely to suffer.

Population growth and inward migration of people is putting additional pressure on coastal settlements, utilities and resources and creating a series of problems in terms of pollution, waste disposal and housing. In many parts of the Pacific, traditional housing styles, techniques and materials have ensured that islanders were resistant to damage or could be repair buildings quickly. Many of these traditional practices are being abandoned today, increasing the vulnerability of coastal settlements.

Coastal erosion is a major problem in small island states. It is a natural process which redistributes sediments but it can be accelerated by both natural and anthropogenic causes. Natural causes include hurricanes and storms. Anthropogenic activities which accelerate erosion include beach mining for building materials, unwise building practices on the coast and activities leading to the destruction of the coral reefs.

Tourism

Tourism is a major economic sector in many small islands and the impacts of climate change on the tourism sector are expected to be significant, and support for economic diversification towards other revenue generating sectors in small island states is necessary.

Sea-level rise and accelerated beach erosion, degradation of coral reefs (including bleaching), and the loss of cultural heritage on the coasts through inundation and flooding will most likely reduce the attractiveness of small island states to tourists. Increases in the frequency or intensity of hurricanes and cyclones will also strongly effect the tourism industry. Shortage of water and increased danger of vector-borne diseases may also steer tourists away from small islands, and warmer climate in the northern countries could reduce the number of tourists who visit small islands in the tropical and subtropical regions.

Key impacts and vulnerabilities identified in the NAPA process

In addition to the national communication process under the UNFCCC, the Pacific SIDS least developed countries: Kiribati, Samoa, Solomon Islands, Tuvalu and Vanuatu have been preparing their national adaptation programmes of action (NAPA). NAPA process identified the most urgent and immediate needs of these countries for adaptation to climate change. In this regard the countries also outlined their key impacts and vulnerabilities. The table below provides key impacts and vulnerabilities in Pacific SIDS LDCs.

K**ey vulnerabilities in Pacific least developed countries**

Country	Key Vulnerabilities
Kiribati	o Stress on environmental systems: coasts, water resources, infrastructure, coral reefs, forests and trees, agriculture, etc. o Human settlements, land and coastal areas: loss of land through erosion, storm surge o Agriculture – saltwater intrusion induced by sea-level rise and storm surge and wave-overtopping o Water resources – saltwater intrusion into freshwater lens o Infrastructure – high risk of damage to key infrastructure from storms, erosion, wave over-topping o Biodiversity – negative impact on terrestrial and marine ecosystems –e.g. coral reef o Health – incidence of vector- and water-borne diseases
Samoa	o Agriculture & Food Security-Instability of food production levels caused by climate induced disasters. o Water is often affected by drought and saltwater intrusion induced by sea-level rise o Health – high incidence of vector- and water-borne disease due to changes in rainfall and temperature. o Biological diversity – affected by droughts and tropical cyclones. o Forestry – high risk of fires during drought and dry seasons. o Coastal infrastructure and environment – sea-level rise, storm surges and coastal erosion and inundation. o Tourism – loss of beaches, inundation and erosion. o Urban settlement – poor design and lack of proper planning. o Village communities – loss of homes and property (cultural values) and livelihood
Solomon	o Agriculture and food security – loss from droughts, flooding, incidences of

Islands[2]	pests and diseases, saltwater intrusion, coastal erosion/land loss/inundation o Water resources – especially on small low-lying islands with saltwater intrusion, wave-overtopping, flooding on high islands o Human health – incidence of vector-borne and water-borne diseases, tropical cyclones o Infrastructure and human settlements – loss of buildings and property, cultural sites, etc o Coastal zones and resources – erosion, land loss/inundation, effect on tourism development. o Fisheries – effect of migratory pattern of tuna fishery and impact on fishing as an economic activity
Tuvalu	o Water resources – esp.. groundwater resources affected by saltwater intrusion, drought o Health and well-being – affected by incidences of water-borne diseases, and drought o Subsistence, agriculture and food security – saltwater intrusion and incidence of fruit fly and coconut scale pest o Coastal areas and erosion - effect of tropical cyclones, storm surges. o Fisheries – effect of coral bleaching on fisheries resources, migration of warm water for tuna fishery o Disasters – drought, tropical cyclones, coastal flooding, etc, high sea surface temperatures, sea-level rise, coastal erosion/inundation/loss of land.
Vanuatu[3]	o Water resources – drought and floods, saltwater intrusion on low-lying islands o Coastal zones and resources – erosion, storm surges, loss of land o Infrastructure and settlement – loss of key infrastructures during cyclones, loss of homes and property, effect on tourism development, etc o Agriculture and food security – drought, sea-level rise, saltwater intrusion, flooding , incidences on pests and diseases. o Fisheries and marine resources – effect of coral damage on loss of fishery resource, warming of seawater on coral reef. o Forests and land management – effect of sea-level rise, increase in temperature on phonological cycle of fruit trees and crops, incidences of invasive and other pests.

Key documentation on impacts and vulnerabilities

[2] Information extracted from Initial National Communication (2004).
[3] Extracted from Final Draft of National Adaptation Programmes of Action (2007) which has been posted on the UNFCCC web site: www.unfccc.int

At the regional level, a number of important documents have been prepared to highlight the vulnerabilities and impacts of climate change on the biophysical and socio-economic systems in the Pacific islands region over the past decade. These documents include:

a) National communications under the UNFCCC
b) National Adaptation Programmes of Action of Pacific Least Developed Countries[4]
c) The World Bank Regional Economic Review and Climate Change Study 2000
d) Organization for Economic Cooperation and Development (OECD) Study on Fiji Islands 2003
e) Asian Development Bank Climate Proofing: A Risk Based Approach to Climate Change Adaptation 2005.
f) Not If But When: Adapting to Natural Hazards in the Pacific islands: A World Bank Policy Note 2006.

All of these documents also highlight the need for integrating climate change adaptation into development planning processes. The need for integration of climate change issues in the development planning processes is also embedded in the development and adoption of the Pacific Islands Framework for Action on Climate Change 2006-2015[5] at the 14th Meeting of SPREP and subsequently endorsed by the 36th Pacific Islands Forum Meeting in 2005. Leaders of the Pacific islands region have recognised the importance of taking action to address climate change through their national development strategies, or their equivalent, which are linked to national budgetary and planning processes[6].

The national communications and national adaptation programmes of action have been reviewed already and the key vulnerabilities and impacts identified in these documents have been outlined in the earlier sections of this paper. The following section will highlight only the key vulnerabilities and impacts from documents (c) to (f) above.

[4] Kiribati, Samoa, Solomon Islands, Tuvalu, and Vanuatu.
[5] Pacific Islands Framework for Action on Climate Change 2006-2015 available at www.sprep.org
[6] Ministers of Fiji, France, French Polynesia, Kiribati, New Zealand, Niue, Samoa, Tokelau and senior Officials of American Samoa, Australia, Cook Islands, Federated States of Micronesia, Guam, Marshall Islands, New Caledonia, Papua New Guinea, Tonga, Tuvalu, United States of America, Vanuatu and Wallis and Futuna, met in Papeete, 17 September 2004.

As part of the World Bank's regional economic report of the Pacific region, a study was conducted to ascertain the key impacts of climate change on two islands; a small low-lying island of Tarawa, Kiribati and, a high island of Viti Levu, Fiji Islands. In this study it has shown that In low islands, the most substantial damage would come from losses to coastal infrastructure as a result of inundation, storm surge, or shoreline erosion.
But climate change could also cause more intense cyclones and droughts, the failure of subsistence crops and coastal fisheries, losses in coral reefs, and the spread of malaria and dengue fever. These impacts could be felt soon: if climate change models are correct, the average sea level could rise 11.21 centimeters and average temperatures could rise 0.5-0.6^{0}C by 2025.

The economic impact could be substantial. Estimates from this study indicate that if climate change scenarios materialize, a high island such as Viti Levu in Fiji could suffer economic damages of more than US$23─$52 million a year by 2050 (in 1998 dollars), equivalent to 2─4 percent of Fiji's gross domestic product (GDP). The Tarawa atoll in Kiribati could face average annual economic damages of US$8─$16 million by 2050 (as compared with a GDP of about US$47 million). In years of strong storm surge, up to 54 percent of South Tarawa could be inundated, with capital losses of up to US$430 million.

Climate change would have the greatest impact on the poorest and most vulnerable segments of the population: those most likely to live in squatter settlements exposed to storm surges and disease (where safety nets have weakened), and those most dependent on subsistence fisheries and crops destroyed by cyclones and droughts. Nevertheless, the impacts of climate change are likely to be pervasive and affect the lives of most Pacific Islanders.

The study carried out by OECD (Environment Directorate 2003) on development and climate change in Fiji reveals the need for mainstreaming climate change responses in development planning and assistance in Fiji. An integrated analysis of impacts and vulnerabilities for Fiji identifies coastal resources as being of the highest priority in terms of certainty, urgency, and severity of impact, as well as the importance of the resource being affected.

A study by Asian Development Bank on climate proofing (ADB 2005) of both infrastructure and communities in the Cook Islands and the Federated States of Micronesia, have revealed that climate-related risks facing both the infrastructure projects and the communities are already substantial, but in all cases are projected to increase substantially as a result of increases in climate extremes and variability. For infrastructure projects it is possible to avoid most of the damage costs attributable to climate change, and to do this in a cost effective manner if "climate proofing" is undertaken at the design stage of the project. Cost effectiveness can be further enhanced if environmental impact assessment procedures require that all development be "climate proofed" (i.e. "climate proofing" is part of best practice, as judged by the environmental impact assessment procedures). "Climate proofing" communities can also be cost effective if planning and regulatory measures take into account both current and future climate-related risks.

"Climate proofing" national strategic development plans enhances the enabling environment for adaptation, establishes the requirement for "climate proofing" sector, sub-national (e.g. state, island and community) development plans as well as "climate proofing" individual development projects (i.e. mainstreaming adaptation) and helps to ensure that actions to reduce climate-related risks are an integral part of, and harmonized with, sustainable development initiatives.

In World Bank Policy Note, it has been shown that in addition to more intense cyclones, the Pacific Islands are already experiencing a change in prevailing climatic conditions: compared to the past, the southern Pacific is now experiencing a significantly drier and warmer climate (by 15 percent and 0.8¢ªC, respectively). The Central Equatorial Pacific, by contrast, is experiencing more intense rain (representing a change of about 30 percent) and a similarly hotter climate (0.6ªC). Sea surface temperatures in both areas have increased by about 0.4ªC (Hay et al. 2003). These changes are also linked in part to an increased frequency of El Niño events.

Rates of change are likely to increase in the future, in terms of both average and extreme conditions as well as increasing climate variability. Average temperatures are expected to rise by between 1.0 and 3.1ªC. Sea level is expected to rise by between 9 and 90 centimeters by the end of the century, with the eastern Pacific experiencing the largest rise. Cyclones are expected to increase in intensity by about 5–20 percent. Storm frequency is likely to increase in the equatorial and northern Pacific. And in general, the future climate is expected to become more El-Niño like, resulting in more droughts in the southern Pacific and more rain and consequent floods in the equatorial Pacific.

C. Conclusion

From the analysis of impacts and vulnerabilities provided in this document, it is obvious that the only option for PICs to manage these impacts and vulnerabilities is through effective adaptation. Climate is changing in more ways and faster rates than before putting enormous pressure on the biophysical systems and human systems in the Pacific island countries.

Pacific island countries have also recognised that climate change and sea level rise issues will need to be integrated into national sustainable development and planning processes. Most climate change projects in the Pacific have concentrated on studies and assessments rather than actual implementation of adaptation measures, strategies and policies. Many of these assessments have been fairly generic, i.e. assessment of impacts of climate change on a range of biophysical and human systems. Local-scale assessments of various sorts, including adaptation studies, are still focused on understanding current vulnerabilities and adaptation strategies. Few comprehensive, comparable studies are available within the region, particularly those focusing on future options and pathways for adaptation.

A good and effective adaptation strategy, measure or practice will depend on a sound understanding of the impacts and vulnerabilities. Thus, managing impacts of climate change on land resources in the Pacific island countries will not only improve understanding of impacts at the local scale but also offer strategies for enhancing adaptive capacity and resilience in the Pacific island countries.

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