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ORIGINAL ARTICLE

Dangerous climate change in the Pacific Islands: food production and food security

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Abstract This paper explores the risks that climate change poses to food security in the islands of the South Pacific. It shows that climate change will adversely affect food systems in the region, including the supply of food from agriculture and fisheries, the ability of countries to import food, systems for the distribution of food, and the ability of households to purchase and utilize food. In these ways, climate change puts at risk the very basic and universal need for people in the islands to have access to sufficient, safe, and nutritious food at all times. It is argued that for people in the South Pacific, the risks climate change poses to food security constitutes a 'dangerous' change in climate.

Keywords Small Islands · Agriculture · Fisheries · Development · Vulnerability

Introduction

During the last 10 years, there has been considerable attention given to articulating the meaning and metrics of 'dangerous' climate change, because the ultimate objective of the United Nations Framework Convention on Climate Change is to prevent such dangers from occurring (Article 2, see Barnett and Adger 2003; Dessai et al. 2004; Mastrandrea and Schneider 2004; O'Neill and Oppenheimer 2002; Schneider 2001). The Pacific Islands have featured prominently in these discussions. This paper explores the risks that climate change poses to food production in the region—the second of the three sectors specifically mentioned in the text of Article 2 of the UNFCCC, which states that the ultimate objective of the Convention is to stabilize greenhouse gases at a level and within a time frame "to allow ecosystems to adapt naturally, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner". The paper also considers the issue of food security, which is a function of, but not necessarily the same as food production.

The focus of this paper is, for the most part, on social systems and the people who shape and are shaped by them. This is, in a sense, a kind of 'bottom up' perspective, informed not so much by abstract models of climate and biophysical systems, but by the author's understanding of the everyday processes that make and remake social life in the region. This is useful because it shifts the focus of analysis to existing vulnerabilities to climate as a basis for determining future vulnerabilities—the importance of which has been stressed by Burton et al. (2002), Lim et al. (2004), and Smit and Wandel (2006).

The Pacific Islands

There are twenty-two island states and territories in the South Pacific, the combined population of which is 9.5 million. Of these, 6.5 million reside in Papua New Guinea {Secretariat of the Pacific Community, 2008 #1907}. Population growth, particularly in the Melanesian countries, is high, and these countries additionally have considerable rates of rural to urban migration.

The total land area of all islands in the region is approximately 550,000 km^2, which contrasts markedly

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with the region's combined exclusive economic zone of some 30 $\times$ 10^6 km^2 (Overton 1999). The largest country is Papua New Guinea with a land area of 462,000 km^2, while the smallest is Tokelau with a land area of 12 km^2. The Melanesian countries are, generally, large and mountainous with fertile soils and mineral resources. The Polynesian and Micronesian islands vary in type from smaller volcanic islands to low-lying coral atolls. Almost all of these islands are small, although they often have extensive reef and lagoon systems that provide a considerable amount of protein to communities. Kiribati, the Marshall Islands, Tokelau, and Tuvalu are comprised entirely of low-lying coral atolls. In all countries, capital cities and most other major urban centers are situated on the coast, and most or all critical infrastructure is located in the coastal zone.

Gross National Products in the region are low, ranging from US $10 million in Niue to US $6 billion in Papua New Guinea {Secretariat of the Pacific Community, 2008 #1908}. GDP per capita is low in most countries, ranging from US $650 in Kiribati to US $29,820 in New Caledonia. Kiribati, Samoa, the Solomon Islands, Tuvalu, and Vanuatu are currently classified as Least Developed Countries. Between 1996–2001, the economies of the Federated States of Micronesia, the Solomon Islands, the Marshall Islands, Palau, Vanuatu, and Papua New Guinea contracted. Tourism is an important industry in some countries, accounting for 49% of GDP in Palau, 47% in the Cook Islands, 17% in Vanuatu, 15% in Kiribati and Tonga, and 13% in Fiji (Commonwealth of Australia 2006). The equatorial countries receive income from licensing fees paid by foreign-operated fishing boats operating within their territorial waters, and that accounts for 43% of GDP in Kiribati and Tuvalu (ADB 2004). Only in Papua New Guinea is the share of primary industries in GDP larger than 30% where it totals 33%. Nowhere else is it larger than 20% (Commonwealth of Australia 2006).

Nine of the region's countries and territories are fully independent. Six are self-governing and constitutionally independent, but with some form of association with either the United States or New Zealand. Seven are dependent territories either of France, the United States, or New Zealand. These political ties influence aid flows and income from remittances. Most of the smaller Polynesian and Micronesian economies are heavily dependent on aid. In the Federated States of Micronesia, Kiribati, the Marshall Islands, Nauru, Niue, and Tuvalu aid accounts for at least one-third of GDP. Remittances sent from migrants living overseas (largely in Australia, New Zealand, and the United States) are also important. Remittances comprise 12% of GDP in Kiribati, 14% in Samoa, 36% in Tuvalu, and 39% in Tonga. The actual remittances in all the countries are probably far larger than these estimates (Commonwealth of Australia 2006).

Pacific Island societies contend with an array of environmental problems, including: land degradation, such as soil nutrient depletion and soil loss; deforestation due to logging for timber exports, clearing for agriculture, and fuel wood collection; biodiversity losses across a range of terrestrial and marine flora and fauna; depletion of freshwater resources through saline incursions and contamination from urban, agricultural, and industrial sources; and coastal and marine degradation, including coastal erosion, coral loss and coral bleaching, contracting artisanal fisheries, and pollution of lagoons (UNEP 1999). These environmental problems increase the vulnerability of ecosystems to the effects of climate change.

Regional scale changes in climate

Projections of the possible changes in climate in the Pacific Islands region apply to the region as a whole and not to specific countries, because the grid squares in General Circulation Models are between 200 and 600 km^2, which provides insufficient resolution for the land areas of almost all the Pacific Islands. Ruosteenoja et al.'s (2003) comparison of the results of several general circulation models gives some indication of the range of changes in rainfall and temperature that may be expected in the region relative to the period 1961–1990, given different scenarios of greenhouse gas emissions in the future (which are taken from the IPCC emissions scenarios). These models suggest that air temperature in the Southern Pacific will increase between: 0.45 and 0.82°C by the 2020s; 0.8 to 1.79°C by the 2050s; and 0.99 to 3.11°C by the 2080s. These projections may be conservative, given that there have been decadal increases in annual temperatures in the region of between 0.3 and 0.5°C since the 1970s (Salinger 2001). Increases in extreme temperature events are also expected as warming increases (Christensen et al. 2007).

Changes in precipitation arising from climate change are less certain than those associated with temperature. Ruosteenoja et al. (2003) offer the following range of changes in precipitation for the Southern Pacific relative to period 1961–1990: -3.9% to $+3.4\%$ by the 2020s; -8.23% to $+6.7\%$ by the 2050s; and -14% to $+14.6\%$ by 2080s. However, with precipitation, it is less the mean annual changes, and rather the frequency and intensity of rainfall events that matter most, particularly given that the region is prone to floods and droughts. Water for agriculture is almost entirely supplied by rainfall rather than by irrigation systems. More rainfall is expected in summer—which is the wet period in the region, and there may be less rainfall in the already dry months. This has implications for sustaining crops throughout the year. Rainfall events are also likely to be more intense, and possibly less frequent, with

implications for flooding and drought events (Lal 2004). Jones et al. (1999) suggest that the intensity of rainfall events may increase by some 20–30%.

Increases in sea-level are also expected due to climate change. The Third Assessment Report of the Intergovernmental Panel on Climate Change suggests that sea-levels would rise by between 9 and 88 cm by the year 2100 (IPCC 2001), and Woodworth (2005) suggests that their mean estimate of a 50 cm rise by 2100 still seems reasonable. Jones et al. (1999) suggest that given emissions of greenhouse gases up to 1995, a 5–12 cm rise in sea-level is inevitable, and that even if all countries meet their Kyoto Protocol commitments and if all emissions of greenhouse gases cease after 2020, a sea-level rise of 14–32 cm is very likely. A 32 cm rise in sea-level is considered to have serious implications for the continued viability of ecological and social systems on low-lying coral atolls (Pearce and Teuatabo 2000).

The risks to coral atolls, and to coral systems throughout the region, is a function not just of rising sea-levels, but also of rapid changes in sea-surface temperature which cause coral reef mortality through coral bleaching (Hoegh-Guldberg et al. 2007; Reaser et al. 2000). Evidence suggests that tropical sea-surface temperatures have been rising over the past 50 years, and in 1998, when sea-surface temperatures reached the highest on record, coral reefs around the region suffered the most severe bleaching on record (Reaser et al. 2000). Rising concentrations of CO_2 in the oceans may also retard the ability of reefs to grow in step with sea-level rise (Hoegh-Guldberg et al. 2007; Kleypas et al. 1999). Kench et al. (2005) suggest that undisturbed reef systems may persist under conditions of rising sea-levels and rapid increases in sea-surface temperature and that it is human disturbances on reefs that make them vulnerable to climate change. Bleaching of reefs causes erosion of shorelines through changes in sedimentation. It may also impact on artisanal fisheries and be a factor in ciguatera fish poisoning (Cowell and Kench 2001; Hales et al. 1999).

Associated with these projected changes in temperature, precipitation and sea-level are projected changes in regional climate systems and extreme events. Of particular importance to development in the region is ENSO, which in El Niño years brings drought to most of the region. For example, the 1997–1998 El Niño caused widespread drought and subsequent food shortages in the islands west of the international dateline. Agricultural losses in Fiji were valued at US $65 million, and some 260,000 people in Papua New Guinea were in a life-threatening condition due to depleted food supply (WMO 1999). In Niue, the 1983 El Niño resulted in a 60% decrease in mean annual rainfall, forest fires, and a dramatic fall in agricultural exports and a dramatic increase in food imports. The effect of climate change on the frequency and intensity of El Niño events is uncertain; however, it is noteworthy that there have been more frequent and intense El Niño events since the 1970s (IPCC 2001).

The ENSO phenomenon has a significant influence on tropical cyclone frequency and possibly also on intensity. El Niño years tend to increase the frequency of tropical cyclones in islands to the east of the international dateline. While the relationship between climate change and tropical cyclones is still highly uncertain, there is evidence that they may become more intense in the future—meaning that such cyclones may last longer, exhibit higher wind speeds, and unleash more rainfall (Walsh 2004). In many Pacific Islands, cyclones are a cause of mortality and injury. They can cause massive financial losses; Cyclone Ofa which struck Western Samoa in 1990 caused US $110 million worth of damage, as did Cyclone Kina which struck Fiji in 1993 (Campbell 1997; Olsthoorn et al. 1999).

In 2004, Cyclone Heta in Niue destroyed 43 houses that were more than 25 m above sea-level, as well as the national hospital, national museum, and the bulk fuel storage tanks (Government of Niue 2004). As well as wind damage, and damage from increased rainfall and flooding, cyclones induce storm surges which can reach up to six meters in height, and, in the case of cyclone Heta in Niue, waves in excess of 30 m in height. Barker (2000) goes so far as to argue that in Niue cyclones have powerfully shaped the structure of contemporary society through their effects on out-migration and aid dependence.

It is the possibility of increases in the frequency and intensity of such hazards, rather than changes in mean conditions, that poses the most immediate danger to Pacific Islands. Barnett and Busse (2002) suggest that a critical factor for social–ecological systems in the region will be a decrease in the return times of extreme events, which in turn will reduce the ability of systems to recover, causing long-term declines in welfare. These changes in extremes will be compounded by changes in mean sea-level, temperature, and rainfall, and both these changes in extremes and mean conditions pose dangers to the Pacific Islands through their impacts on agriculture, fisheries, health, food security, economic development, and population movements. Of these, the following discussion is limited to the issues of food production and food security. In terms of food production, the focus is on the two most important local sources of food for most Pacific Islanders—agriculture and fisheries.

Impacts on agriculture

In most Pacific Islands, agriculture is primarily conducted for subsistence purposes, and in some cases for sale to

domestic and international markets. For the most part, the value of agricultural exports is small relative to imports. Few households meet their own food needs entirely through their own production, and most rely in part on markets for at least some of their food needs.

Agricultural production in the Pacific Islands is likely to be adversely affected by climate change in a number of ways. For coastal communities, the effects of erosion, increased contamination of groundwater and estuaries by saltwater incursion, cyclones and storm surges, heat stress, and drought may individually or in combination undermine food production. Cyclones are a significant cause of lost agricultural production, for example, Cyclone Ami caused over US $35 million in lost crops in Fiji in 2003 (McKenzie et al. 2005). Drought presents problems to agriculture everywhere in the region, particularly given the lack of irrigation. The increased risk of flooding in river catchments also threatens food production, for example, severe flooding of the Wainibuka and Rewa Rivers in Fiji in April 2004 caused damages to between 50 and 70% of crops (Fiji Government 2004). Increasingly intense rainfall events, coupled with ongoing processes of deforestation and longer dry spells, may all impact on soil fertility.

The effects of climate change on critical infrastructure may also undermine agriculture for both subsistence and commercial purposes. Damage to equipment for processing and storing food can undermine the effective supply of food, and damages to roads, rail, and vehicles due to storms and cyclones can disrupt the supply of goods to markets, undermining the livelihoods of rural growers. Large-scale economic changes can also undermine food production. Impacts on production in key sectors such as tourism, and increasing public expenditure on repairing and replacing lost infrastructure may all have impacts on employment and incomes. This in turn could suppress demand for locally grown foods sold in local markets.

Traditionally Pacific Island communities grew multiple crops, which tended to confer some resilience in food supply as not all crops were affected by specific hazards such as a drought or cyclone (Campbell 1990; Elmqvist 2000). Repeated attempts to develop monocultural cash crops, such as copra, coffee, and sugar cane, combined with the effects of the cash economy and penetration of markets of often cheaper if less healthy foods, have all served to weaken the diversity and intensity of local production in many places. The effects of these changes have been increased dependence on the market for food, decreased resilience of food supply in the face of hazards (given low incomes and relatively high food prices), and a 'nutrition transition' in the region associated with increased rates of obesity and cardiovascular disease (Popkin and Horton 2001).

These changes are all functions of increased penetration of international markets and of development assistance of various kinds, as well as increased urbanization and in some cases, decreases in security of land tenure (Colding et al. 2003; Clarke and Thaman 1993). The problem is that these attempted shifts toward modern agricultural economies and, more generally affluent industrial societies, have failed to deliver the kinds of resilient agricultural and food systems that developed countries enjoy, while at the same time undermining the resilience associated with traditional, agricultural systems. Vulnerability is then manifested in the seemingly permanent transitional nature of Pacific societies.

Impacts on fisheries

Given that the ratio of land area to sea area in the Pacific region is 1:300, it is not surprising that fisheries play a critical role in food supply and economic development in the Pacific Islands. Fish is an important source of protein for most coastal communities in the Pacific (Bell et al. 2009). Per capita consumption of fish in the region is very high by global standards, with an average of 70 kg of fish being consumed per person per year across the region in the early 1990s (Gillett et al. 2001). Fisheries also provide income to many coastal communities who harvest shellfish and shells, corals, crustaceans, marine plants, finfish, and other species. Inland freshwater fisheries are also important sources of food in Papua New Guinea, the Solomon Islands, and Fiji.

In terms of economic development, the value of landed tuna caught in the waters of the South Pacific is approximately US $1.9 billion with a final market value of approximately US $6 billion. Of this, around 45% is caught in the Exclusive Economic Zones of Pacific Island countries, although of this only a small proportion is landed on the Pacific Islands. Most of the fish caught is by distant water fishing nations, which pay Pacific Island governments some US $60–70 million a year in access fees (Gillett et al. 2001; Petersen 2001; Tarte 1999). The most valued target species of these deep water fishing operations is tuna.

Fishing is very important to the economies of some countries, for example, domestic fishing activity accounts for 13% of GDP in the Solomon Islands, and 12% in Kiribati; and exportation of fish accounts for 95% of exports from the Federated States of Micronesia, 73% from Palau and 61% from Samoa (Gillett et al. 2001). For some countries, including Kiribati and the Solomon Islands, the remittances sent home from workers on fishing boats are also important. Gillett et al. (2001) estimate that the industrial tuna fishery accounts for half of all exports,

25,000 jobs, and 11% of production in the Pacific Islands region.

Fishing is a combination of luck and skill. Pacific Islanders are highly skilled at fishing, with many societies having a rich body of traditional knowledge about where and how to catch fish (see for example Hooper 1983; Johannes 1978). There is considerable uncertainty about the effects of climate change on the artisanal fisheries upon which many Pacific Islanders depend for food and income. It is important to note that increasing temporal and spatial variability in fish abundance caused by the degradation of reefs and mangroves, and the turbidity, salinity, and temperature of water due to climate change is possible. These changes extend the abilities of Pacific Islanders to sustain fish catches. The effect of increasing variability in abundance may affect nutrition and the incomes of coastal populations dependent on artisanal fisheries. It may also increase the time and fuel costs associated with catching fish, with opportunity costs for other livelihood strategies.

In terms of the tuna fishery, changes in ENSO conditions cause variations in catch per unit of effort rates across the South Pacific (SPC 2006). If climate change causes ENSO events to become more frequent or more severe, then this may in turn affect the amount of fish caught in the Exclusive Economic Zones of the equatorial Pacific Islands and the revenue they earn from access fees paid by distant water fishing nations. Climate change may also cause an extension of the present range of tuna to higher latitudes, a decrease in net productivity, increase variability in the catches and so decrease catch per unit of effort with subsequent impacts on the costs of production and prices, and potentially increase pressure on the most valuable species of bigeye and yellowfin in an attempt to offset increasing costs (SPC 2006).

Increases in storm damages due to climate change in the region may also impact on fisheries development through damage to and loss of boats, boat launching facilities, fuel facilities, and fish storage and processing facilities. For example, cyclone Heta, which struck Niue in 2004, caused severe damage to sea tracks from which fisherman launch canoes, as well as to both of the derricks used for lifting small vessels into and out of the water, with the result being that fishing for subsistence purposes ceased for some weeks. So, through changes in fish habitats, migration patterns, and in fishing-related infrastructure, climate change poses significant risks to fisheries and to the people and islands that depend on them for food and income.

Impacts on food security

Food production, as specifically identified in Article 2, is only one component of food security. Food security is defined as a situation "when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary and food preferences for an active and healthy life" (FAO 2002). Food security has three components: food availability, ability to access food, and the ability to utilize food.

There are macro- and microdimensions to food security. Macrodimensions include issues such as the total supply of food in country and the prices of food, which is a function of local production and imports. In as much as common illnesses in developing countries, such as malaria and gastro-intestinal disorders, impede a body's ability to effectively utilize food, then public health issues associated with water quality and disease control are also important. The ability of people to purchase food is also a function of markets for local products and labor, including the costs of labor relative to the costs of food. Micro issues include the ability of a household to grow its own food, or to purchase food, and the health of people as this affects their ability to effectively utilize food. People's food needs include a sufficient supply of calories, protein, and micronutrients, and so the types of food that can be accessed are also important for food security.

There is also a temporal dimension to food security. People who are poor may be chronically food insecure—meaning they consistently consume insufficient amounts of food. People may also be generally food secure, but vulnerable to periods of food insecurity arising from, for example, disasters undermining their own production for subsistence purposes and for sale to markets, or sudden changes in food prices and/or wages. When large-scale food crises occur—as they still do in parts of Africa—it is the chronically food insecure who are most at risk of death.

Because food security is a function of food production, economic growth and employment, poverty, and public health, it is perhaps a far better indicator of 'dangerous' climate change than 'food production' as mentioned in Article 2. For this reason, the possible impacts of climate change on food security in the Pacific Islands should be considered.

In the Pacific Islands at present, the situation with respect to food security is not as serious as in parts of South Asia and Africa, in large part because poverty is generally not as acute. There are problems with micronutrient deficiencies in many communities where access to an adequate range of healthy foods is restricted by either local growing conditions or the types and costs of foods available on the market. A part of the problem here is that penetration of local markets by imported foods has resulted in the importation of cheap, poor quality foods of little nutritional value. This results in increasing rates of non-communicable diseases such as obesity, diabetes, and heart disease.

However, there are signs that food insecurity may increase in the future (Sharma 2006; Bell et al. 2009), and, when considering the possible impacts of climate change in the region, an increase in food insecurity is a distinct possibility. Climate change may negatively impact on each of the broad determinants of food security—namely food production, economic growth and poverty, and health.

Bell et al. (2009) posit that the current dependence on fish by many Pacific communities leaves them vulnerable to food insecurity in the future. The coastal fisheries available in most states do not currently have the capacity to provide more fish to meet the needs of future population growth and urban migration, and so rural fish consumption will decline as population increases. The risk of overfishing may be increased by pressure on rural communities to use their resources for income generation as well as subsistence. In conjunction with changes to the availability of fish as a result of climate change, there is an urgent need for the diversification of supply in order to make rural communities more resilient to climate change and extreme events and help rebuild overexploited fisheries resources.

Across the region, there has been in the last 10 years a decline in per capita food production and an increase in dependence on imported foods (Sharma 2006). In all countries, almost all cereals are imported and imports of cereals have steadily increased since 1991, exports of food products have decreased, and trade deficits have increased (Sharma 2006). Declining per capita food production is a function of: population growth; insufficient private and public investment in agricultural production; limitations on production due to water scarcity and effective scarcity of land (due to absolute shortages, or insecurity of tenure discouraging capital investment); increasing costs of inputs relative to the value of production; disasters; and rural to urban migration. Total food availability in the Pacific Islands, then, is increasingly becoming a function of the ability to pay for food imports.

The ability to pay for food imports at an aggregate level is a function of national income, and so assessing the impacts of climate change on food security in part involves assessing its impacts on the ability of Pacific Islands countries to pay for food imports as populations grow. The impacts of climate change in labor markets in New Zealand, Australia, and the United States could adversely affect countries which are dependent on remittances, but the impacts are highly uncertain. At least for those Pacific Islanders working in agriculture and agriculture-dependent industries, there may be grounds for concern as these industries in donor countries may also be impacted by climate change. Nevertheless, the assumed higher capacity to adapt to climate change in the developed donor countries would seem to insulate the Pacific Islands against declines in remittances due to climate change.

For those island countries that are heavily dependent on aid, the impacts of climate change on the capacity of donors to sustain aid flows, and the motives for those flows, is also important. In general, aid to the countries in the region is delivered for numerous reasons varying from country to country, including for strategic, historical, constitutional, economic, and humanitarian reasons. Assessing the impacts of climate change on these kinds of flows is beyond the scope of this paper; however, we might surmise that the strategic and historical/constitutional reasons for giving aid are relatively independent of the effects of climate change. Economic reasons may change depending on the distribution of economic impacts within and among donor countries, and that aid for humanitarian reasons may increase as climate change results in more damages due to disasters and increasing poverty.

This discussion of aid flows and remittances and their likely changes are simplistic and uncertain, but it does go to show that some of the more important factors in the economic impacts of climate change in many Pacific Island countries concern changes outside of those countries, and that climate change may have little impact on the ability of those countries that are dependent on aid and remittances to purchase food imports. Yet this tentative conclusion assumes that these extra-territorial flows will increase as demand for them increases due to population growth, rising expectations, and increasing costs due to damages caused by climate change.

There may be some significant costs to island economies due to climate change. For example, the World Bank (2001) estimates that by 2050 damages from climate change could cost Tarawa atoll in Kiribati US $8–16 million, or 17–34% of current GDP. Another study estimates that the economic impacts of climate change on Pacific Island economies may be "so profound that they dwarf any strategic issue currently confronting a major peacetime economy" (Hoegh-Guldberg and Greenpeace Australia Pacific 2000). Those disasters such as cyclones and droughts already have significant costs suggest that increases in their intensity or frequency in the future will place further demands at both donor and household-level to substitute for lost crops, income, infrastructure, and housing.

The region's other main source of income, aside from agriculture, fisheries, aid, and remittances, is tourism. Tourism, too, is sensitive to climate change. Impacts on tourism have yet to be seriously examined, but it is believed that the industry may be affected directly, for example, through the loss of beaches, and indirectly, for example through milder winters in traditional markets reducing the motivation to take vacations abroad (Becken 2005). Extreme events will also be increasingly costly for tourism infrastructure and may dampen demand for travel

to the Pacific Islands. Potential tourists may fear for their safety. If climate change results in the spread of malaria and dengue fever to tourist dependent countries such as the Cook Islands, Palau, and Fiji, then this too may decrease demand as tourists may seek alternative holiday destinations. Rising airfares due to increasing fuel costs associated with potential policy measures to implement the Kyoto Protocol and post-Kyoto agreements, coupled with increasing scarcity of jet fuel, may also undermine demand for tourism.

So, some of the region's main forms of income generation—agriculture, fisheries, and tourism—are likely to be adversely effected by climate change. It follows then that employment in these sectors may also suffer, either through long-term contraction in the number of jobs, short-term fluctuations and/or increasing casualization of jobs in response to increasing variability in production, or through downward pressure on wages as employment opportunities decrease and demand for jobs grows due to population growth. The impacts of climate change on these key sectors may also have other important secondary effects. For instance, not only farmers' livelihoods are at risk from climate change, but also those whose livelihoods depend on agricultural production, such as input, transport, information, and credit suppliers. Impacts in one sector may, in turn, impact on others. For example, declining incomes from agriculture may cause migration to urban areas, increasing urban poverty and placing increasing demand on urban services such as running water, disease prevention programs, and health care. If climate change results in economic contraction and increasing unemployment, then the ability of States to provide these services may also weaken, further exacerbating poverty and food insecurity.

Thus, through its impacts on agriculture, fisheries, and tourism, climate change may increase levels of chronic and transitory poverty, and, subsequently, decrease the ability of households to purchase food. This, coupled with potential impacts on household food production for subsistence purposes, suggests that not only may per capita food availability contract due to the combined effects of climate change on domestic production and the ability to pay for food imports, so too may the ability of people to access food.

Finally, it is important to consider the impacts of climate change on health as this too affects food security. In most countries of the region, people are relatively healthy compared to other developing regions of the world. Nevertheless, there are problems of undernutrition in parts of Melanesia and in some of the more remote islands in a number of countries. Malaria is a major cause of illness in Melanesia, and across the region outbreaks of dengue fever occur. Disasters also cause injury and loss of life, and there are problems of diarrhea and other water borne diseases such as cholera in a number of islands and in urban areas. Incidences of Ciguatera (fish poisoning) appear to be increasing. Climate change may extend the spread of malaria and dengue fever as the factors that encourage the breeding of the mosquitoes that carry these diseases are influenced by climate. Warming in Papua New Guinea, for example, is likely to cause a contraction of the cooler malaria free zone in the highlands. There are also demonstrated positive associations between temperature increases and diarrhea, and between warmer sea-surface temperatures and Ciguatera outbreaks (Singh et al. 2001; Hales et al. 1999). Heat stress, increased injuries, and deaths from extreme events are also likely to result. Finally, the health services in most Pacific Island countries are ill-equipped and already struggling to cope with existing health problems. They are, therefore, unlikely to be able to adequately respond to the increased health burden of climate change.

Many rural Pacific islanders are simultaneously engaged in some sale of products or labor for cash, as well as gardening or fishing to meet a proportion of their own food needs. In some cases, hunting is also undertaken (Meleisea 1996). This confers some degree of food security, as it means one or two of these activities can still meet basic food needs. This diversity of livelihood strategies in part explains why in even the poorest communities severe disasters do not result in mass mortality. The risk to food security is that climate change may cause chronic and or sporadic contractions in the food people access through agriculture, fisheries, and the market, creating in turn chronic and transitory food problems. These problems of access, coupled with possible increases in illness due to climate change, mean that climate change poses real risks to food security in the region.

Conclusion

To determine what kinds of climate impacts may be 'dangerous' is a question of values. Different societies value different things, and the degradation or loss of things that are most valued to a society can rightfully be called 'dangerous'. The problem for a global convention such as the United Nations Framework Convention for Climate Change is that this diversity of values means that it is exceedingly difficult to find a common metric of 'danger' to which all Parties agree. The problem is akin to the problem of human rights, where some rights are to some extent culturally specific, but where it is accepted in principle that there are universal 'basic' rights—such as freedom from torture (Shue 1980). In this vein, there may be some universal 'dangers' as well. In terms of the three sectors specified in Article 2 of the UNFCCC, damage to ecosystems may not be a concern of all people, nor even

may 'food production' or 'economic development' as these are larger system conditions that people may or not may not identify as being valuable. Yet it is a reasonable proposition that all people value the choice of having enough to eat—and so food security perhaps offers a useful and near universal basis upon which to assess 'dangerous' climate change.

Given this, climate change is dangerous to the Pacific Islands. It seems likely to impact on agricultural production for both subsistence and commercial purposes, undermining both local availability of food as well as the ability of people and societies to purchase food. The impacts on production may be both long-term declines, as well as short-term variations. The other major sector of food production in the region is fisheries, which, like agriculture, supports domestic consumption as well as domestic and international trade. Climate change may also have negative impacts on fisheries, although the nature of change may be less one of mean declines in abundance, but rather increasing variability of supply. Thus, even considering the criteria of food production, climate change is dangerous to the Pacific Islands. Yet it is the compounding effects on the systems that determine food security in the region and thus the larger cause for concern. Through its impacts on production, the ability of countries to import food and the ability of households to purchase food, and human health, climate change puts at risk the very basic and universal need for people in the islands to have access to sufficient, safe, and nutritious food at all times.

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References

ADB (2004) Key indicators 2004: poverty in Asia: measurement, estimates, and prospects. Asian Development Bank, Manila, The Philippines

Barker JC (2000) Hurricanes and socio-economic development on Niue Island. Asia Pac Viewp 41:191–205

Barnett J, Adger W (2003) Climate dangers and atoll countries. Clim Change 61(3):321–337

Barnett J, Busse M (2002) Conclusions. In: Barnett J, Busse M (eds) The APN workshop on ethnographic perspectives on resilience to climate variability in Pacific Island Countries, Christchurch. Macmillan Brown Centre for Pacific Studies, pp 75–77

Becken S (2005) Harmonising climate change adaptation and mitigation: the case of tourist resorts in Fiji. Glob Environ Change Hum Policy Dimens 15(4):381–393

Bell JD, Kronen M, Vunisea A, Nash WJ, Keeble G, Demmke A, Pontifex S, Andrefouet S (2009) Planning the use of fish for food security in the Pacific. Mar Policy 33(1):64–76

Burton I, Huq S, Lim B, Pilifosova O, Schipper L (2002) From impacts assessment to adaptation priorities: the shaping of adaptation policy. Clim Policy 2(2–3):145–149

Campbell JR (1990) Disasters and development in historical context: tropical cyclone response in the Banks Islands, Northern Vanuatu. Int J Mass Emerg Disasters 8(3):401–424

Campbell JR (1997) Examining Pacific Island vulnerability to natural hazards In: Planitz A, Chung J (eds) VIII Pacific science intercongress, Suva. United Nations Department for Humanitarian Affairs, South Pacific Programme Office, pp 53–62

Christensen JH, Hewitson B, Busuioc A, Chen A, Gao X, Held I, Jones R, Kolli RK, Kwon W-T, Laprise R, Magaña Rueda V, Mearns L, Menéndez CG, Räisänen J, Rinke A, Sarr A, Whetton P (2007) Regional climate projections. In: Solomon S, Qin D, Manning M et al (eds) Climate change 2007: the physical science basis. Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, UK and New York, NY, USA, p 996

Clarke W, Thaman R (eds) (1993) Agroforestry in the Pacific Islands: systems for sustainability. United Nations University Press, Tokyo

Colding J, Elmqvist T, Olsson P (2003) Living with disturbance: building resilience in social-ecological systems. In: Berkes F, Colding J, Folke C (eds) Navigating social-ecological systems: building resilience for complexity and change. Cambridge University Press, Cambridge, pp 163–185

Commonwealth of Australia (2006) Pacific 2020: challenges and opportunities for growth. Australian Agency for International Development, Canberra

Cowell PJ, Kench PS (2001) The morphological response of atoll islands to sea level rise. Part 1: modifications to the modified shore face translation model. J Coast Res 34:633–644

Dessai S, Adger WN, Hulme M, Turnpenny J, Kohler J, Warren R (2004) Defining and experiencing dangerous climate change—an editorial essay. Clim Change 64(1–2):11–25

Elmqvist T (2000) Indigenous institutions, resilience and failure of co-management of rainforest preserves in Samoa. Paper presented at the constituting the commons: crafting sustainable commons in the new millennium, eighth conference of the international association for the study of common property, Bloomington, Indiana, May 31–June 4, 2000

FAO (2002) The state of food insecurity in the world 2002 FAO. Rome, Italy

Fiji Government (2004) Preliminary estimates of flood affected areas. Press release April 17. Ministry of Information. http://www.fiji.gov.fj/cgi-bin/cms/exec/view.cgi/19/2282/printer

Gillett R, McCoy M, Rodwell L, Tamate J (2001) Tuna: a key economic resource in the Pacific Islands. Pacific studies series. Asian Development Bank, Manila

Government of Niue (2004) National impact assessment report of cyclone Heta. Alofi, Niue

Hales S, Weinstein P, Woodward A (1999) Ciguatera (fish poisoning), El Niño, and Pacific sea surface temperatures. Ecosyst Health 5:20–25

Hoegh-Guldberg O, Greenpeace Australia Pacific (2000) Pacific in peril: biological, economic and social impacts of climate change on Pacific coral reefs. Greenpeace Australia Pacific Suva, Fiji

Hoegh-Guldberg O, Mumby PJ, Hooten AJ, Steneck RS, Greenfield P, Gomez E, Harvell CD, Sale PF, Edwards AJ, Caldeira K, Knowlton N, Eakin CM, Iglesias-Prieto R, Muthiga N, Bradbury RH, Dubi A, Hatziolos ME (2007) Coral reefs under rapid climate change and ocean acidification. Science 318(5857): 1737–1742. doi:10.1126/science.1152509

Hooper A (1983) Tokelau fishing in traditional and modern contexts. In: Ruddle K, Johannes R (eds) The traditional knowledge and management of coastal systems in Asia and the Pacific. UNESCO, Djakarta, pp 11–38

IPCC (ed) (2001) Climate change 2001: the scientific basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK and New York, NY, USA

Johannes RE (1978) Traditional marine conservation methods in oceania and their demise. Ann Rev Ecol Syst 9:349–364

Jones R, Hennessy K, Page C, Walsh K, Whetton P (1999) An analysis of the effects of the Kyoto Protocol on Pacific Island Countries: regional climate change scenarios and risk assessment methods. South Pacific Regional Environment Programme and CSIRO, Apia

Kench PS, McLean RF, Nichol SL (2005) New model of reef-island evolution: Maldives, Indian Ocean. Geology 33(2):145–148

Kleypas JA, Buddemeier RW, Archer D, Gattuso JP, Langdon C, Opdyke BN (1999) Geochemical consequences of increased atmospheric carbon dioxide on coral reefs. Science 284(5411): 118–120

Lal M (2004) Climate change and small island developing countries of the South Pacific. Fijian Stud 2(1):1–15

Lim B, Spanger-Siegfried E, Burton I, Malone E, Huq S (2004) Adaptation policy frameworks for climate change: developing strategies, policies and measures. Cambridge University Press, Cambridge

Mastrandrea MD, Schneider SH (2004) Probabilistic integrated assessment of "dangerous" climate change. Science 304(5670): 571–575

McKenzie E, Prasad B, Kaloumaira A (2005) Economic impact of natural disasters on development in the Pacific. Volume 1: research report. University of the South Pacific (USP), The South Pacific Applied Geoscience Commission (SOPAC)

Meleisea P (1996) Sociocultural issues and economic development in the Pacific Islands. Pacific studies series. Asian Development Bank, Manila

O'Neill BC, Oppenheimer M (2002) Climate change—dangerous climate impacts and the Kyoto protocol. Science 296(5575): 1971–1972

Olsthoorn A, Maunder W, Tol R (1999) Tropical cyclones in the Southwest Pacific: impacts on Pacific Island countries with particular reference to Fiji. In: Downing T, Olsthoorn A, Tol R (eds) Climate, change and risk. Routledge, London and New York, pp 221–244

Overton J (1999) Sustainable development and the Pacific Islands. In: Overton J, Scheyvens R (eds) Strategies for sustainable development: experiences from the Pacific. UNSW Press, Sydney, pp 1–15

Pearce F, Teuatabo N (2000) Turning back the tide. New Sci 165(2225):44–47

Petersen L (2001) Governance of the South Pacific tuna fishery. Paper presented at the 30th annual conference of economists, Perth, 23–26 September

Popkin B, Horton SSK (2001) The nutrition transition and prevention of diet-related diseases in Asia and the Pacific. Food and nutrition bulletin 22 (special supplement). United Nations University, Tokyo

Reaser JK, Pomerance R, Thomas PO (2000) Coral bleaching and global climate change: scientific findings and policy recommendations. Conserv Biol 14(5):1500–1511

Ruosteenoja K, Carter TR, Jylha K, Tuomenvirta H (2003) Future climate in world regions: an intercomparison of model-based projections for the new IPCC emissions scenarios. Finnish Environment Institute, Helsinki

Salinger MJ (2001) Climate variation in New Zealand and the Southwest Pacific. In: The physical environment. A New Zealand perspective. Oxford University Press, Victoria

Schneider SH (2001) What is 'dangerous' climate change? Nature 411(6833):17–19

Sharma KL (2006) Food security in the South Pacific Island countries with special reference to the Fiji Islands. WIDER Research Paper no. 2006/68. World Institute for Development Economics Research, United Nations University, Helsinki

Shue H (1980) Basic rights: subsistence, affluence and US Foreign Policy. Princeton University Press, Princeton

Singh RBK, Hales S, de Wet N, Raj R, Hearnden M, Weinstein P (2001) The influence of climate variation and change on diarrheal disease in the Pacific Islands. Environ Health Perspect 109(2):155–159

Smit B, Wandel J (2006) Adaptation, adaptive capacity and vulnerability. Glob Environ Change 16(3):282–292

SPC (2006) Climate and tuna fisheries. Oceanic Fisheries Programme. Secretariat of the Pacific Community, Noumea, New Caledonia

Tarte S (1999) Negotiating a Tuna management regime for the western and central pacific: the MHLC process 1994–1999. J Pac Hist 34(3):273–280

UNEP (1999) Pacific Islands environmental outlook. UNEP and the South Pacific Regional Environment Programme, Samoa

Walsh K (2004) Tropical cyclones and climate change: unresolved issues. Clim Res 27(1):77–83

WMO (1999) The 1997–1998 El Niño event : a scientific and technical retrospective: a contribution to the United Nations Task Force on El Niño for implementation of United Nations General Assembly Resolutions 52/200 and 53/185. World Meteorological Organization, Geneva, Switzerland

Woodworth PL (2005) Have there been large recent sea level changes in the Maldive Islands? Glob Planet Change 49(1–2):1–18

World Bank (2001) Cities, seas, and storms: managing change in Pacific Island Economies. World Bank, Washington