Climate Change, Vulnerability and Social Justice

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Preface

The paper that follows seeks to summarize briefly some of the major findings emerging from assessments of the potential impacts of ongoing and future climate change. In the spring of 2001, the Stockholm Environment Institute proposed to the Swedish International Development Cooperation Agency (Sida) that an overview of major vulnerability issues involved with climate change might be useful to a variety of users and interested persons. In this review, the authors accord particular attention to people and regions at highest risk to such changes, particularly those in developing countries. In doing so, they draw heavily upon the three assessments of the Intergovernmental Panel on Climate Change (IPCC) as well as related work undertaken by independent scholars and assessors. It is important to note that although the authors undertook no original research, they have addressed the types of knowledge and approaches required for identifying and assessing highly vulnerable groups and ecosystems.

The review argues that vulnerability assessment is essential for a full analysis of climate-change impacts and for delineating social-justice issues that require attention in any successful international climate-change regime. The importance of complementing emissions reduction with strategies aimed at reducing human vulnerabilities, enlarging coping resources and adaptive capacity, and strengthening resilience is a recurrent theme. The authors conclude by proposing constructive pathways for future efforts aimed at creating societies more resilient to climate change and other global environmental hazards.

Climate Change, Vulnerability, and Social Justice

Introduction

As we enter a new century, it is apparent that people have already altered the climates in which they live and will alter them even more dramatically in the coming decades. We know from the Third Assessment of the Intergovernmental Panel on Climate Change (IPCC 2001) that over the past century average surface temperatures across the globe have increased by 0.6^{o}C, and we now have stronger evidence that human activities are responsible for most of this warming. We also know that the 1990s were the warmest decade and 1998 was the warmest single year since 1861. These ongoing and future changes in climate will continue to alter nature's life-support systems for human life in many parts of the globe: through an ongoing rise in global average sea level, increases in precipitation over most mid- and high-latitudes of the northern hemisphere, increased intensity and frequency of droughts, floods, and severe storms, and as yet unforeseen abrupt changes and extreme climatic events. Meanwhile, decades will pass before the current human efforts to reduce ongoing climate change will register their effects. In short, time is at a premium.

The impacts of these human-induced changes in climate, although in their early stages, are showing up in shrinking glaciers, thawing permafrost regions, longer growing seasons in mid- and high-latitude agricultural areas, shifts in plant and animal ranges, and declines in some plant and animal populations. But these effects now in progress only suggest the much more far-reaching changes likely to come. Major global-warming threats to human security and well-being across the planet include diverse risks (Box 1).

Box 1. Threats and potential benefits of global warming

Threats

- reduced potential crop yields in some tropical and subtropical regions and many mid-latitude regions;
- decreased water availability for populations in many water-scarce regions, particularly those with inadequate management systems;
- an increase in the number of people exposed to vectorborne diseases (e.g., malaria) and waterborne diseases (e.g., cholera);
- increases in the number of people dying from heat stress, particularly in large cities in developing countries;
- a widespread increase in the risk of flooding for many human settlements throughout the world;
- and severe threats to millions of people living on low-lying islands and atolls.

Potential benefits

- increased potential crop yields in some mid-latitude regions;
- a potential increase in global timber supply from appropriately managed forests;
- increased water availability for populations in some water scarce regions (e.g., parts of South East Asia);
- reduced winter mortality in mid- and high latitudes.

Unfortunately, it is unrealistic to expect that positive and negative effects will balance out, because they will register their impacts on different regions, ecosystems, and people. And many of these regions and peoples will be highly vulnerable and poorly equipped to cope with the major changes in climate that may occur. Further, many people and places are already under severe stress vulnerability arising from other environmental and socioeconomic forces, including those emanating from globalization processes. The last thing they need is to have to add climate-change impacts to the likes of population growth, increasing concentrations of populations in megacities, poverty and poor nutrition, accumulating levels of atmospheric, land, and water contamination, a growing dependence upon distant global markets, growing gender and class inequalities, the ravages of the AIDS epidemic, and politically corrupt governments. Climate change will produce varied effects that will interact with these other stresses and multiple vulnerabilities, and they will take their toll particularly among the most exposed and poorest people of the world. As we have stated elsewhere (Kasperson and Kasperson 2001, 274-275): "The lesson from climate change is a more general one: risks do not register their effects in the abstract; they occur in particular regions and places, to particular peoples, and to specific ecosystems. Global environmental risks will not be the first insult or perturbation in the various regions and locales of the world; rather, they will be the latest in a series of pressures and stresses that will add to (and interact with) what has come before, what is ongoing, and what will come in the future."

Recognizing and understanding this differential vulnerability is a key to understanding the meaning of climate change. And understanding both the nature of the stresses that climate change will exert upon ecological and human systems and the extent of their vulnerabilities to those stresses is essential. Over the past decade, studies of climate change have largely focussed on issues of science—how releases of greenhouse gases accumulate in the atmosphere and interact with biogeophysical processes to alter attributes of climate. In-depth analysis of the impacts of climate change, and particularly the impacts on the most vulnerable people and places is only beginning. It will be the commanding task for climate-related studies over the next decade. And yet, we do know something about the major types of vulnerability that exist and about where to find the most vulnerable regions and places.

Indeed, it is easy to identify some of the most vulnerable human and ecological systems. One-third to one-half of the world's population already lacks adequate clean water, and climate change—due to increased temperature and droughts in many areas—will add to the severity of these issues. Many developing countries (especially in Africa) are likely to suffer declines in agricultural production and food security, particularly among small farmers and isolated rural populations. Increased flooding from sea-level rise will ravage low-lying coastal areas in many parts of the globe, in both rich and poor countries, leading to loss of life and infrastructure damages from more severe storms as well as loss of wetlands and mangroves. Small-island states in particular face the prospect of such devastating effects that it may prove necessary for some peoples to abandon their island homes and migrate to other locales.

The poor, elderly, and sick in the burgeoning megacities of the world face increased risk of death and illness from more severe heat and humidity. Dense populations in developing countries face increased threats from riverine flooding and its associated impacts on nutrition and disease. These threats only suggest, of course, the broad panoply of effects that will confront the most vulnerable regions of the world. It is the rates and patterns of climate change and their interaction with place-specific vulnerabilities that will drive the realities as to the eventual severities of these effects and the potential effectiveness of mitigation efforts and human adaptation.

What is vulnerability?

Put simply, vulnerability is the capacity to be wounded from a perturbation or stress, whether environmental or socioeconomic, upon peoples, systems, or other receptors. In the case of this paper, it is the exposure and susceptibility to harm or damage from climate change. The IPCC has adopted the following definitions relevant to assessing vulnerability:

Vulnerability. The extent to which climate change may damage or harm a system; vulnerability is a function of not only the system's sensitivity, but also its ability to adapt to new climatic conditions.

Sensitivity. The degree to which a system will respond to a change in climatic conditions (e.g., the extent of change in ecosystem composition, structure and functioning, including net primary productivity, resulting from a given change in temperature or precipitation).

Adaptability. The degree to which adjustments are possible in practices, processes, or structures of systems to projected or actual changes of climate; adaptation can be spontaneous or planned, and can be carried out in response to or in anticipation of changes in conditions.

Assessments of the ecological and human risks from climate change need to take account of both the magnitude of the stresses that may result from alterations in the characteristics of climate--precipitation, temperature, droughts, severe storms--and the degree of vulnerability of human and ecological systems to them. Thus, even modest changes in climate, either in mean temperature change or in the frequency and severity of extreme events, can have large effects if people or ecological systems are highly sensitive to the climate change. Such sensitivity may be very high if exposure to the change is high or if the buffering or coping capacity of people or systems is constrained. Assessing such effects requires an integrated approach, one that examines interactions between ecological and human systems as a particular place or region responds to the change or perturbation.

Ecosystems are important in relation to climate change because they provide the life-support systems that sustain human societies. In doing so, they deliver such essential goods and services as (1) providing food, fiber, shelter, medicines, and energy; (2) processing and storing carbon and nutrients; (3) assimilating and remediating wastes; (4) purifying water; (5) building soils and reducing soil degradation; and (6) housing the planet's store of genetic and species diversity. Climate change will alter these goods and services in complex and uncertain ways--through their geographic location, mixes of species, and array or bundles of services essential to human well-being. Those ecological goods and services themselves are also constantly changing because of ongoing human activities, so that climate change and human activities will interact, often in unknown ways, in modifying patterns of ecological goods and services that support human societies.

Human societies show a wide variability in their sensitivity to environmental change and their abilities to anticipate, cope with, and adapt to such change. Many factors shape this variability, including wealth, technology, knowledge, infrastructure, institutional capabilities, preparedness, and access to resources. Human endowments in such assets vary widely in a world of mounting inequality. *Developing countries, and particularly the least developed countries, are clearly the most vulnerable regions to climate change. They will experience the greatest loss of life, the most negative effects on economy and development, and the largest diversion of resources from other pressing needs*. Since such countries and regions are also under stress from the forces of globalization, including population growth, urbanization, resource depletion, contamination of environments, dependence on global markets, and growing poverty, climate change will interact in uncertain ways with other accumulating problems. All peoples and regions have some level of vulnerability, and even the richer countries will not escape future damage and loss of life from climate change. *Nevertheless, the vulnerable countries, regions, and places of the world will almost certainly bear most of the ongoing and future toll that will occur as a result of climate change.*

Peoples and systems vulnerable to climate change

Food-insecure areas

Climate change will affect agriculture and food security in a variety of ways, bringing benefits to some areas and losses to others. On the one hand, increased carbon dioxide in the atmosphere can enhance plant growth and crop yields; on the other, agricultural pests may thrive under increased CO_2 concentrations while excessive heat and drought may produce widespread adverse effects on agriculture. Much depends upon the rate, magnitude, and geographic pattern of climate change. Some regions, particularly in the mid-latitudes, are likely to register modest gains in agricultural yields and food supply, whereas agriculture in food insecure regions will undergo radical declines or even disappear due to rising sea level or saltwater intrusion.

Geographic shifts in agriculture will certainly pose major challenges for those regions caught in the largest transitions. In some areas, agriculture will encroach on virgin lands and natural ecosystems. A warmer climate regime will generally alter the present distribution and productivity of forests, grasslands, savannahs, wetlands, and tundras. For example, thawing of permafrost regions may dry out tundras, sea-level rise may lead to the flooding of coastal agricultural areas, and the prior adaptation of plants and animals to a particular region may be disrupted. In areas with larger or more abrupt climate changes, farmers will find their accumulated experience a less reliable guide to the future than it has been in the past. Their ability to adapt without making large errors will be severely tested. In many areas they will be forced to change planting dates, rates of fertilization, uses of irrigation, and selection of plant and animal species, and to do so within a changing physical environment and uncertain regional and global markets. Trial and error will have both winners and losers, and the losers are likely to be those with the highest sensitivity and the least adaptive capacity.

Past studies suggest that adverse effects of climate change on agriculture and food security will be concentrated in developing countries. There these impacts will interact with other environmental and socioeconomic vulnerabilities to exacerbate hunger and to endanger food security (IPCC 2001). Economic assessments suggest that a climate change of a few degrees C can jeopardize the growth of the global food supply. Much of the adverse impact will be on small agriculturalists and the urban poor in developing countries. Incomes of the most vulnerable people are likely to decline as the numbers of people at risk of hunger increase. Over all, owing to geographic and temporal shifts in agriculture, worsening social and economic situations, and new extremes in temperature and precipitation, food security in areas already insecure, and particularly in Africa, will worsen.

The case of Egypt suggests how far-reaching climate change may be for some developing countries. Historically, Egypt's rich agricultural system has been predicated on favourable temperature conditions, fertile soils, and abundant irrigation water from the Nile River. With a rapidly growing population that now numbers some 63 million people (World Bank 2001, 26), Egypt has expanded its agriculture into desert lands adjoining the Nile basin and reclaimed long-used areas that have become salinized or waterlogged. Nonetheless, Egypt remains totally dependent upon water from the Nile, a situation posing severe challenges to Egypt's economic future, even without climate change. But with climate change, an array of serious threats is apparent. Sea-level rise will jeopardize areas of the Nile delta currently lying below one metre in elevation; as much as 12-15% of the existing agricultural land in the Nile delta could be lost (Nicholls and Leatherman 1994). Sea-level rise is likely to accelerate the intrusion of saline water into surface water sources and the underlying coastal aquifer (Sestini 1992). Temperature rises are likely to reduce agricultural productivity throughout Egypt. Although the effects of climate change upon the flow of the Nile itself are uncertain, they are likely to increase demand for irrigation water and to exact a toll on heat-sensitive crops. Much can be done to mitigate these effects over the coming decades, including slowing population growth, but widespread and vigorous intervention will be essential to ward off a growing shortage and eventual crisis of food supply in Egypt.

The Philippines are another case of potential food insecurity. Indeed, agriculture is the economic lifeline of this archipelago nation; more than 70% of the foreign exchange earnings of the Philippines come from agricultural exports and 50% of the country's working population is in the agricultural sector (Rosenzweig and Hillel 1998, 200). Rice, the primary staple crop, is very vulnerable to the pattern of tropical cyclones, and floods, and to drought-inducing delays in the onset of the rainy season. Climate change could lead to declines in rice yields in this highly dependent country. Major changes in cropping patterns, with earlier planting dates and choice of cultivars may be needed. But such changes will also require a major transformation in the farming system of this poor country and farmers may be subject to new and uncertain risks (such as strong winds later in the season) that may arise (Escano and Buendia 1994).

Water-scarce regions

One-third of the world's population now lives in countries that are water stressed (where more than 20% of the renewable water supply is being used). The world's population living in such circumstances is expected to increase from an estimated 1.5 billion people currently to about 5 billion people in 2025 (IPCC 2001). One in five of the world's people now lack access to safe and affordable drinking water. Half of the world's population does not have access to sanitation. Each year 3-4 million people die of waterborne disease, including more than 2 million young children who die of diarrhoea. Half of the world's wetlands have been destroyed in the 20th century. As much as 10 per cent of global annual water consumption may come from depleting groundwater resources that are also undergoing contamination. In most countries, highly fragmented water institutions manage growing water scarcities and block integrated water management approaches (Cosgrove and Rijsberman 2000). Indeed, the greatest vulnerabilities worldwide in 2001 are in unmanaged or unsustainable water systems in developing countries. Typically, such systems are already at high risk due to other forces--population growth, water contamination, poor pricing systems, and growing irrigation uses--pushing the systems further into unsustainability. Climate change threatens to exacerbate problems already severe and create further water deficits and shortages.

Climate change, it is generally thought, will produce increases in annual mean streamflow in high-latitude countries but reductions in central Asia, the Mediterranean, Southern Africa, and Australia. Higher temperatures will mean a general trend toward increases in demands for irrigation water. Higher water temperatures may also degrade water quality in many regions, particularly when taken in conjunction with increased pollutants attendant on growing populations, urbanization, and consumption. The frequency and magnitudes of floods will also increase in many regions due to more frequent heavy rainfalls. In some regions increased precipitation will offset higher temperatures and evaporation; in other regions, greater stress of existing water resources will occur.

These potential effects of future climate change are very apparent in Africa. Currently, approximately two-thirds of Africa's rural population and one-fourth of the urban population lack safe drinking water. Even higher percentages are without proper sanitation (Zinyowera *et al*. 1998, 49). In 1990, eight African countries south of the Sahara were experiencing water stress or scarcity, and the situation has worsened since then. By 2025, it is estimated that the number of countries subjected to water stress will grow from 8 to 18 countries and affect some 600 million to 4 billion people (Cosgrove and Rijsberman 2000, 28; World Bank 1996). Eight African river basins already face water stress and another four confront water scarcity. Simply taking account of declining water availability due to population growth reveals the grim picture apparent in Figure 1.

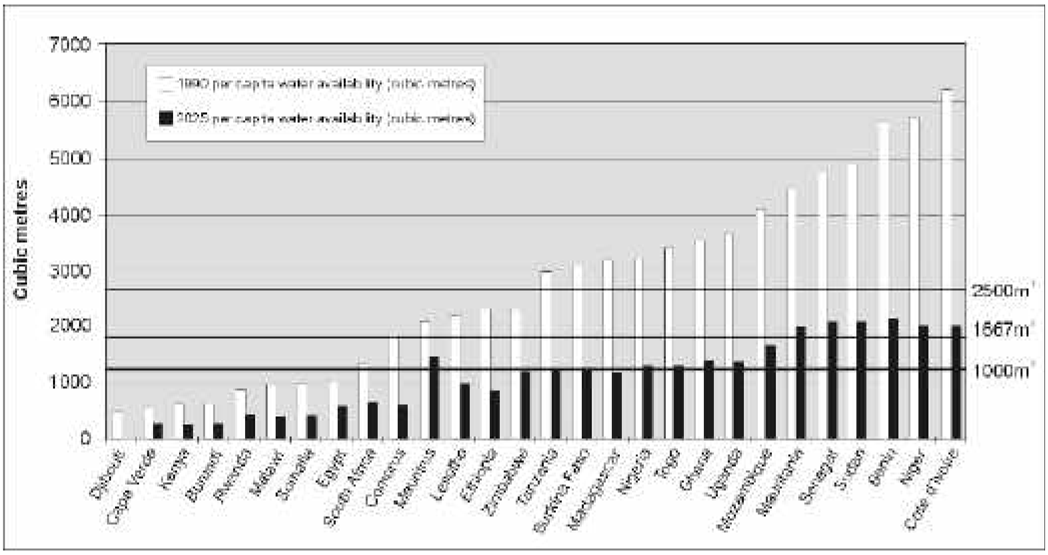

Figure 1. Projected water scarcity in Africa

Source: After Sharma *et al.* (1996, 15).

The effects of ongoing and future climate change on water availability in Africa are still uncertain, but Africa has experienced serious droughts in 1965-66, 1972-74, 1981-84, 1986-87, 1991-92, and 1994-95. These droughts have often been connected to El Niño Southern Oscillation (ENSO) anomalies. But if projections of reduced stream flow from climate change on southern Africa materialize, *they will overlay a precarious situation already jeopardizing poor countries beset by a panoply of other environmental and social threats and in a weak position to cope with additional climate-induced threats.*

Northern China is another area highly vulnerable to further water scarcity induced by climate change. With a population of 371 million, it is a major economic center of China. It is a region already at risk from normal climate variability and longer term climatic shifts. Both surface water and groundwater are quite sensitive to climate variability, especially on the Huang-Hai plain. Already this is a region under water-shortage stress; water resource availability is only 500m^3 per capita--one-half the critical value of the UN standard of 1,000m^3 per capita for maintaining sustainable development. Because of the shortage of surface water, groundwater resources are being depleted, and "the water table under some of the major grain-producing areas of northern China is falling at a rate of five feet (1.5 metres) per year" (USCIA 2001, 20). To these immense shortages, add those induced by climate change, which, as the IPCC (1998, 374) points out, have the potential in dry years to exacerbate a serious situation and hamper socioeconomic development in the region.

Vulnerable marine ecosystems

Climate change will change oceans in important ways: sea ice-cover will decrease in the polar regions, salinity and wave conditions will change, sea-surface temperatures and mean sea level will rise, and more severe storms and shore erosion must be anticipated. Such changes, interacting with growing population densities and developmental pressures in coastal areas, will impose major ecological and human impacts, principally:

- loss of land and displacement of population
- flooding of low-lying coastal areas
- loss of agricultural yields and employment
- negative impacts on coastal aquaculture
- erosion of sandy beaches and associated losses in tourism

But serious impacts will also befall marine ecosystems, such as coral reefs, atolls, salt marshes, and mangrove forests, depending on the rate of sea-level rise. The case of coral reefs, which the World Conservation Strategy has identified as one of the ecological life-support systems essential for global food production, health, and sustainable development, highlights the magnitude of possible effects. Their future is already in jeopardy due to overexploitation, coastal development, and land-based pollution. Coral reefs are, however, highly sensitive to prolonged rises in seawater temperature and increased irradiance. Future sea-surface warming associated with global warming could seriously increase stress on coral reefs. Moreover, experience with severe coral bleaching in Indonesia signals that coral reefs may well fail to recover successfully over the longer term, even after warming events have receded (Brown and Suharsono 1990).

The mean temperatures of the world's oceans are increasing at an accelerating rate, currently approximately 2^{o}C per century (Souter, Obura, and Lindén 2000,12). When this warming combined with the strongest El Niño ever recorded in 1998, corals throughout the world's tropical islands suffered extensive bleaching and mortality. Along the coasts of East Africa and in Indian Ocean islands, 90-100% of corals exposed to water temperature higher than 32^{o}C died. And 18 months later, the coral reefs showed few signs of recovery (Souter, Obura, and Lindén 2000, 14). Global warming poses a serious further threat to coral reefs through increases in sea surface temperature and increased frequency of marine diseases. Since healthy coral are essential in the Indian Ocean for coastal fisheries and tourism, declines in fish stocks, threats to food security, and losses in income from tourism are likely for large portions of coastal populations.

Other human effects of sea-level rise may be widespread and serious. One estimate, for example, suggests that losses of land from a 1-metre rise in sea level would total 30,000 km^2 in Bangladesh, 6,000 km^2 in India, 34,000 km^2 in Indonesia, and 7,000 km^2 in Malaysia (Nicholls, Mimura, and Topping 1995). Viet Nam could find 5,000 km^2 of land inundated in the Red River delta, while 15,000-20,000 km^2 of land could be threatened in the Mekong delta.

The case of the Ganges-Brahmaputra delta, one of the world's most densely populated regions, speaks to the range of interlocking problems that climate change is likely to produce. With higher sea levels, severe storms and storm surges will affect larger areas of the delta as saline and brackish waters increasingly contaminate inland freshwater lakes and aquifers. Tidal damages will move further upstream and increases in soil and freshwater salinity may cause widespread problems for potable water and irrigation sources. Since these are already under pressure owing to a very large and growing population, the human impacts and obstacles for attempts to control the damage are almost certain to be far-reaching (Alam 1996, Broadus 2001).

Awareness of the widespread potential effects on coastal systems already undergoing rapid change has prompted rethinking about whether human societies can effectively adapt. Focus is shifting away from strategies aimed at protecting shorelines with engineered protection systems (e.g., seawalls, groins) to strategies geared to coastal land-use planning, efforts to enhance resilience in biophysical and social systems, and even managed retreat from coastal regions (IPCC 2001).

Fish-dependent societies

Many societies depend heavily upon fish as a significant part of their food supply. For example, as much as one-third of protein supply in densely populated Nigeria comes from fish. The vulnerability of fisheries to climate change depends upon the character and rate of the change, the nature of the fishery, and changes in the associated species and habitat. According to Carpenter and colleagues (1992), climate change threatens to affect fisheries through:

- changes in water temperatures;
- the timing and duration of temperature extremes;
- the magnitude and patterns of annual stream flows;
- surface water elevations; and
- the shorelines of lakes, reservoirs, and near-shore marine environments.

The Organization for Economic Cooperation and Development (OECD) has recently flagged overfishing as a "red light" issue of global significance. Indeed, a new report indicates that more than one-fourth of the world's marine fisheries are "already either exhausted, over-fished, or recovering from over-fishing" (OECD 2001, 8). Climate changes are expected to increase sea surface temperature and mean sea level of the oceans. Associated changes in oceans are now recognized to alter strongly patterns of fish abundance and those population dynamics. If we take just one but the most important of these changes--elevated temperatures--vulnerable areas dependent upon marine fisheries will face severe stresses:

- a shift in centers of fish production and the composition of species as ecosystems change in their distribution and their internal structure;
- falling economic return until long-term stability in the fisheries is achieved; and
- disproportionate suffering among the subsistence and other small-scale fishermen in Africa.

(Zinyowera *et al*. 1998, 63)

The situation in Africa suggests that *it is the most vulnerable people and places that will bear most of the costs.* Fish make up a significant part of the total food supply of Africa. In the past, economic activities rather than climate variability have been the major stressors on the productivity of freshwater areas and the sea margins. But climate-induced fluctuations could cause significant disruption in food supply in those African societies that depend heavily upon fisheries and that have limited potential for adaptation to other sources of food supply. Mauritania, Namibia, and Somalia are particularly at risk.

The potential impacts of climate change on fisheries in tropical Asia have not been well established. But fisheries are very important throughout the region, including inland areas in which people depend on freshwater fish in food supply. In the Philippines, fisheries employ nearly a million people, 26% of whom are in aquaculture operations and 68% in marine and freshwater fishing (Lim, Matsuda, and Shigemi, 1995). Throughout much of south and southeast Asia, overexploitation of inshore and inland fisheries is already endangering fishing livelihoods. Climate change will affect the region's fisheries in uncertain ways, by changing marine conditions that alter the abundance of fish populations, introducing saline waters into inland freshwaters, and inundating regional aquaculture.

The type of fisheries disruption that environmental changes can induce is apparent in the case of the Nile. There the building of the Aswan Dam so regulated the flow of the Nile that the river delta succumbed to thorough ecological degradation. A dramatic change in surges of floodwater and nutrient pulses triggered a collapse of the local sardine population that had long thrived and provided an important source of food for the region.

Threats to human health

Climate change may be expected to affect human health and disease patterns in various direct and indirect ways (Figure 2). Direct effects will occur in the form of changes in temperature and humidity, heat-stress mortality, flooding, tropical vector-borne diseases, and decreases in cold-related illnesses. But climate change will also affect the proportion of the world's population living in cities, availability of sanitation and potable water supplies, human migration, and living conditions. These all interact to complicate the task of gauging the impacts of climate on human health.

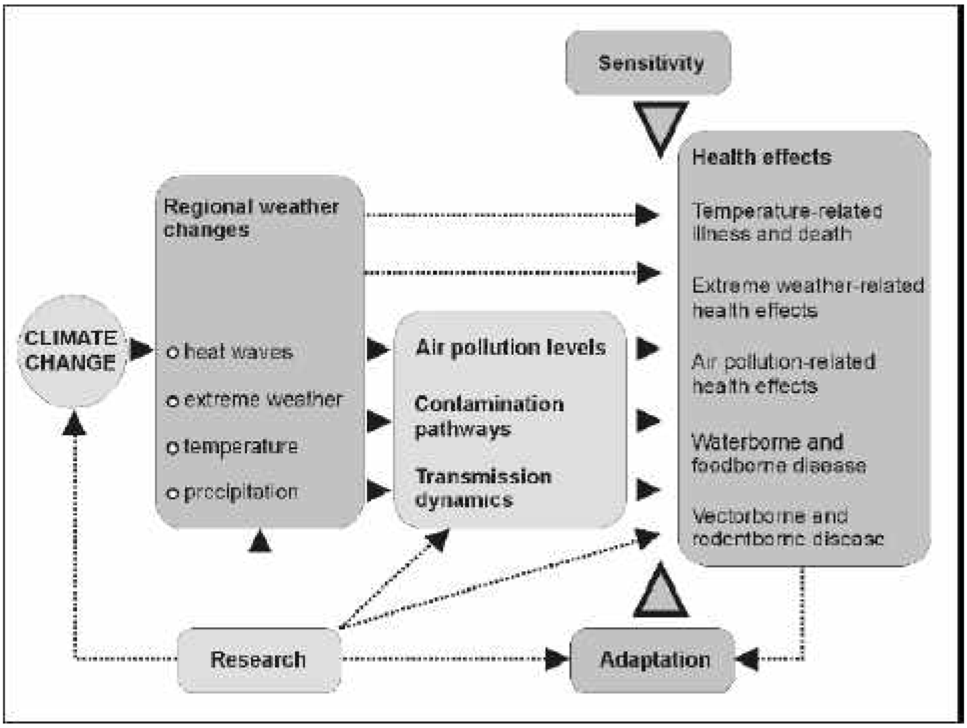

Figure 2. Assessing potential health effects of climate change.

Source: After Patz et al. (2000, 369)

But some things are reasonably clear. The World Health Organization has concluded that climate change is likely to alter the incidence and range of major tropical vector-borne diseases (Table 1). The geographic range of two important infectious diseases--malaria and dengue--is likely to increase. It is estimated that, should a temperature increase in the upper part of the IPCC-projected range (3-5^{o}C by 2100) occur, the proportion of the world's population affected by malaria would increase from the current 45 per cent to about 60 per cent in the second half of the 2100s. This would produce about an additional 50-80 million cases annually (Watson *et al*. 1998, 7). Malaria is already one of the most serious and complex global diseases and it is the disease most likely to be affected by climate change (Kovats *et al*. 2000). Currently, around 270 million people are infected by malaria at any given time, 1-2 million people die from malaria each year (mostly in Africa), and approximately 2 billion people worldwide are at risk (McGranahan *et al*. 1999, 176). Climate change will affect the underlying conditions--higher temperatures, increased precipitation and relative humidity, mosquito habitats, and access to washing and drinking water--that support the spread of the disease. Recent models of the potential effects of climate change suggest that the global population at risk of malaria would increase significantly, including a widespread increase in the seasonal duration of transmission in new areas (Kovats *et al*. 2000, 18). At particularly high risk would be the latitudes adjoining the current malarial zones and the high-altitude areas within the zones, particularly the mountainous

Table 1. Climate change and major tropical vector-borne diseases

Disease	Likelihood of change with climate change	Vector	Present distribution	People at risk (millions)
Malaria	+++	Mosquito	Tropics/sub-tropics	2020
Schistosomiasis	++	Water snail	Tropics/sub-tropics	600
Leishmaniasis	++	Phlebotomine sandfly	Asia/southern Europe/Africa/Americas	350
American trypanosomiasis (Chagas disease)	+	Triatomine bug	Central and South America	100
African trypanosomiasis (Sleeping sickness)	+	Tsetse fly	Tropical Africa	55
Lymphatic filariasis	+	Mosquito	Tropics/sub-tropics	1100
Dengue	++	Mosquito	All tropical countries	2500-3000
Onchocerciasis (River blindness)	+	Blackfly	Africa/Latin America	120
Yellow fever	+	Mosquito	Tropical South America and Africa	-
Dracunculiasis (Guineau worm)	?	Crustacean (copepod)	South Asia/Arabian peninsula/Central-West Africa	100

+++ Highly likely, ++ Very likely, + Likely, ? Unknown

Source: Kovats *et al*. (2000, 20)

areas in eastern Africa where temperatures currently curtail transmission of the disease. (McGranahan *et al*. 1999, 179).

Climate change may be expected to have other health consequences, both positive and negative. Schistosomiasis would be likely to spread beyond its current distribution limits though it might well also decrease in some areas. Dengue may undergo a latitudinal and altitudinal expansion similar to malaria. Certain other vector-borne diseases, such as onchocerciasis (river blindness), yellow fever, and possibly trypanosomiasis (sleeping sickness) might also undergo climate-induced redistribution (McGranahan *et al.* 1999, 180). Increased frequency of heat waves, often accompanied by increased humidity and urban air pollution, will cause increases in heat-related deaths and illnesses, particularly among the elderly and those in poor health. Finally, increased flooding events, should they occur, could produce serious consequences from flood disasters, particularly in densely populated areas (such as parts of China and Bangladesh).

Extreme vulnerability: Small-island states

The island states of the world are among the areas most endangered by climate change. They also hold an extraordinary richness in the planet's cultural resources and diversity. Over one-third of all known languages, for example, are spoken in four countries of Melanesia (Papua New Guinea, the Solomons, Vanuatu, New Caledonia). The island states possess distinctive human cultures and traditional knowledge and technologies found nowhere else.

Although these islands are culturally heterogeneous and diverse, they share common features that endanger them. Generally, they have high population densities concentrated in limited land areas, and the largest settlements are typically located no further than 1-2 km from the coast. In nearly all the states, large settlements are found on beaches or sand terraces. Because populations are often concentrated in the few urban centers where most infrastructure is located, sea-level rise could produce widespread disruption to economic and social activities. Indeed a sea-level rise of between 50 cm and one metre could convert many islands to sandbars and substantially reduce remaining drylands on even the larger and more heavily populated islands. Table 2 lists the small island states that fall into this category.

Table 2. Small Island States (United Nations Member States and Members of the Alliance of Small Island States (AOSIS))

Antigua and Barbuda	Malta
The Bahamas	Marshall Islands
Barbados	Mauritius
Cape Verde	Nauru
Comoros	Palau
Cook Islands	Saint Kitts and Nevis
Cuba	Saint Lucia
Cyprus	Saint Vincent and the Grenadines
Dominica	Samoa
Dominican Republic	Sao Tome and Principe
Federated States of Micronesia	Seychelles
Fiji	Solomon Islands
Grenada	Tonga
Haiti	Trinidad and Tobago
Jamaica	Tuvalu
Kiribati	Vanuatu
Maldives	

Beyond the question of direct inundation resulting from sea-level rise is the vulnerable nature of small island economies. A few activities--agriculture, fisheries, tourism, and international transport--typically dominate small island state economies. As a result they are highly sensitive to global market forces beyond their control. The survival of many islands also depends heavily upon remittances from expatriate nationals and development funds from the international donor community. Since primary production plays a large role in the economies, disruptions to agricultural support systems from climate change is likely to produce widespread disruption and economic loss. Meanwhile, island populations are growing at more than 3% per year, and populations are migrating to island cities or emigrating in search of work (Pernetta 1992).

The physical circumstances of island states leave them highly vulnerable to potential climate-induced changes. Much of the critical infrastructure and economic activities are located close to coastal areas, many of which are at or close to current sea level. Coastal erosion, saline intrusion, and sea flooding are already serious problems. Potable water supplies are typically in short supply. Of particular concern is whether climate change will lead to an increase in the frequency and severity of storms that may be experienced by these island states, particularly the effects of hurricanes and typhoons. Adding to the concern over vulnerability is the cumulative and interacting presence of nonclimate related natural disasters, rapidly growing populations, and few possibilities for adaptation.

The Republic of the Maldives reveals dramatically the extreme vulnerability of small island states to climate change. The Maldives include 19 major atolls and approximately 1190 islands, of which 202 are populated. No island is more than three metres above mean sea level and most are less than one meter high. With a tidal range of one meter, even distant storms in the Indian Ocean cause severe flooding. The offshore reef system supports a complex coral community that sustains the economy and everyday life of the Maldives. Coral are used for building material, fisheries are the leading economic activity, and tourism is the second pillar of the economy. Confronted by an array of economic and development problems and rapid population growth, the Maldives face possibly devastating effects from climate change driven sea-level rise and severe storms, as indicated in Box 2.

Box 2. Maldives: Risks associated with global climate change

- Increased rated of coastal erosion and alteration of beaches with increased impacts from high waves
- Changes in aquifer volume associated with increased saline intrusion
- Increased energy consumption (e.g. air-conditioning)
- Coral deaths as a result of increased seawater temperatures
- Loss of capital infrastructure on smaller tourist resort islands
- Changes in reef growth and current patterns
- Increased vulnerability of human settlements due to aggregation and increasing size

Sources: Pernetta and Sestine (1989); May (2001).

It is clear that small-island states are among the world's regions most endangered by climate change and will require extensive intervention by the larger international community to ward off long-term disruptions and the loss of the rich cultural heritage of the islands.

Environmental security and environmental refugees

A major concern surrounding climate change is that, owing to the potential effects and disruptions noted above, increased tensions and conflict among nations or cultures may occur in the international system. A case in point, described by Postel (2000, 46-47), is the prospect for increased international competition for water as populations grow rapidly in a number of water-scarce regions. In what she describes as "hot-spots of water dispute" the Aral Sea region, the Ganges, the Jordan, the Nile, and the Tigris-Euphrates, populations of the nations within these basins are projected to grow 32-71 per cent by 2025. If water sharing agreements are not found, she warns, "competition could lead to regional instability or even conflict" (Postel 2000, 47).

Homer-Dixon, Boutwell, and Rathjens (1993), meanwhile, have attempted to explore systematically the relationships between environmental degradation and political conflict, concluding that:

- resource scarcity, per se, does not promote much direct violence, though water may be a partial exception;
- environmental degradation can lead to mass migration, which can spark ethnic conflict; and
- environmental harm can bring about institutional decay and economic deprivation, leading to civil strife.

The tenuous nature of such findings, after more than a decade's research, suggests how limited our knowledge remains of these relationships and how opaque the structure of causal linkages between environmental change and security outcomes is. As Levy (1995, 58) points out, "by the time one arrives at the end of the logical chain-violent conflict-so many intervening variables have been added that it is difficult to see the independent contribution of environmental degradation."

A similar situation surrounds the dire warnings concerning a potential future flood of "environmental refugees." Norman Myers and Jennifer Kent (1995, 1) have estimated that such refugees, people forced to leave land that can no longer support them, have grown to an all-time high of 25 million. They are concerned particularly over "environmental discontinuities," events that occur when resources stocks or ecosystems absorb stresses over long periods of time without much outward sign of damage, until they suddenly reach a disruption level. They see the clear prospect that countries such as the Philippines, Mexico, and the Ivory Coast will have lost most of their forests within the next few decades, while Ethiopia, Nepal, and El Salvador will have little of their topsoil remaining. Unless immediate action is taken, they warn, the flow of environmental refugees is likely to become unprecedented in scale. Indeed, their analysis of climate change concludes that 200 million people globally are at risk from global warming and that this is a "conservative minimal figure" (Myers and Kent 1995, 149). Earlier Homer-Dixon (1991) had warned that environmental degradation would produce "waves of environmental refugees that spill across borders with destabilizing effects on domestic political stability and international relations."

Such arguments remain quite speculative, given the difficulties in defining and identifying "refugees" and in establishing clear linkages between environmental change and population displacement. Homer-Dixon (1991, 97; 1999, 93-96) himself notes that environmental disruption will be only one of many interacting physical and social variables that ultimately force people from their homelands. On the other hand, the IPCC in its 1990 assessment noted that the greatest effect of climate change could be human migration-millions of people displaced due to coastal inundation, shoreline erosion, and agricultural disruption. There is, in short, enough indicated of potential effects to suggest that linkages among climate change, environmental modification, and security and refugee risks need to be much better established so that vulnerabilities and risks can be better specified (Lonergan and Swain 1999).

Considerations of social justice

It is widely appreciated that in fashioning a socially acceptable and viable international regime for climate change, equity issues must play a prominent role. And vulnerability considerations underlie global equity issues in a fundamental way. The authors find that most deliberations about global equity are incomplete and propose the following as key elements of climate-change problems that need to be addressed in developing equity or social justice principles upon which global policy may be proceed:

- taking into account past and current emissions, the industrialized countries are overwhelmingly responsible for the current legacy of greenhouse gas emissions;
- annual greenhouse gas emissions of developing countries are growing rapidly and will equal those of developing countries around 2037;
- per capita emissions of greenhouse gases are higher in industrialized countries than in developing countries and are likely to remain so for the foreseeable future;
- because of their greater vulnerability, the negative impacts of climate change will be disproportionately concentrated in developing countries and particularly in the poorer regions of such countries;

- similarly, because of their sparser social and economic endowments and their pressing development needs, developing countries are far less able to reduce emissions or mitigate potential impacts without interfering with other development priorities;

- developing countries are at a disadvantage in the processes to develop an international climate regime because of their more limited expertise and access to knowledge bases.

The Kyoto Protocol recognizes the general need for equity, and thus calls upon the industrialized nations to take the lead in reducing their own greenhouse gas emissions and to assist developing countries to fulfill their obligations. But equity is one element of a broader approach in which greenhouse gas emissions reduction is the overriding goal and economic efficiency the primary means of getting there. Various other objectives were involved, including other environmental goals, technology transfer, and trade liberalization. And within the Kyoto approach, tradeoffs are always a possibility (Jackson, Begg, and Parkinson 2001, 4). The emphasis upon flexibility mechanisms, joint implementation, and the introduction of carbon sinks has enlarged significantly the potential for the rich countries to avoid the basic Protocol objective-reducing greenhouse gas emissions.

This is a situation in which vulnerability-driven considerations have occupied a secondary place as efforts to implement the Protocol have proceeded. Thus it is not surprising that some analysts in developing countries see the Protocol's Clean Development Mechanism as designed "to get the cheapest and most efficient deal to 'assist the industrialized countries avoid their commitments'" in a "creative carbon accounting game" (Agarwal and Narain 1999, 18). And so, Agarwal and Narain have called for the adoption of two social justice principles -- *the principle of convergence* and the *principle of equitable entitlements.* The principle of entitlement would set emission levels for all nations, either by establishing an overall CO_2 atmospheric-concentration target and sharing the resulting CO_2 budget equitably or by accepting a per capita carbon entitlement for all people. The principle of convergence would hold every nation responsible to make efforts to live within its entitlements. Put simply, this approach would require the world's largest emitters (the industrialized countries) to make urgent efforts to reduce their emissions to entitled amounts and the world's growing emitters (the developing countries) to take steps not to exceed their amounts (Agarwal and Narain 1999, 19).

Whether one accepts the Kyoto approach, that suggested by Agarwal and Narain, or some other view, an effective climate regime over the longer term needs to be rooted in social justice principles that command support from developed and developing countries alike. Principles that would appear to be useful in fashioning such an ethical base are:

- those who have created the existing environmental problem have the *early* and *primary* responsibility to reduce further emissions and to ameliorate harm that past emissions may cause for current and future generations, wherever they may live;

- those with the greatest capability to reduce future emissions and to avert potential climate-related harm have the primary responsibility to undertake mitigative action and to assist those with fewer capabilities; and

- those who are most vulnerable to climate change and who will bear the greatest harm deserve special consideration and protective assistance by those who will be less affected.

Such principles, however, which may be articulated in future climate regimes, point to the responsibility of the industrialized countries to undertake early action and assume burdens in behalf of the greater global community. At the same time, they underscore the need for those who will almost certainly bear the greatest harm-the developing countries-to be among the principal architects of global solutions.

Forging constructive responses

Under the Kyoto Protocol, despite some significant inroads, progress is well short of the scale and effectiveness of what is needed. Most emphasis has been on emissions reductions and economically efficient ways of securing them. Thus primary attention has been given to no-regrets interventions, co-benefit policies, and flexibility mechanisms. *No-regrets strategies* involve actions with such secure benefits that they involve no regret in the future. Emission-reduction opportunities exist that arise from market failures and other barriers that impede economically efficient solutions. No-regret strategies here will permit emission reductions at negative costs. *Co-benefit approaches* seek to secure emission reductions while achieving other desired benefits. These involve curbing air pollution, promoting energy efficiency, improving land-use practices, and designing better transportation systems. In some cases, the co-benefits of reducing greenhouse gas emissions may be comparable to costs, and thus become part of no-regret measures (IPCC 2001). Finally, *flexibility mechanisms,* such as the Clean Development Mechanism and Joint Implementation, are designed to create a broad panoply of emission-reduction options so that interventions can proceed flexibly with many options and choice, high efficiency, and low social disruption. Taken together, these efforts aimed at emissions reductions are essential for global efforts for climate stabilization and must be expanded as a matter of urgency.

But as a risk-management strategy for combating global warming, emissions reductions are insufficient in themselves. The stressors and environmental perturbations are only one part of the risk problem. Differential vulnerability and strategies aimed at creating greater resilience are the other part. Such efforts at increased adaptation and resilience have received much less attention and shown fewer signs of progress. To achieve a comprehensive and equitable risk-management approach, one that works on all major components of the climate-change problem, major new efforts are in order.

What is the "stuff" of such a resilience strategy to complement current efforts at emissions reductions? A full treatment is beyond the scope of this paper but some primary elements include:

- *broad transition strategies.* The essential task of ameliorating vulnerabilities to climate change is part of a broader global transition needed to a more sustainable world. Increasing coping resources and adaptive capacity for more vulnerable societies is an essential part of the needed transitions from ever greater vulnerability to increased sustainability. Thus, climate-change mitigation and impact reduction need to be integrated into broader socioeconomic developmental programs aimed at sustainable futures.

- *attacking poverty and inequalities.* Efforts aimed at poverty reduction are now under way in a broad set of aid and financial institutions. These initiatives need to be expanded and accelerated, with greater funding commitments from the richer nations, which need to keep centre stage the insight of the Brundtland Commission (WCED 1987, 8) more than a decade ago, that "widespread poverty is not inevitable" (Box 3).

Box 3. On poverty

Poverty is not only an evil in itself, but sustainable development requires meeting the basic needs of all and extending to all the opportunity to fulfil their aspirations for a better life. A world in which poverty is endemic will always be prone to ecological and other catastrophes.

Source: WCED (1987, 8)

- *technology flow*. As emphasized in nearly all analyses of climate change and at the Earth Summit in 1992, the transfer of needed technologies to developing countries is an essential part of the transition referred to above. Such broadened technology choices will undoubtedly expand the portfolio of options for these countries but may, on the other hand, require substantial related institutional and social development.

- *institutions and governance*. The development of civil society and the strengthening of local institutions are an essential part of global transition strategies. Effective means for reducing vulnerability must be built bottom-up, from the places in which vulnerability resides. The articulation of the importance of vulnerability can occur only in governance systems in which such views can be articulated and heard.

- *knowledge gaps*. Most of the access to knowledge concerning climate change resides in the richer nations. Much can be done to improve the participation of developing countries in the climate-change regime. Unlike the science of climate change, vulnerability is a matter of what happens in particular places to particular people in particular local cultures. The building of the knowledge system needed to reduce vulnerability and to build resilience must proceed bottom-up. And the active participation of those whose well-beings and livelihoods are at stake is required. The generation of such vulnerability/resilience knowledge systems calls for new assessment procedures and techniques that in turn will be necessary ingredients for global strategies aimed at enhancing resilience and adaptive capacity.

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SEI is an independent, international research institute specializing in sustainable development and environment issues. It works at local, national, regional and global policy levels. The SEI research programmes aim to clarify the requirements, strategies and policies for a transition to sustainability. These goals are linked to the principles advocated in Agenda 21 and the Conventions such as Climate Change, Ozone Layer Protection and Biological Diversity. SEI along with its predecessor, the Beijer Institute, has been engaged in major environment and development issues for a quarter of a century.

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