SESSION I: WHAT'S IN STORE FOR THE WORLD'S POOR
FRIDAY, AUGUST 1, 9:00-10:00 A.M.

CLIMATE CHANGE IMPACTS IN THE DEVELOPING WORLD: IMPLICATIONS FOR SUSTAINABLE DEVELOPMENT

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EXECUTIVE SUMMARY:

Global warming is taking place at an unprecedented rate since instrumental records have been kept. This warming is largely caused by anthropogenic factors through the emission of greenhouse gases, with implications for precipitation and sea level rise. Although the developing countries have contributed a small part of the greenhouse gas, they bear the brunt of the adverse impacts of global warming. The heightened vulnerability of the developing countries to climate change is not only caused by climate elements but by complex combinations of social, economic, and environmental factors. Some of these factors discussed below, pose challenges to development and exacerbate vulnerability to climate change by reducing the adaptive capacity in these countries. Projected impacts of climate change cut through all the important sectors of the economies of the developing countries: agriculture and forestry, hydrology and water resources, natural ecosystems and biodiversity, coastal areas and settlements, and health. The economic costs of climate change in the developing countries are huge. While, there are several efforts to reduce the vulnerability of the developing countries to climate change, the magnitude of resources required for effective adaptation requires external assistance. If left unchecked, climate

change would hamper the achievement of the millennium development goals and even undo the modest achievements that these countries have made towards sustainable development.

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007) has noted that between 1906 and 2005, the global average surface temperature has increased by about 0.74°C. The IPCC climate models have conservatively estimated that global average surface temperature could increase by up to 5.8°C by 2100. Most of the warming observed over the last 50 years is attributable to anthropogenic activities, through the emission of greenhouse gases, mainly carbon dioxide (CO_2), methane (CH_4) and nitrous oxides (N_2O) with carbon dioxide being the most important contributor. While the industrialized countries are largely responsible for a greater proportion of the CO_2 emissions through fossil fuel burning, the largest share of the emission of methane and nitrous oxide are from the developing countries, generated through agriculture and forestry.

Observed and Projected Climate Changes

Warming of the climate system is unequivocal and has implications for precipitation and sea level rise. Observations show that the oceans have been warming considerably, causing seawater to expand and contributing to sea level rise. Global average sea level rose at an average rate of 1.8 mm per year between 1961 and 2003, but the rate was faster at about 3.1 mm per year over the period 1993 to 2003 (IPCC, 2007). Widespread changes in precipitation amounts and aspects of extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones have all been observed, with strong regional variations. Significantly increased precipitation has been observed in eastern parts of North and South America, northern Europe, and northern and central Asia. Drying has been observed in the Sahel, southern Africa, the Mediterranean, and parts of southern Asia. More intense and longer droughts have been observed over wider areas since the 1970s, particularly in the tropics and subtropics.

A warming of about 0.2° C per decade is projected by the 2020s and continued greenhouse gas emissions even at current rates would cause further warming and induce many changes in the global climate system. Increases in the amount of precipitation are very likely in high-latitudes, while decreases are expected in most subtropical regions. Throughout Africa, warming is expected to be larger than the global annual mean warming. Annual rainfall is likely to decrease in much of Mediterranean Africa, the northern Sahara, and southern Africa while an increase is expected in eastern Africa (Christensen et al., 2007). Central and northern Asia will likely experience a warming greater than the global mean. Winter precipitation is likely to increase in eastern Asia and the southern parts of Southeast Asia. Most parts of Southeast Asia will receive an increased summer precipitation, with a high probability of an increase in the frequency of intense precipitation events (Cruz et al., 2007). In Central & South America, the annual mean warming is likely to be above the global mean. Annual precipitation is likely to decrease in most of Central America (Magrin et al., 2007). In the small islands developing states (SIDS), the warming will likely be smaller than the global annual mean. Sea levels are likely to rise during the century around the small islands of the Caribbean Sea, Indian Ocean, and northern and southern Pacific Oceans, although the rise will not be geographically uniform. Annual rainfall is likely to increase in

the northern Indian Ocean with increases likely around Seychelles in December, January, and February, and around the Maldives in June, July, and August, while decreases are likely in the vicinity of Mauritius in June, July, and August (Mimura et al., 2007).

Current Developmental Challenges

Every published literature and assessment has concluded that the developing countries are more vulnerable to the adverse impacts of climate change. This vulnerability is not only determined by climate events but by complex combinations of social, economic, and environmental factors. Some of these factors discussed below, pose challenges to development and exacerbate vulnerability to climate change by reducing the adaptive capacity in these countries.

Social factors**:** Many of the factors that characterize the developing countries and contribute to their heightened vulnerability to climate change include rapid population growth, endemic poverty and hunger, poor health, low levels of education, gender inequality, fragile and hazardous location, and lack of access to resources and services, including knowledge and technological means. When people are socially disadvantaged or lack political voice, this vulnerability is exacerbated further. Assessments of health in Africa, for instance, show that many communities are already impacted by health stresses that are coupled to several causes, including poor nutrition. An estimated 700,000 to 2.7 million people die of malaria each year in the developing countries. The economic burden of malaria is estimated as an average annual reduction in economic growth of 1.3 percent for those African countries with the highest burden (Gallup and Sachs, 2001).

Economic vulnerability: There are important economic processes that serve to heighten vulnerability to climate variability in the developing countries. Issues of particular importance include globalization, trade, and equity. Structural adjustment accompanied by complex market reforms and market liberalisation has aggravated the vulnerability of many developing countries. Although globalization offers opportunities for growth and development in all parts of the world, structural challenges faced by many developing countries have dimmed the hopes and promises that should accompany the liberalisation of trade. The integration of markets has subjected the economies of many developing countries to a more fiercely competitive external trading environment; a competition they are neither prepared for nor equipped to deal with.

Environmental factors: Many developing countries are contending with adverse environmental factors such as erosion, land degradation, and deforestation, which have caused irreversible damage to terrestrial and marine ecosystems with consequent loss of production potential in several areas. About 40 percent of the world's arable land is degraded, and most of the degraded soils are found in the poorest countries, where deforestation, over-exploitation, and inappropriate land use practices compound the problem (UNEP, 2007).

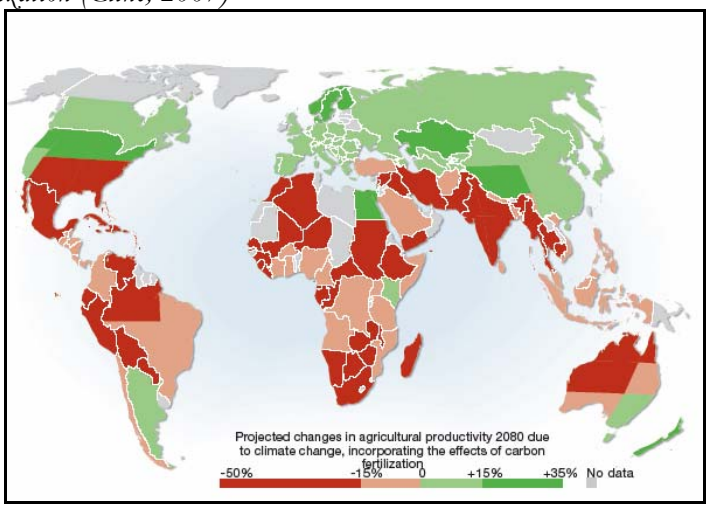
CLIMATE CHANGE IMPACTS IN THE DEVELOPING COUNTRIES

Agriculture and food security

Agriculture is unarguably the most vulnerable sector to climate change and a majority of the population in the developing countries derives their livelihoods from agriculture. Key impacts of climate change in the agriculture sector in the developing countries are outlined below.[1]

In mid- to high-latitude regions, temperature increases of between 1°C and 3°C will likely have small but beneficial impacts on the main cereal crops such as rice, wheat, and maize. Further warming beyond this range will likely have increasing negative impacts. In the low-latitude regions, where most developing countries are found, even moderate temperature increases are likely to result in declining yields for these cereals (figure 1). Countries such as Sudan, Nigeria, Somalia, Ethiopia, Zimbabwe, and Chad, could lose cereal-production potential by 2080 (Fischer at al., 2005). In Latin America, there are generalized reductions in rice yields by the 2020s, while cereal yields could decrease up to 30% by 2050 in South Asia. The net loss in yield will exceed the net gains and this is expected to cause a modest increase of between 2 and 20 percent in the price of agricultural products in the short to medium term at the global level. Climate change could lead to a reduction in GDP of about 1.5 percent in many developing countries, particularly around the tropics by 2080 (Fischer et al., 2005).

Figure 1. Projected Changes in Agricultural productivity by 2080 due to climate change, incorporating the effects of carbon fertilization (Cline, 2007)



More frequent extreme events like floods and droughts may lower long-term yields by directly damaging crops at specific developmental stages. Heavy rainfall could precipitate soil erosion resulting in substantial agricultural loss. Several studies in Africa have established a positive relationship between drought and animal death. In most regions of Asia pasture availability limits the expansion of livestock numbers. Higher temperatures and longer growing seasons could result in increased pest and insect populations in temperate regions of

[1] This section draws substantially from the conclusions of the Fourth Assessment Report of the IPCC (IPCC, 2007).

Asia. In Africa, rift valley fever epidemics, which always accompany El Niño events, could increase with a higher frequency of El Niño events. This has a strong negative impact on livestock health in the continent.

However, global warming will also present opportunities for some countries to expand their agricultural potentials. For instance, global warming will likely increase the area that is conducive to growth and production of agricultural crops, as well as extend the length of growing periods in some countries. For other countries, particularly those in Africa, Latin America, and Asia, a significant decrease in land that will be suitable for rainfed agriculture is projected by 2080. In Africa, it is projected that the area of arid and semi-arid land could increase by 5 to 8 percent (Boko et al., 2007). By the middle of this century in northern China, tri-planting boundary will likely shift by 500 km and double planting regions will move towards the existing single planting areas, while single planting areas will shrink by 23 percent (Wang, 2002). However, suitable land and production potentials for cereals could marginally increase in some parts of East Asia (Fischer et al., 2002).

Fisheries could be affected by different biophysical impacts of climate change. A 1.5°C to 2.0°C rise in temperature could result in the loss in productivity on the fisheries in northwest Africa and the East African lakes. In the small island states, the two main effects of climate change on tuna fishing are likely to be a decline in the total stock and a migration of the stock eastwards, both of which will lead to changes in the catch (McLean et al., 2001; Lehodey et al., 2003). The Asia-Pacific region, which is the world's largest producer of fish, will likely see a reduction of primary production in the tropical oceans because of changes in oceanic circulation in a warmer atmosphere (IPCC, 2001). Global warming will also bring some opportunities to this region. Moderate warming in some parts of Asia is likely to improve the conditions for some economically gainful fisheries, such as cod and herring.

Food security is a function of food availability, food access, and food utilization. Climate change could directly or indirectly impact on these three pillars of food security. It is estimated that in 2080 about 768 million people will be undernourished (Fischer et al., 2005). Most of the undernourished will be in the developing countries, particularly in Sub-Saharan Africa and South Asia, where crop production is projected to decline considerably. A projected 2 to 3 percent reduction in African cereal production by 2030 is enough to put 10 million people at risk of hunger. By 2080, the total population of the currently over 80 food-insecure countries is projected to increase from about 4.2 billion to about 6.8 billion.

Hydrology and Water Resources

Climate change will have implications for water availability and demand in the developing countries. A rising population and a weak infrastructure will exacerbate this situation. Under a changing climate, some areas will experience an increased precipitation and consequent flooding, while others will experience a reduction leading to droughts. Many developing countries would be exposed to severe water stress. In the small island states, the wet and dry cycles associated with ENSO episodes will have serious impacts on water supply. For instance the la Niña of 1998 to 2000 was responsible for acute water shortages in many islands in the Indian and Pacific Oceans, which resulted in partial shutdowns in the tourism and industrial sectors (Shea et al., 2001; Hay et al., 2003). In Fiji and Mauritius, borehole yields decreased by 40 percent during the dry periods (World Bank, 2000). In Asia

ENSO events have also contributed to increase water shortage and a 6 to 10 percent increase in water demand for agricultural irrigation is expected for a 1°C rise in surface air temperature by the 2020s (Cruz et al., 2007). Expansion of areas under severe water stress will be one of the most pressing environmental problems in South and South-East Asia in the foreseeable future as the number of people living under severe water stress is likely to increase substantially in absolute terms. It is estimated that 120 million to 1.2 billion, and 185 to 981 million people will experience increased water stress by the 2020s, and the 2050s, respectively (Arnell, 2004). The decline in annual flow of the Red River by 13 to 19 percent and that of Mekong River by 16 to 24 percent by the end of 21st century will contribute in increasing water stress (ADB, 1994).

In Africa, an already bad situation of water resources will be exacerbated by climate change and variability, which will likely impose additional pressures on water availability, water accessibility, and water demand. The population at risk of increased water stress in Africa is projected to be between 75 and 250 million people by 2020 and 350 and 600 million people by 2050. Northern Africa and southern Africa will likely see an increase in the number of people that could experience water stress by 2055 (Arnell, 2004). A 3°C temperature increase could lead to 0.4 to 1.8 billion more people at risk of water stress in the continent, while many African countries will exceed the limits of their economically usable, land-based water resources before 2025 (Ashton, 2002). About 14% of the Latin American population has no access to a safe water supply—63 percent of these live in rural areas (Magrin et al., 2007). More than 22 million people are estimated to be living in water-stressed watersheds (less than 1,000 m^3/capita per year) in the absence of climate change in 1995 (Arnell, 2004). The net increases in the number of people living in water-stressed watersheds by 2025 ranges between 7 and 77 million. While, for the second half of the century, the potential water availability reduction and the increasing demand from an increasing regional population would increase these figures to between 60 and 150 million (Arnell, 2004).

In addition to its effect on water availability and demand, climate change will also affect water quality. Over-exploitation of groundwater in many coastal countries has resulted in a drop in its level, leading to saltwater intrusion in coastal areas making the sub-surface water saline. Coastal regions of Africa, India, China, Bangladesh, and the small island states are especially susceptible to increasing salinity of their groundwater as well as surface water resources due to increases in sea level as a direct impact of global warming. In Latin America, climate change induced drying, coupled with inappropriate agricultural practices (deforestation, soil erosion and the excessive use of agrochemicals) will deteriorate surface and groundwater quantity and quality, particularly in already degraded areas (UNEP, 2007).

Natural Ecosystem and Biodiversity

The ecosystem is very important to the economy of many developing countries, as a significant proportion of its population derives their livelihoods from there. However, recent assessments have identified significant impacts that climate change will have on both the terrestrial and aquatic ecosystem. In the small island states, the middle and high-latitude islands will be threatened by non-indigenous invasive species, previously limited by unfavorable temperature conditions. Under future climate change, there is a risk of significant species extinctions in many areas of tropical South and Central America. Seven

out of the 25 most critical places with high endemic species concentrations are in Latin America and these areas are undergoing habitat loss. By 2050, Mexico will likely experience significant increases in losses in species: mammals up to 26 percent, birds up to 8 percent, and butterflies up to 19 percent (Thomas et al. 2004). Replacement of tropical forest by savannas is expected in Eastern Amazonia and the tropical forests of central and southern Mexico, along with replacement of semi-arid vegetation by arid vegetation in parts of north-east Brazil and most of central and northern Mexico due to the synergistic effects of both land-use and climate changes (Magrin, 2007). Other key ecosystem impacts in south and Central America include significant loss of tree species (Thomas et al., 2004), more frequent wildfire in Amazonia (the risks of forest losses through fires in some parts of Amazonia exceed 40 percent for temperature increases of more than 3°C), more runoff in northwestern South America, and less runoff in Central America.

In Asia, up to 50 percent of the region's total biodiversity is at risk due to climate change. Boreal forests in North Asia would move further north. Projections show that 105 to 1,522 plant species and 5 to 77 vertebrates in China and 133 to 2,835 plants and 10 to 213 vertebrates in Indo-Burma could become extinct by the end of the of the century. Projections have shown that an average temperature increase of 1°C could increase the duration of the wild fire season in North Asia by 30 percent (Cruz et a., 2007), which could have varying adverse impacts on biodiversity, forest structure and composition, outbreaks of pest and diseases, wildlife habitat quality, and other key forest ecosystem functions. The natural grassland coverage and the grass yield in Asia, in general, are projected to decline by about 10 to 30 percent as a consequence of climate change by the end of this century. This will have negative consequences on livestock production in the region. More frequent and prolonged droughts as a consequence of climate change and other anthropogenic factors together will result in the increasing trends of desertification in Asia.

In Africa, climatic threats to ecosystems are very severe with strong consequences on the sustainability of livelihoods. It is estimated that the ice caps on Mount Kilimanjaro could disappear by 2020 (Thompson et al., 2002). Changes induced by climate change are also likely to result in shifts in species range, as well as in changes in tree productivity, adding further stress to forest ecosystems (UNEP, 2007). There are also possible changes in other ecosystems, such as grasslands, with implications for park animals. A study of the sensitivity of African mammals in 141 national parks in Sub-Saharan Africa showed that, assuming no migration of species, 10 to 15 percent of the species were projected to fall within the IUCN Critically Endangered or Extinct categories by 2050, increasing to 25 to 40 percent of species by 2080 (Thuiller et al., 2006). Major impacts on Africa's coastal ecosystem include the possible extinction of endangered species associated with these ecosystems, such as manatees and marine turtles, along with migratory birds, coral bleaching, disappearance of low-lying corals, and losses of biodiversity. All these impacts will have negative effects on fisheries and tourism.

Coastal Areas and Settlements

Most of the physical development and infrastructure in the developing countries are concentrated close to the coasts. The expected increases in sea-level rise, weather, and climatic variability and extremes are very likely to affect coastal areas, resulting in heavy economic losses. Significant impacts of projected climate change and sea level rise are

expected between 2050 and 2080 on the Latin American coastal areas. With most of their population, economic activities and infrastructure located at or near sea-level, coastal areas will very likely suffer from floods and erosion, with high impacts on people, resources, and economic activities Some of these impacts include population displacement; increased erosion and altered coastal morphology; disruption of access to fishing grounds; negative impacts on biodiversity, including mangroves; salinization and over-exploitation of water resources, including groundwater; and pollution and sea-water acidification in marine and coastal environments (Conde, 2001; Magrin, 2007).

As noted by Cruz et al (2007), all coastal areas in Asia are facing an increasing range of stresses and shocks—the scale of which now poses a threat to the resilience of both human and environmental coastal systems, and are likely to be exacerbated by climate change. A 40 cm increase in sea level by the end of the century is projected to increase the annual number of people flooded in coastal populations from 13 million to 94 million. A significant proportion of this will occur in South Asia. The projected sea-level rise could inundate low lying areas, drown coastal marshes and wetlands, erode beaches, exacerbate flooding, and increase the salinity of rivers, bays, and aquifers.

In Africa, highly productive ecosystems, which form the basis for important economic activities such as tourism and fisheries, are located in the coastal zone. Forty percent of the population of West Africa live in coastal cities, and it is expected that the 500 km of coastline between Accra and the Niger delta will become a continuous urban megalopolis of more than 50 million inhabitants by 2020 (Hewawasam, 2002). By 2015, 3 coastal megacities of at least 8 million inhabitants will be located in Africa, which like most cities in the continent will consist of a sizeable proportion of slum dwellers (Klein et al., 2002). Sea level rise will lead to floods in these coastal megacities, particularly affecting the poor who are prone to live in potentially vulnerable hazardous areas. The flooding will ultimately displace a significant number of people and create environmental refugees.

The coastlines of small islands are often diverse and resource-rich, providing a range of goods and services, and population concentrations, many of which are threatened by a combination of human pressures and climate change and variability arising especially from sea-level rise, increases in sea surface temperature, and possible increases in extreme weather events (Mimura, 2007). In many of the Caribbean islands, more than half of the population live within 1.5 km of the shoreline. Fishing villages, government buildings, and important facilities such as hospitals are frequently located close to the shore. Moreover, population growth and internal migration of people are putting additional pressure on coastal settlements. Like settlements and industry, the infrastructural base that supports the vital socio-economic sectors of island economies tends to occupy coastal locations.

Key climate change impacts in the islands will include accelerated coastal erosion, saline intrusion, and increased flooding from the sea. The impacts on transportation infrastructure will include closure of roads, airports, and bridges due to flooding and landslides, and damage to port facilities. The resulting disruption would not be confined to the transportation sector alone, but would impact other key dependent sectors and services including tourism, agriculture, the delivery of health care, clean water, food security, and market supplies. In the Caribbean, the damage to coastal infrastructure from storm surge alone has been severe. In November 1999, surge damage in St. Lucia associated with

Hurricane Lenny was in excess of US$6 million, even though the storm was centred many kilometers offshore (Mimura et al., 2007). In extreme cases, climate change could induce island abandonment in the region, where entire populations are forced to vacate the island.

Health

Climate change will pose a series of threats to health in the developing countries. The main health impacts due to climate change in Latin America are heat stress, malaria, Chaga's disease, dengue, cholera, and other water-borne diseases. Malaria continues to pose a serious health risk in Latin America, where the potential risk of transmission ranges from 9 percent in Argentina to 100 percent in El Salvador (PAHO, 2003). Climate change is likely to increase the risk of forest fires in some countries in the region. Forest fires have been associated with an increased risk of respiratory diseases and breathing problems (WHO, 2000). Migration, resulting from climatic threats provides a good avenue for the spread of diseases.

Many small island states lie in tropical or sub-tropical zones with weather conducive to the transmission of diseases such as malaria, dengue, filariasis, schistosomiasis, and food- and waterborne diseases (Ebi et al., 2006). The rates of many of these diseases are increasing in small island states for a number of reasons, including poor public health practices, inadequate infrastructure, poor waste management practices, increasing global travel, and changing climatic conditions (WHO, 2003). In the Caribbean, the incidence of dengue fever increases during the warm years of ENSO cycles (Rawlins et al., 2005). The incidence of diarrheal diseases is associated with annual average temperature and negatively associated with water availability in the Pacific (Singh et al., 2001). Therefore, increasing temperatures and decreasing water availability due to climate change may increase burdens of diarrheal and other infectious diseases in some small island states. Tropical cyclones, storm surges, flooding, and drought have both short- and long-term effects on human health, including drowning, injuries, increased disease transmission, decreases in agricultural productivity, and an increased incidence of common mental disorders (Hajat et al., 2003).

Climate change poses substantial risks to human health in Asia. The global burden of climate-change attributable to diarrhea and malnutrition are very high in Southeast Asian countries and the relative risks for these conditions for 2030 is expected to be also the largest (McMichael et al., 2004). The population at risk of dengue fever will be larger in India and China (Hales et al., 2002). Also in India and China, the excess mortality due to heat stress is projected to be very high (Takahashi et al., 2007). There is already evidence of widespread damage to human health by urban air quality and enhanced climate variability in Asia. Warmer sea-surface temperatures along coastlines of South and South-East Asia would support higher phytoplankton blooms. These phytoplankton blooms are excellent habitats for the survival and spread of infectious bacterial diseases such as cholera (Pascual et al., 2002).

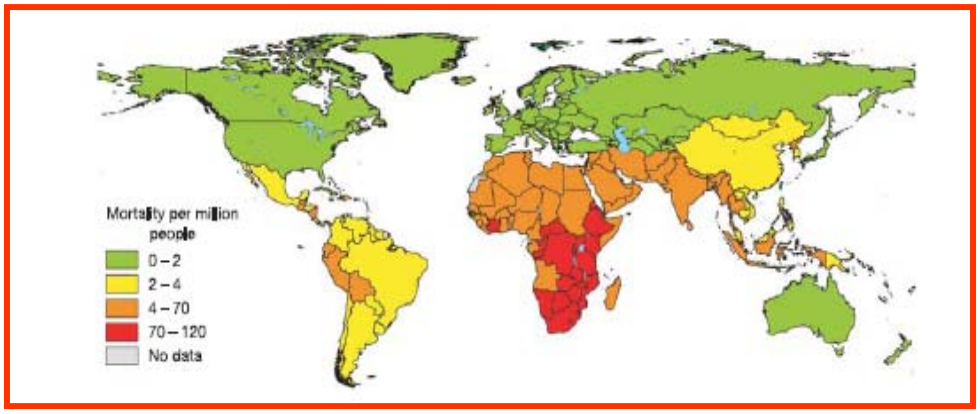
Africa is already prone to serious health hazards and climate change will exacerbate these. These health hazards range from health-related risks arising from climate change, including direct risks (e.g. physical hazards from floods, storms, fires, and heat stress) and

less direct risks (e.g. climate change negatively affecting livelihoods, food supplies or access to water, or exacerbating air-pollution problems). Research has highlighted some of the health hazards that will likely be experienced in Africa as a result of climate change (See McMichael et al.2008; Nyong, 2008; Confalonieri et al, 2007; and Few et al., 2004). These include:

- an increased burden of diarrheal disease and cholera;
- increased frequency of cardio-respiratory diseases due to higher concentrations of ground-level ozone related to climate change;
- altered spatial distribution of some infectious disease vectors such as malaria, and other arboviruses like dengue fever, Rift valley fever, West Nile virus, for instance as warmer average temperatures permit an expansion of the area in which many "tropical" diseases can occur. Expansion is likely in the area in which the mosquitoes that spread malaria and dengue fever can survive and breed. In Africa, malaria is expected to expand its range horizontally and vertically, from its currently endemic range to southern Africa and the east African highlands;
- and mental illness as natural disasters such as floods and hurricanes take a heavy toll on the mental health of the people involved.

Other health threats that will be exacerbated by climate change include malnutrition and displacement of population, injuries, and mortalities. For instance, a global assessment of mortalities arising from climate change shows that Africa has a disproportionately higher share (figure 2). Climate variability and change will interact with other background stresses and additional vulnerabilities such as HIV/AIDS and conflict and war in the future, resulting in increased susceptibility and risk of other infectious diseases (e.g., cholera) and malnutrition.

Figure 2. Climate related mortality, 2000 (Source: Patz et al., 2005)



ADDRESSING CLIMATE CHANGE

The United Nations Framework Convention on Climate Change (UNFCCC) identifies two responses to climate change: mitigation of climate change by reducing greenhouse gas emissions and enhancing sinks, and adaptation to the impacts of climate change. Considering that the total greenhouse gas emissions from the developing countries

is small, the usual expectation of the developing countries is to adapt, while the industrialized countries are mandated under the Kyoto protocol to mitigate. However, current practice has tended to treat these two measures as mutually exclusive, with different spheres of responsibilities, where the responsibility for mitigation rests in the more industrialized countries and that of adaptation in the poor developing countries. This section will however focus on actions that developing countries have taken to reduce their vulnerabilities to climate change through adaptation.

Given the urgency for adaptation in many developing countries, particularly in Africa, there has been an increase in *ad hoc* stand-alone sectoral projects to address adaptation in specific sectors. Some of these include:

- ***Agriculture and forestry***: Several strategies are being implemented. The first strategy involves management practices at the farm level that address crop and livestock vulnerability. A second strategy involves the reliance on insurance and other financial mechanisms. A third short-term adaptation strategy is temporary migration where migrant farmers relocate from drought-affected areas to more favorable regions to farm, and subsequently return to their villages when conditions improve.
- ***Water resources***: Sample adaptation actions include reevaluating the design and safety criteria of structural measures for water management; developing groundwater protection and restoration plans to maintain water storage for dry seasons; developing public awareness campaigns to highlight the value of rivers and wetlands as buffers against increased climate variability and to improve participation of vulnerable groups in flood adaptation and mitigation programmes.
- ***Coasts and settlements***: Some responses to sea-level rise have entailed the development of coastal zone management, monitoring, and protection plans, improvement and further development of legislation related to land use on floodplains, ensuring compliance with existing regulations of risk zones, floodplain use, and building codes, and construction of coastal defense systems.
- ***Human health***: There are many initiatives that are being proposed or implemented to address health impacts due to climate change in the developing world. These include raising awareness regarding climate change impacts on health, development of surveillance systems for potential disease outbreaks, and strengthening of national health infrastructures.

Adaptive capacity and constraints to adaptation

The main determinants of a country's adaptive capacity to climate change are: economic wealth, technology, information and skills, infrastructure, institutions, and equity. Poverty is identified as the largest barrier to developing the capacity to cope and adapt (Adger et al., 2001). The poor usually have a very low adaptive capacity due to their limited access to information, technology, and other capital assets, which make them highly vulnerable to climate change. Poverty also constrains adaptation in other sectors. Poverty, along with infrastructural limitations and other socioeconomic factors, will continue to limit efforts to successfully implement adaptation in many developing countries. Adaptive capacity in countries where there is a high incidence of poverty will likely remain limited.

A common constraint confronting most developing countries is the lack of in-country adaptive capacity, to design and implement appropriate adaptation strategies. In many of these countries, the cost of adopting and implementing adaptation options are often very prohibitive and would constitute a significant proportion of a country's economic wealth. Financial resources that are generally not available to these poor developing countries would need to come from outside. This need for international support to assist with the adaptation process in vulnerable, developing countries is also strongly emphasized by Stern (2007). Similarly, there are often inadequate human resources available to accommodate, cope with, or benefit from the effects of climate change; a situation that may be compounded by the brain drain that characterizes many developing countries. To overcome this deficiency, the adaptive capacity of many developing countries will need to be built up in several important areas, including:

- improving access to high quality information about the impacts of climate change;
- improving the ability to carry out scientific adaptation and vulnerability assessment;
- putting in place early warning systems and information distribution systems to enhance disaster preparedness;
- reducing the vulnerability of livelihoods and infrastructure to climate change;
- promoting good governance including responsible policy and decision making;
- empowering communities and other local stakeholders so that they participate actively in vulnerability assessment and implementation of adaptation;
- and mainstreaming climate change into development planning at all scales, levels and sectors.

Adaptation costs

Many of the options outlined above come with a range of costs and constraints, including large transaction costs. However, assessments of the impacts of sea-level rise in coastal countries show that costs of adaptation could amount to at least 5 to 10 percent of GDP (Niang-Diop, 2005). However, if no adaptation is undertaken, then the losses due to climate change could be up to 14 percent GDP (Van Drunen et al., 2005). However, there are very few studies that estimate the costs and the value of the climate change damages avoided (i.e. benefits) of projects and policies that directly or indirectly have the potential to adapt to climate change in Africa or for that matter any place else in the world. Estimating the costs and benefits of projects and policies to adapt to climate change is important because it will allow multi- and bi-lateral donors and national governments to compare projects and policies for adapting to climate change on their economic grounds. The UNFCCC estimates that the additional global investment and financial flows needed for adaptation in 2030 are:

- US$14 billion for forestry, fisheries, and agriculture
- $11 billion for water supply infrastructure (85 percent in non-annex 1)
- $5 billion for treating diarrheal diseases, malnutrition, and malaria
- $11 billion for beach nourishment and dykes (c. 50 percent in non-annex 1)
- $8 to 130 billion to adapt new infrastructure vulnerable to climate change

This brings the total to between US$ 48-175 billion.

A more detailed study found coastal protection to be the least-cost strategy to combat sea-level rise in Singapore, under three scenarios. They noted that the annual cost of shoreline protection would increase as sea-level rises, and would range from $0.3 to 5.7 million by 2050 to $0.9 to 16.8 million by 2100 (Ng and Mendolsohn, 2005). It was concluded that it would be more costly to the country to allow the coast to become inundated than to defend it. Studies of this type could provide useful guidance to developing country governments in the future, as they are confronted with the difficult task of making adaptation choices.

Adaptation is no substitute to mitigation. Efforts should be made at all stages to create synergies between mitigation and adaptation. Creating synergies between adaptation and mitigation can increase the cost-effectiveness of actions and make them more attractive to stakeholders, including potential funding agencies.

IMPLICATIONS FOR SUSTAINABLE DEVELOPMENT

The economic, social, and environmental linkages between climate change and sustainable development, and their implications for poverty alleviation, have been highlighted in various studies (Hay et al., 2003; Huq and Reid, 2004) and these are very relevant to all the developing countries. While climate change may not have featured directly in the setting of the MDGs, it is clear from the evidence presented in the earlier sections that climate change and variability may be an additional impediment to achieving them. The link between climate change and the MDGs is presented in table 1 (see the following page). Although future climate change seems to be marginally important when compared to other development issues in many developing countries, it is clear that climate change and variability, and associated increased disaster risks, will seriously hamper future development (Davidson et al., 2003).

The economic costs of climate change in the developing countries are huge. In the small island states, studies have shown that sea-level rise would so seriously damage the fishing and tourism industries that GDP would be reduced by more than 40 percent in the Maldives (Majeed and Abdulla, 2004). In Latin America, it is noted that if no action is taken to slow down climate change, in the next decades, climate-related disasters could cost $300 billion per year. On an annual basis, for example, developing countries have already absorbed $35 billion in direct losses from natural disasters (Mirza, 2003). However, these figures do not include livelihood assets and losses and overall emotional and other stresses that are often more difficult to assess. A challenge, therefore, is to shape and manage development that also builds resilience to shocks, including those related to climate change and variability (Davidson et al., 2003; Adger et al., 2004).

In summary, climate change can and will severely constrain development in the developing countries if left unchecked; it will become a major obstacle to continued poverty reduction.

- Falling agricultural output and deteriorating conditions in rural areas caused by climate change will directly increase poverty of households in many countries.
- Climate change and variability cuts the revenues and increases the spending of nations, worsening their budget situation.
- Strategies to manage the risks and impacts of an adverse climate can lock people into long-term poverty traps. Extreme weather events can—and do—affect growth rates in developing countries. Climate change presents a greater threat still.
- Slower growth could cause an increase in poverty and child mortality relative to a world without climate change.
- Under a high-climate-change scenario, the mean cost of climate change is predicted to be 2.7 percent of GDP in Africa by 2100. Climate-driven reduction in GDP would increase the number of people below the $2 a day poverty line by 2100 (100 million in Africa), and raise the child mortality rate.
- Greater resource scarcity, desertification, risks of droughts and floods, and rising sea levels could drive many millions of people to migrate—a last-resort adaptation for individuals, but one that could be very costly to them and the world.
- Drought and other climate-related shocks may spark conflict and violence, as they have done already in many parts of Africa.

Table 1.

Millennium Development Goals: climate change as a cross-cutting issue	
Potential impacts	***Millennium Development Goal****
Climate Change (CC) may reduce poor people's livelihood assets, for example health, access to water, homes and infrastructure. It may also alter the path and rate of economic growth due to changes in natural systems and resources, infrastructure and labour productivity. A reduction in economic growth directly impacts poverty through reduced income opportunities. In addition to CC, expected impacts on regional food security are likely, particularly in Africa, where food security is expected to worsen (see Sections 9.4.1, 9.4.3, 9.4.4 and 9.4.8).	Eradicate extreme poverty and hunger (Goal 1)
Climate change is likely to directly impact children and pregnant women because they are particularly susceptible to vector- and water-borne diseases, e.g., malaria is currently responsible for a quarter of maternal mortality. Other expected impacts include: • increased heat-related mortality and illness associated with heatwaves (which may be balanced by less winter-cold-related deaths in some countries); • increased prevalence of some vector-borne diseases (e.g., malaria, dengue fever), and vulnerability to water, food or person-to-person diseases (e.g. cholera, dysentery) (see Section 9.4.3); • declining quantity and quality of drinking water, which worsens malnutrition, since it is a prerequisite for good health; • reduced natural resource productivity and threatened food security, particularly in sub-Saharan Africa (see Sections 9.4.3, 9.4.3, 9.4.4, 9.6.1).	Health-related goals: • reduce infant mortality (Goal 4); • improve maternal health (Goal 5); • combat major diseases (Goal 6).
Direct impacts: • Climate change may alter the quality and productivity of natural resources and ecosystems, some of which may be irreversibly damaged, and these changes may also decrease biological diversity and compound existing environmental degradation (see Section 9.4.4). • Climate change would alter the ecosystem-human interfaces and interactions that may lead to loss of biodiversity and hence erode the basic support systems for the livelihood of many people in Africa (see Section 9.4, Table 9.1 and Chapter 4).	Ensure environmental sustainability (Goal 7)
Indirect impacts: links to climate change include: • Loss of livelihood assets (natural, health, financial and physical capital) may reduce opportunities for full time education in numerous ways. • Natural disasters and drought reduce children's available time (which may be diverted to household tasks), while displacement and migration can reduce access to education opportunities (see Sections 9.2.1 and 9.2.2).	Achieve universal primary education (Goal 2)
One of the expected impacts of climate change is that it could exacerbate current gender inequalities, through impacting on the natural resource base, leading to decreasing agricultural productivity. This may place additional burdens on women's health, and reduce time available to participate in decision-making and for practicing income-generation activities. Climate-related disasters have been found to impact female-headed households, particularly where they have fewer assets (see Section 9.7.1, Table 9.2).	Promote gender equality and empower women (Goal 3)
Global climate change is a global issue, and responses require global co-operation, especially to help developing countries adapt to the adverse impacts of climate change.	Global partnerships (Goal 8)

* The order in which the Millennium Development Goals are listed here places the goals that could be directly impacted first, followed by those that are indirectly impacted.

REFERENCES

Asian Development Bank (1994): *Climate Change in Asia: Vietnam Country Report*. Asian Development Bank, Manila, 103 pp.

Adger, W.N., P.M. Kelly and N.H. Ninh, Eds., (2001): *Living with Environmental Change: Social Vulnerability, Adaptation and Resilience in Vietnam*. Routledge, London, 314 pp.

Adger, N., N. Brooks, M. Kelly, G. Bentham, M. Agnew and S. Eriksen (2004): New indicators of vulnerability and adaptive capacity. Technical Report 7, Tyndall Centre for Climate Change Research, University of East Anglia, Norwich, 128 pp.

Arnell, N.W. (2004): Climate change and global water resources: SRES emissions and socio-economic scenarios. *Global Environ.l Chang.*, **14**, 13-52.

Ashton, P.J. (2002): Avoiding conflicts over Africa's water resources. *Ambio*, **31**, 236-242.

Boko, M., I. Niang, A. Nyong, C. Vogel, A. Githeko, M. Medany, B. Osman, R. Tabo and P. Yanda (2007): Africa, Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge. Pp. 433-467.

Christensen, J.H., B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, R.K. Kolli, W.-T. Kwon, R. Laprise, V. Magaña Rueda, L. Mearns, C.G. Menéndez, J. Räisänen, A. Rinke, A. Sarr and P. Whetton (2007): Regional Climate Projections. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Cline, W.R. (2007): Global Warming and Agriculture: Impact Estimates by Country. Washington, D.C., Peterson Institute.

Conde, J.E. (2001): The Orinoco River Delta, Venezuela. *Coastal Marine Ecosystems of Latin America*, U. Seeliger and B. Kjerfve, Eds., Ecological Studies 144, Springer-Verlag, Berlin, 61-70.

Confalonieri, U., B. Menne, R. Akhtar, K.L. Ebi, M. Hauengue, R.S. Kovats, B. Revich and A. Woodward (2007): "Human Health." In M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, eds. *Climate Change 2007: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, UK: Cambridge University Press. Pp. 391-431.

Cruz, R.V., H. Harasawa, M. Lal, S. Wu, Y. Anokhin, B. Punsalmaa, Y. Honda, M. Jafari, C. Li and N. Huu Nin (2007): Asia. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 469-506.

Ebi, K.L., N.D. Lewis and C. Corvalan (2006): Climate variability and change and their potential health effects in small island states: information for adaptation planning in the health sector. *Environ. Health Persp.*, **114**, 1957-1963.

Davidson, O., K. Halsnaes, S. Huq,M. Kok, B.Metz,Y. Sokona and J. Verhagen (2003): The development and climate nexus: the case of sub-Saharan Africa. *Clim. Policy*, **3**, 97-113.

FAO (2000): Third Session of the Sub-Committee on Aquaculture: Committee on Fisheries (COFI). Food and Agriculture Organization of the United Nations (FAO), New Delhi, India, 4-8 September.

Few, R., M. Ahern, F. Matthies and S. Kovats (2004): Floods, health and climate change: a strategic review. Working Paper 63, Tyndall Centre for Climate Change Research, University of East Anglia, Norwich, 138 pp.

Fischer, G., M. Shah and H. van Velthuizen (2002): Climate change and agricultural vulnerability. Preprints, *World Summit on Sustainable Development*, Johannesburg, 160 pp.

Fischer, G., M. Shah, F.N. Tubiello, H. van Velhuizen (2005):'Socio-economic and climate change impacts on agriculture: an integrated assessment 1990 – 2080.' Philosophical Transactions of the Royal Society. 360 2067-2083.

Gallup, J.L. and J.D. Sachs (2001): The economic burden of malaria. *Am. J. Trop. Med. Hyg.*, **64**, 85-96.

Hajat, S., K.L. Ebi, S. Edwards,A. Haines, S. Kovats and B.Menne (2003): Review of the human health consequences of flooding in Europe and other industrialized civilizations. *Applied Environmental Science and Public Health*, **1**, 13-21.

Hewawasam, I. (2002): Managing the marine and coastal environment of sub-Saharan Africa: strategic directions for sustainable development. World Bank, Washington, District of Columbia, 57 pp.

Hales, S, N., de Wet, J. Maindonald and A. Woodward (2002): Potential effect of population and climate changes on global distribution of dengue fever: an empirical model. *Lancet*, **360**, 830-834.

Hay, J., N.Mimura, J. Cambell, S. Fifita, K. Koshy, R.F.McLean, T. Nakalevu, P. Nunn and N. deWet (2003): *Climate Variability and Change and Sea level Rise in the Pacific Islands Region: A Resource Book for Policy and Decision Makers*, *Educators and Other Stakeholders.* South Pacific Regional Environment Programme (SPREP), Apia, Samoa, 94 pp.

Huq, S. and H. Reid (2004): Mainstreaming adaptation in development. *IDS Bull.*, **35**, 15-21.

IPCC (2001): *Climate Change 2001: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*, J.J.McCarthy, O.F. Canziani, N.A. Leary, D.J. Dokken and K.S. White, Eds., Cambridge University Press, Cambridge, 1032 pp.

IPCC (2007): 'Summary for Policymakers. Working Group II Climate Change 2007: Climate Change Impacts, Adaptation and Vulnerability.' IPCC, Geneva.

Klein, R.J.T., R.J. Nicholls and F. Thomalla (2002): The resilience of coastal megacities to weather-related hazards. *Building Safer Cities: The Future of Disaster Risk*, A. Kreimer, M. Arnold and A. Carlin, Eds., The World Bank Disaster Management Facility, Washington, District of Columbia, 101-120.

Lehodey, P., F. Chai and J. Hampton (2003):Modelling the climate-related fluctuations of tuna populations from a coupled ocean-biogeochemical-populations dynamics model. *Fish. Oceanogr.*, **13**, 483-494

Magrin, G., C. Gay García, D. Cruz Choque, J.C. Giménez, A.R. Moreno, G.J. Nagy, C. Nobre and A. Villamizar (2007): Latin America. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 581-615.

Majeed,A. and A.Abdulla (2004): Economic and environmental vulnerabilities of the Maldives and graduation from LDC status. *Economic Vulnerability and Resilience of Small States*, L. Briguglio and E. Kisanga, Eds., Commonwealth Secretariat and the University ofMalta, 243-255.

McLean, R.F., A. Tsyban, V. Burkett, J.O. Codignotto, D.L. Forbes, N. Mimura, R.J. Beamish and V. Ittekkot (2001): Coastal zones and marine ecosystems. *Climate Change 2001: Impacts*, *Adaptation*, *and Vulnerability. Contribution of WorkingGroup II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*, J.J.McCarthy, O.F. Canziani, N.A. Leary, D.J. Dokken and K.S.White, Eds., Cambridge University Press, Cambridge, 343-379.

McMichael,A.J., D. Campbell-Lendrum, S. Kovats, S. Edwards, P.Wilkinson, T. Wilson, R. Nicholls and Co-authors (2004): Global climate change. *Comparative Quantification of Health Risks: Global and Regional Burden of Disease due to Selected Major Risk Factors*, M. Ezzati, A. Lopez, A. Rodgers and C. Murray, Eds.,World Health Organization, Geneva, 1543-1649.

McMichael, AJ., Friel, S., Nyong, A. and C. Corvalan (2008): "Global Environmental Change and Human Health: Implications for Health Inequalities, Social Policy and the Health Sector". *British Medical Journal*, 336:191-194.

Mimura, N., L. Nurse, R.F. McLean, J. Agard, L. Briguglio, P. Lefale, R. Payet and G. Sem (2007): Small islands. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 687-716.

Mirza, M.M.Q. (2003): Climate change and extreme weather events: can developing countries adapt? *Clim. Policy*, **3**, 233-248.

Ng, W.S. and R. Mendelsohn (2005): The impact of sea level rise on Singapore. *Environ. Dev. Econ.*, **10**, 201-215.

Niang-Diop, I. (2005): Impacts of climate change on the coastal zones of Africa. *Coastal Zones in Sub-Saharan Africa: A Scientific Review of the Priority Issues Influencing Sustainability and Vulnerability in Coastal Communities*, IOC, Ed., IOC Workshop Report No. 186. ICAM Dossier No. 4, 27-33.

Nyong, A. (2008): "Climate and Diseases in Africa." In *New Encyclopedia of Africa*, 2nd Edition. Charles Scribners and Sons, Mississippi, USA.

PAHO (2003): *Status Report on Malaria Programs in the Americas*. 44th Directing Council, 55th Session of the Regional Comité. Pan American Health Organization, Washington, District of Columbia.

Pascual,M., M.J. Bouma and A.P. Dobson (2002): Cholera and climate: revisiting the quantitative evidence. *Microbes Infect.*, **4**, 237-245.

Patz, J.A., D. Cambell-Lendrum, T. Holloway and J.A. Foley (2005): Impact of regional climate on human health. *Nature*, **438**, 310-317.

Rawlins, S.C.,A. Chen,M. Ivey, D.Amarakoon and K. Polson (2005): The impact of climate change/variability events on the occurrence of dengue fever in parts of the Caribbean: a retrospective study for the period 1980-2002.*W. Indian Med. J.*, **53**, 54.

Shea, E., G. Dolcemascolo, C.L Anderson, A. Banston, C.P.Guard, M.P. Hamnett, S.T. Kubota, N. Lewis, J. Loschinigg and G. Meehls (2001): *Preparing for a Changing Climate: The Potential Consequences of Climate Variability and Change, Pacific Islands*. Report of the Pacific Islands Regional Assessment Group for the US Global Change Research Program. East West Center, University of Hawaii, Honolulu, Hawaii, 102 pp.

Stern, N. (2007): *Stern Review on the Economics of Climate Change*. Cambridge University Press. Cambridge, 692 pp.

Takahashi, K., Y. Honda and S. Emori (2007): Estimation of changes in mortality due to heat stress under changed climate. *Risk. Res.*, **10**, 339-354.

Thomas, C.D., A. Cameron, R.E. Green, M. Bakkenes, L.J. Beaumont, Y.C. Collingham, B.F.N. Erasmus,M.F. de Siqueira and co-authors (2004): Extinction risk from climate change. *Nature*, **427**, 145-147.

Thompson, L.G., E. Mosley-Thompson, M.E. Davis, K.A. Henderson, H.H. Brecher, V.S. Zagorodnov, T.A. Mashiotta, P.N. Lin and Co-authors (2002): Kilimanjaro ice core records: evidence of Holocene change in tropical Africa. *Science*, **298**, 589-593.

Thuiller,W., O. Broennimann, G. Hughes, J.R.M. Alkemade, G.F.Midgley and F. Corsi (2006):Vulnerability of African mammals to anthropogenic climate change under conservative land transformation assumptions. *Glob. Change Biol.*, **12**, 424-440.

UNEP (2007): Global Environment Outlook – GEO4: Environment for Development. United Nations Environment Programme, 540 pp.

Van Drunen, M.A., R. Lasage and C. Dorland, Eds. (2005): *Climate Change in Developing Countries: An Overview of Study Results from the Netherlands Climate Change Studies Assistance Programme*. CABI Publishing, Amsterdam, 320 pp.

Wang, F.T. (2002): Advances in climate warming impacts research in China in recent ten years. *Journal of Applied Meteorological Science*, **13**, 766.

WHO, 2000: *Vegetation Fires*. World Health Organization, Fact Sheet No. 254. August 2000, 3 pp. http://www.who.int/mediacentre/factsheets/fs254/en/index.html.

WHO (World Health Organization), 2003: *Climate Change and Human Health-Risks and Responses*. Summary. World Health Organization, Geneva.

World Bank (2000): Cities, Seas and Storms: Managing Change in Pacific Island Economies. Vol. IV: Adapting to Climate Change. World Bank, Washington D.C., 135 pp.