THE IMPACT OF CLIMATE CHANGE ON THE DEVELOPMENT PROSPECTS OF THE LEAST DEVELOPED COUNTRIES AND SMALL ISLAND DEVELOPING STATES

2009

Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States (UN-OHRLLS)

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Acknowledgements

This study was commissioned by the United Nations Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States.

It was prepared by Dr. Graham Sem with the research assistance of Rawleston Moore

Note

The views expressed in this report do not necessarily reflect those of the United Nations

LIST OF ABBREVIATIONS

AOSIS	Alliance of Small Island States
EC$	East Caribbean Dollar
ENSO	El Niño-Southern Oscillation
GDP	Gross Domestic Product
GHG	Greenhouse Gasses
IPCC	Intergovernmental Panel on Climate Chance
LDCs	Least Developed Countries
NAPA	National Adaptation Programmes of Action
NWP	Nairobi Work Programme
SIDS	Small Island Developing States
UNFCCC	United Nations Framework Convention on Climate Change
US$	United States Dollar
WTO	World Trade Organization

PREFACE

Climate change affects all, but it does not affect us equally. Nor do we possess the same capacity to respond to its challenges.

As is often the case, the most vulnerable countries – particularly the Least Developed Countries and Small Island Developing States – find themselves in the worst situation once again.

In these countries, climate change is already affecting economic growth, health indicators, water availability, food production and the fragile ecosystems.

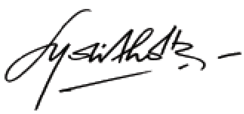
The Intergovernmental Panel on Climate Change (IPPC) concluded in 2007 that a sea-level rise resulting from a global temperature increase of 4 degrees Celsius would completely submerge low-lying island states like Tuvalu, Kiribati, and the Maldives.

For the LDCs in Africa and Asia, climate change will result in flooding of low-lying coastal areas, increased water scarcity, decline in agricultural yields and fisheries resources, and loss of biological resources. The IPPC has predicted that yields from rain-fed agriculture in Africa could be reduced by as much as 50 percent by 2020.

Water shortages and the shrinking of land suitable for agriculture would cause other social and political disruptions, including forced migration and conflict.

These are dire predictions which demand serious attention as we move closer to the historic Copenhagen summit on climate change in December 2009. It is an opportunity that should be seized to produce tangible commitments for the benefit the most vulnerable to climate change.

I hope that this study will contribute to that effort by highlighting the gravity of the situation for the Least Developed Countries and the Small Island Developing States, as well as highlighting some possible actions to meet the challenge.



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OVERVIEW

The Least Developed Countries (LDCs) and Small Island Developing States (SIDS) are the most vulnerable to the effects of climate change. Changing weather patterns, particularly severe floods and droughts, will increase the exposure of millions of people in LDCs to poverty, hunger and disease. The rising sea level, along with other climatic changes, threatens the very survival of many SIDS. Approximately 860 million people in LDCs and SIDS will be adversely affected by climate change, many of them becoming environmental refugees.

Compared to developed and other developing states, LDCs and SIDS use relatively small amounts of fossil fuels and thus contribute little to the problem of climate change. Yet, LDCs and SIDS will suffer the most. Adaptation to climate change is, therefore, of the essence for LDCs and SIDS.

Several adaptation initiatives are being undertaken by LDCs and SIDS, including the implementation of National Adaptation Programmes of Action. However, it is clear that considerably more adaptation actions are required, along with added capacity building and technology transfer in order to meet adaptation needs.

Greater emphasis ought to be placed on incorporating climate change into development priorities at the national and regional levels. Additional resources, earmarked to address climate change issues, are required from the international community. It is imperative to recognize that SIDS could physically disappear as a consequence of climate change.

Through international negotiations, LDCs and SIDS should lobby for more significant reductions in global greenhouse gas emissions. Adaptation, a process that is crucial to the survival of SIDS and necessary for sustaining stability in LDCs, will require significant funding. As such, negotiations on a post-Kyoto framework should urgently resolve the outstanding issues related to the Kyoto Protocol Adaptation Fund.

This report is divided into five sections. Section I places the problem of climate change in the context of LDCs and SIDS; Section II highlights the key vulnerabilities associated with climate change and their effects on LDCs and SIDS; Section III outlines the major issues related to adaptation and sustainable development; Section IV focuses on the level of international cooperation necessary to effectively address the adverse effects of climate change on the development of the vulnerable countries; and Section V outlines the key conclusions and recommendations for action.

CLIMATE CHANGE IN THE CONTEXT OF SIDS AND LDCs

National Circumstances, Sustainable Development and Equity

1.1 Least Developed Countries

Least Developed Countries (LDCs) are a group of 49 countries (see table 1) that are recognised as the world's poorest and weakest countries. LDCs have a per capita Gross Domestic Product (GDP) of less than $900 and very low levels of capital, human and technological development. These 49 countries have a combined population of about 785 million[1], which is equivalent to just over 10 percent of the world's population.

LDCs are defined by the following three criteria[2]:

a. A low-income criterion, based on a three-year average estimate of the gross national income (GNI) per capita (under $750 for inclusion, above $900 for graduation);

b. A human resource weakness criterion, involving a composite Human Assets Index (HAI) based on indicators of: (a) nutrition; (b) health; (c) education; and (d) adult literacy;

c. An economic vulnerability criterion, involving a composite Economic Vulnerability Index (EVI) based on indicators of: (a) the instability of agricultural production; (b) the instability of exports of goods and services; (c) the economic importance of non-traditional economic activities (d) merchandise export concentration; (e) remoteness from world markets; (f) population size; and (g) share of the population displaced by natural disasters.

LDCs have particular concerns in dealing with the effects of climate change, climate variability and extreme weather events. Along with Small Island Developing States (SIDS), they are recognised under Articles 4.8 and 4.9 of the United Nations Framework Convention on Climate Change (UNFCCC) as being the most vulnerable to the adverse effects of climate change. Article 4, paragraph 9 of the Convention particularly requires that "Parties shall take full account of the specific needs and special situations of the least developed countries in their actions with regard to funding and transfer of technology."[3]

[1] United Nations, 2008, Implementation of the Programme of Action for the Least Developed Countries for the Decade 2001-2010, Report of the Secretary-General, A/63/77

[2] See http://www.un.org/esa/policy/devplan/profile/criteria.html.

[3] United National Framework Convention on Climate Change

Table 1: List of 49 Least Developed Countries				
Afghanistan	Comoros	Kiribati	Myanmar	Sudan
Angola	Dem. Republic of Congo	Lao People's Democratic Republic	Nepal	Timor-Leste
Bangladesh	Djibouti	Lesotho	Niger	Togo
Benin	Equatorial Guinea	Liberia	Rwanda	Tuvalu
Bhutan	Eritrea	Madagascar	Samoa	Uganda
Burkina Faso	Ethiopia	Malawi	Sao Tome and Principe	United Republic of Tanzania
Burundi	Gambia	Maldives	Senegal	Vanuatu
Cambodia	Guinea	Mali	Sierra Leone	Yemen
Central African Republic	Guinea-Bissau	Mauritania	Solomon Islands	Zambia
Chad	Haiti	Mozambique	Somalia	

Compared to other developing countries, LDCs emit relatively small amounts of greenhouse gases, the main cause of global warming and climate change. However, LDCs are extremely vulnerable to the effects of climate change as they lack the resources necessary to adapt. The Intergovernmental Panel on Climate Change (IPCC) (2001)[4] describes the requirements for a high adaptive capacity as follows:

- A stable and prosperous economy;
- A high degree of access to technology at all levels;
- Well delineated roles and responsibilities for implementation of adaptation strategies;
- Systems for the national, regional and local dissemination of climate change and adaptation information; and
- An equitable distribution of access to resources.

Clearly, the LDCs do not meet these requirements, which speaks to their low adaptive capacity.

The international community has recognised the vulnerability of LDCs to climate change and their low adaptation capacity. This is evident in the Marrakech Accords[5] where a special LDC Fund has been established for the purpose of assisting LDCs to adapt to climate change.

[4] IPCC, 2001. Climate change 2001–Impacts, adaptation and vulnerability: Contribution of Working Group II to the Third Assessment Report, Cambridge University Press, 1032 pp.

[5] United Nations Framework Convention on Climate Change, Report of the Conference of Parties on its Seventh Session held at Marrakesh from 20 October to 10 November 2001, http://unfccc.int/resource/docs/cop7/13a02.pdf

According to the recently published Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR4), most of the anticipated climate change effects would be felt across the African continent, which contains 33 LDCs. The IPCC[6] concluded that:

a. Africa is one of the most vulnerable continents to climate change and climate variability – a situation aggravated by the interaction of multiple stresses occurring at various levels, and including low adaptive capacities;

b. Current adaptations to climate change and variability in farming may not necessarily be sufficient for future changes of climate;

c. Agricultural production and food security in many African countries and regions will most likely be severely compromised by climate change;

d. Climate change will aggravate the current state of water stress that is present in some African countries, and will place other African countries at a higher risk of the same, owing to alterations in water resources as a consequence of climate change and climate variability;

e. Changes in the structure and composition of the ecosystem are taking place at a rate that was not anticipated;

f. Climate change and sea-level rise could result in the inundation of low-lying coastal areas and settlements;

g. Human health could be further negatively impacted by climate change and climate variability – as evidenced by occurrence of malaria in Southern Africa and the East African highlands.

Over 70 percent of the population in the LDCs resides in rural areas and is dependent on income from agriculture. People in LDCs are therefore more exposed than those in other countries to the effects of land degradation, drought, desertification, deforestation, as well as water and air pollution, which are associated with climate change. The effect of climate change on agriculture is likely to deprive large sections of the population in the LDCs of their livelihoods, condemning them to perpetual poverty.

1.2 Small Island Developing States

Small Island Developing States (SIDS) comprise small islands and low-lying coastal countries that face the development constraints of a small population, limited resources, remoteness, vulnerability to natural disasters and susceptibility to external shocks.

[6] Boko, M., I. Niang, A. Nyong, C. Vogel, A. Githeko, M. Medany, B. Osman-Elasha, 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 UK, 433-467.

The growth and development of SIDS is often further stymied by high transportation and communication costs, disproportionately expensive public administration and infrastructural constraints due to their small size, and little to no opportunity to create economies of scale[7].

There are 51 Small Island Developing States; 14 of which are non-UN members or are associate members of UN regional commissions (See Table 2). Small Island Developing States are located across the Indian, Pacific and Atlantic Oceans. The Caribbean and the southwest Pacific have a high concentration of SIDS, while those SIDS located in the Atlantic and Indian Ocean are located mainly around the African continent. There are 11 countries which are both LDCs and SIDS (See Table 4).

Although Small Island Developing States vary in their geography, climate, culture and stage of economic development, they have many common characteristics which highlight their vulnerability, particularly as it relates to sustainable development and climatic change[8] [9]. These characteristics include:

a. Limited physical size, which effectively reduces some adaptation options to climate change and sea-level rise (e.g., retreat; in some cases entire islands could be eliminated, so abandonment would be the only option);

b. Generally limited natural resources, which are, in many cases, already heavily stressed from unsustainable human activities;

c. High susceptibility to natural hazards such as tropical cyclones (hurricanes) and associated storm surge, droughts, tsunamis, and volcanic eruptions;

d. Relatively thin water lenses that are highly sensitive to the sea-level changes; in some cases, relative isolation and great distance to major markets;

e. Extreme openness of small economies and high sensitivity to external market shocks, over which they exert little or no control (low economic resilience);

f. Generally high population densities and in some cases high population growth rates;

g. Frequently poorly developed infrastructure (except for major foreign exchange-earning sectors such as tourism);

Limited funds and human resource skills, which may severely limit the capacity of small islands to mitigate and adapt to the effects of climate change[10].

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[7] See http://www.un.org/esa/sustdev/sids/sidslist.htm

[8] See Maul, G.A., 1996: *Marine Science and Sustainable Development*. Coastal and Estuarine Studies, America Geophysical Union, Washington, DC, US 467 pp.

[9] Leatherman, S.P., 1997. Beach ratings: a methodological approach. *Journal of Coastal Research*, **13**, 1050–1063.

[10] L.A. Nurse and G. Sem, 'Small Island States', in J.J. McCarthy et al. (eds), *Climate Change 2001: Impacts, Adaptation and Vulnerability – Contribution of Working Group II to the Third Assessment Report* (Cambridge University Press, 2000), at 843–875.

Table 2: List of Small Island Developing States								
Antigua and Barbuda	Cuba	Guyana	Federated States of Micronesia	Sao Tome and Principe*	Solomon Islands*	Vanuatu	Cook Islands+	Niue+
Bahamas	Dominica	Haiti*	Mauritius	Singapore	Suriname	American Samoa+	French Polynesia+	Puerto Rico+
Barbados	Dominican Republic	Jamaica	Nauru	St.Kitts and Nevis	Timor-Leste*	Anguilla+	Guam+	U.S. Virgin Islands+
Belize	Fiji	Kiribati*	Palau	St.Lucia	Tonga	Aruba+	Montserrat+	
Cape Verde	Grenada	Maldives*	Papua New Guinea	St.Vincent and the Grenadines	Trinidad and Tobago	British Virgin Islands+	Netherlands Antilles+	
Comoros*	Guinea-Bissau*	Marshall Islands	Samoa*	Seychelles	Tuvalu*	Commonwealth of Northern Marianas+	New Calendonia+	

+ Non UN Member/Associate Members of Regional Commissions
* Also a Least Developed Country

Small island states possess unique biodiversity such as coral reefs and mangroves, and are often dependant upon their limited natural resources.

Naturally, the climatic atmosphere of SIDS is influenced strongly by the ocean-atmosphere interactions. Sea level rise and storm surges will contribute to flooding and inundation; whilst increasing sea surface temperature will cause coral bleaching, an important economic resource for many islands.

Islands are extremely susceptible to hurricanes and cyclones that damage socio-economic and cultural infrastructure. In the Pacific island regions, cyclones accounted for 76 percent of the reported disasters from 1950 to 2004, with the average costs per cyclone estimated at US$75.7 million in real 2004 value.

The Caribbean island of Grenada suffered extensive damage as a result of Hurricane Ivan in 2004, which left more than 90 percent of hotel rooms and 80 percent of indigenous trees destroyed. In addition, 90 percent of the housing stock was damaged, amounting to EC$1,381 (US$527 million) or 38 percent of the country's gross domestic product[11].

The 2004 Caribbean hurricane season alone caused damage estimated at US$2.2 billion in only four countries: the Bahamas, Grenada, Jamaica and the Dominican Republic.

Critical infrastructure such as electricity generation and fuel storage facilities, hospitals, police stations, and schools tend to be located in coastal areas because of a higher

[11] See Organization of the Eastern Caribbean States (2004), *Grenada: Macro Socio-economic Assessment of the Damages Caused by Hurricane Ivan*

population concentration. Thus they suffer great damage in case of hurricanes and floods, as they are exposed to the open sea, leaving large populations without basic social services.

Many SIDS rely on one or few economic activities, especially tourism or fisheries, both of which are highly susceptible to natural disasters. In 2004, 19 of the top 25 countries ranked according to the contribution of tourism and travel to their gross domestic product (GDP) were SIDS. In each of them, tourism and travel accounted for more than 25 percent of GDP and in half of them, it accounted for more than 50 percent[12]. These features make SIDS particularly vulnerable to climate change effects.

Changes in global markets and loss of preferential market access, as a consequence of WTO processes, have caused further marginalization of many SIDS, putting them under increased pressure. This factor exacerbates the vulnerability of SIDS to climate change by adversely affecting their economies, and therefore their resilience and adaptive capacity.

SIDS are also often heavily dependent on imported petroleum products which leads to high electricity prices (ranging from USD 0.13 to over USD 0.30 per kWh) and constrains economic and social development efforts.

While SIDS are heavily reliant on fossil-fuel based energy for their economic and social development, the amount of fossil fuels they utilize is quite small compared to developed and many developing countries.

SIDS account for less than one percent of global greenhouse gas (GHG) emissions (see Table 3). For example, in the Pacific islands, the average per capita emissions are 0.96 tonnes of carbon dioxide (CO_2) per year; this equates to only 25 percent of the CO_2 emissions attributable to the average person worldwide. Similarly, LDCs contribution to GHG emissions is quite low.

It is an irony that SIDS and LDCs contribute little to the problem of climate change but are impacted most severely, hence suffering disproportionate damage.

Many SIDS have identified the development of sustainable energy systems as a priority. The Pacific islands, for example, have set as a priority the development of technology for moderate-scale production of clean, renewable energy to initially complement and eventually replace existing sources of energy. This technology would immediately make significant reductions in emissions of industrially generated GHGs, carbon dioxide in particular.

[12] Agarwal S. and Shaw G., Managing Coastal Tourism Resorts: A Global Perspective, Clevedon, 2007, p. 113.

Table 3: Total Greenhouse Gas Emissions 2003 – Selected Countries[13]			
Country	**Mega Tonnes Carbon**	**World Rank**	**Percent of World Total**
USA	1,576.90	1	22.27
China	1,227/40	2	17.34
European Union	1,092.60	-	15.43
India	313.4	6	4.43
Brazil	90.7	19	1.28
Least Developed Countries	38.1	-	0.54
Alliance of Small Island Developing States[14]	37.7	-	0.53

Significant socio-economic impacts of climate change which are distinctive to many SIDS relate to equity and sovereignty. The impacts of climate change have the potential to make atoll islands such as Kiribati, Tuvalu and the Maldives uninhabitable owing to changes in precipitation which would lead to droughts that affect the supplies of drinking water and food security in general.

Climate change has also fostered a rise in sea surface temperatures. This causes coral bleaching that affects artisanal fisheries and reduces storm surge protection.

Yet another consequence of climate change is evident in extreme environmental shifts that impact infrastructure, agriculture and cause salt water intrusion into the freshwater lens.

The characteristics of small island states thus make them extremely vulnerable to the sea level rise and other consequences of a changing climate. Unlike many other countries, the size of SIDS relative to the geographic extent of extreme climatic and disaster events means that large areas or entire island states can be directly affected, precluding the option of intra-national relief.

In contrast to larger countries, a SIDS natural disaster can lead to a complete breakdown of economic processes, extensive environmental damage and substantial and extensive disruptions in social fabric of the island states in question. Indeed, complete inundation of some islands due to sea-level rise is real possibility.

[13] Data obtained from http://cait.wri.org

[14] Members of the Alliance of Small Island States (AOSIS) are Antigua and Barbuda, Bahamas, Barbados, Belize, Cape Verde, Comoros, Cook Islands, Cuba, Cyprus Dominica, Dominican Republic, Fiji, Federated States of Micronesia, Grenada, Guinea-Bissau, Guyana, Haiti, Jamaica, Kiribati, Maldives, Marshall Islands, Mauritius, Nauru, Niue, Palau, Papua New Guinea, Samoa, Singapore, Seychelles, Sao Tome and Principe, Solomon Islands, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Suriname, Tonga, Trinidad and Tobago, Tuvalu, and Vanuatu

Table 4: Countries which are SIDS and LDCs			
Comoros	Kiribati	Sao Tome and Principe	Tuvalu
Guinea-Bissau	Maldives	Solomon Islands	Vanuatu
Haiti	Samoa	Timor-Leste	

ENVIRONMENTAL AND SOCIO-ECONOMIC VULNERABILITIES

1. Least Developed Countries

1.1 Climate Change Projections

The climate of the African continent, where 33 of the 49 LDCs are located, is controlled by complex maritime and terrestrial interactions that produce a variety of weather changes across a range of regions, from the humid tropics to the hyper-arid Sahara[15].

The African climate has a major influence on day-to-day economic developments, particularly in the agricultural and water-resources sectors.

Since 2001, observed temperatures have indicated a greater warming trend since the 1960s. Although these trends seem to be consistent across the continent, the changes are not always uniform. For instance, decadal warming rates of 0.29°C in the African tropical forests and 0.1 to 0.3°C in South Africa have been observed. In South Africa and Ethiopia, minimum temperatures have increased slightly faster than maximum or mean temperatures[16 17].

Between 1961 and 2000, there was an increase in the number of warm spells over southern and western Africa, and a decrease in the number of extremely cold days; whilst in eastern Africa, new trends in temperature have been observed from weather stations located close to the coast or to major inland lakes.[18]

For precipitation, the situation is more complicated in areas where rainfall exhibits significant spatial and temporal variability. Inter-annual rainfall variability is large over most of Africa and, for some regions; multi-decadal variability is quite substantial. The drying of the Sahel region since the 1970s has, for example, been linked to an increase in equatorial Indian Ocean sea-surface temperature.[19]

Changes in extreme events, such as droughts and floods, have major implications for the various African regions. Droughts have attracted much interest over the past 30 years, particularly with reference to their impact on ecological systems and on society.

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[15] Christensen, J.H., B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, R.K. Koli, W.-T. Kwon, R. Laprise, V.M. Rueda, L. Mearns, C.G. Menéndez, J. Räisänen, A. Rinke, A. Sarr and P. Whetton, 2007: Regional climate projections. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller, Eds., Cambridge University Press, Cambridge, 847-940.

[16] Conway, D., C. Mould and W. Bewket, 2004: Over one century of rainfall and temperature observations in Addis Ababa, Ethiopia. *Int. J. Climatol.*, **24**, 77-91.

[17] Kruger, A.C. and S. Shongwe, 2004: Temperature trends in South Africa: 1960–2003. *Int. J. Climatol.*, **24**, 1929-1945.

[18] King'uyu, S.M., L.A. Ogallo and E.K. Anyamba, 2000: Recent trends of minimum and maximum surface temperatures over Eastern Africa. *J. Climate*, **13**, 2876-2886.

[19] Giannini, A., R. Saravanan and P. Chang, 2003: Oceanic forcing of Sahel rainfall on interannual to interdecadal time scales. *Science*, **302**, 1027-1030.

One third of the people in Africa live in drought-prone areas. In the mid 1980s, economic losses from droughts that affected the Sahelian region, the Horn of Africa and Southern African were in the several hundred millions of dollars.[20]

Floods also have a significant impact on African development. Recurrent floods in some countries are linked, in some cases, with El Niño-Southern Oscillation (ENSO) events. ENSO occurrences have resulted in major economic and human losses in LDCs such as Mozambique[21] [22] and Somalia[23].

The impacts of droughts and floods are often further exacerbated by health problems, such as diarrhea, cholera and malaria[24].

About half of the 16 Asian LDCs are located in South and Southeast Asia.[25] South Asia is one of the regions predicted by the Intergovernmental Panel on Climate Change (IPCC) to experience warming above the global average. Precipitation in summer is likely to increase in South Asia and most of Southeast Asia, along with Northern Asia and East Asia. Fewer days are expected in South (and East) Asia. Extreme rainfall and winds associated with tropical cyclones are likely to increase in South, Southeast and East Asia.[26]

All these climatic changes will have a significant impact on the regions concerned.

1.2 Effects and Vulnerabilities

1.2.1 Water Resources

Climate change will have a significant impact on the quality of life in most of the LDCs. It is projected that by 2020, between 75 and 250 million people will be exposed to an increase of water stress owing to climate change in Africa. Coupled with increased demand, this will adversely affect livelihoods and exacerbate water-related problems in Africa.

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[20] Christensen, J.H., B. Hewitson, A. Busuioc, A. Chen, X. Gao, I. Held, R. Jones, Räisänen, A. Rinke, A. Sarr and P. Whetton, 2007: Regional climate projections. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller, Eds., Cambridge University Press, Cambridge, 847-940.

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

[22] Obasi, G.O.P., 2005: The impacts of ENSO in Africa. *Climate Change and Africa*, P.S Low, Ed., Cambridge University Press, Cambridge, 218-230.

[23] Kabat, P., R.E. Schulze, M.E. Hellmuth and J.A. Veraart, Eds., 2002: Coping with impacts of climate variability and climate change in watermanagement: a scoping paper. DWC-Report No. DWCSSO-01 (2002). Dialogue on Water and Climate, Wageningen, 114 pp.

[24] 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.

[25] The actual number depends on the definitions adopted for the two regions. LDCs considered part of South and Southeast Asia may include Bangladesh, Bhutan, the Maldives, Nepal, Afghanistan, Myanmar, Cambodia, East Timor and Lao Peoples Democratic Republic.

[26] Ibid 32

Glacier melting in the Himalayas is projected to increase flooding, rock avalanches from destabilized slopes, and affect water resources within the next two to three decades. River flow is also predicted to decrease as glaciers recede. The LDCs of Bhutan and Nepal will likely to be severely affected by these changes.

The predictions for climate change in Africa seem to show a trend of decreased precipitation in current semi-arid to arid parts of the continent. One of the main impacts of climate change will be a reduction in soil moisture in the sub-humid zones and a reduction in runoff. This may pose a problem for the future water resources of these sub-humid regions.

However, precipitation scenarios are not the same everywhere in Africa, as simulations seem to indicate a possible increase in precipitation in East Africa but a decrease in rainfall in Southern Africa for the next 100 years.

These changes in precipitation will affect the levels of water storage in lakes and reservoirs as they respond to climate variability. This could cause major problems for lakes, such as Lake Chad, which has already decreased in size by about 50 percent in the last 40 years.

For the Niger River Basin, which covers the LDCs of Benin, Guinea, Mali and Niger (in addition to Nigeria, a non-LDC), a possible 10 percent change in precipitation, potential evaporation and runoff have been predicted.

The Zambezi River, however, has the worst scenario of decreased rainfall (about 15 percent), increased potential evaporative losses (about 15 percent to 25 percent) and diminished runoff (about 30 percent to 40 percent). The Zambezi River and its basin feed the LDCs of Angola, Democratic Republic of Congo, Malawi, Mozambique, Tanzania and Zambia, as well as the non-LDCs of Botswana, Namibia and Zimbabwe.

The Gambia River, which is particularly important to Gambia, Guinea and Senegal, is also very sensitive to climate change. Climate change alone could cause a 50 percent change in runoff in the Gambia River catchment. A 1 percent change in rainfall can cause a 3 percent change in runoff for the Gambia River, and this could have serious repercussions, increased salt-water intrusion among them.

As in Africa, Least Developed Countries in Asia are likely to suffer from the adverse effects of climate change on water resources.

Water availability is expected to be highly vulnerable to future climate change with significant changes in runoff systems. Increases in the high latitudes and near the equator, and decreases in the mid-latitudes have been predicted for Asia. In general, most of the climate models project an increase in annual mean rainfall over most of Asia.

Surface runoff is predicted to decline in the arid and semi-arid zones of Asia and this would have a detrimental effect on the availability of water for irrigation. The average annual runoff in certain basins could decline by as much as 27 percent by 2050[27].

The perennial rivers in the High Himalayas receive water from the melting of snow and glaciers. The melting season of snow occurs at the same time as the summer monsoon season, so any intensification of the monsoon would cause flood disasters in Himalayan catchments. Countries such as Nepal and Bangladesh would be at risk of increasing flood disasters in the wet season. The intensity of extreme events may be higher in a warmer climate, which would also increase the risk of flash floods in parts of Nepal and Bangladesh.

New water management strategies and increased investments will be required to help Asia cope with future water problems. The effects of climate change on the water systems and public water supply in the arid and semi-arid regions of Asia will require priority attention to avoid local and international conflicts. Many of the watersheds in Asia are already stressed by intensive land use and unfavorable climates thus making them highly vulnerable to climate change if no appropriate adaptation strategies are developed[28].

1.2.2. Human Health

Results from the “Mapping Malaria Risk in Africa” project (MARA/ARMA) reveal, depending on the location, a possible expansion and contraction of climatically suitable areas for malaria on the continent by the years 2020, 2050 and 2080. By 2050 and continuing into 2080, for example, a large part of the western Sahel and much of southern central Africa is likely to become unsuitable for malaria transmission. Other assessments[29], using 16 climate-change scenarios, show that by 2100, changes in temperature and precipitation could alter the geographical distribution of malaria with previously unsuitable areas of dense human population becoming suitable for transmission[30].

Using parasite survey data in conjunction with results from the Global Circulation Models (GCMs), projected scenarios estimate a 5 percent to 7 percent potential increase (mainly altitudinal) in malaria distribution, with little increase in the latitudinal extent of the disease by 2100.

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[27] See 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.

[28] See ibid

[29] See Hartmann, J., K. Ebi, J.McConnell, N. Chan and J.P.Weyant, 2002: Climate suitability: for stable malaria transmission in Zimbabwe under different climate change scenarios. *Global Change and Human Health*, **3**, 42-54.

[30] Ibid 47.

Previously malaria-free highland areas in Ethiopia and Rwanda could also experience incursions of malaria by the year 2050, with conditions for transmission becoming highly suitable by the year 2080. By this period, areas currently with low rates of malaria transmission in central Somalia and the Angolan highlands could also become highly suitable.

Among all scenarios, the highlands of Eastern Africa and some areas of Southern Africa are likely to become more suitable for transmission.[31]

As the rate of malaria transmission increases in the highlands, the likelihood of epidemics may increase due to the lack of immunity in the newly-affected populations.

A malaria epidemic in Rwanda, for example, led to a four-fold increase in malaria admissions among pregnant women and a five-fold increase in maternal deaths. The social and economic costs of malaria are substantial and include considerable costs to individuals and households as well as high costs at the community and national levels.

Conflicts, wars and malnutrition are among several background stresses that aggravate the effects of climate variability, promoting additional vulnerabilities in certain regions. Immuno-compromised populations with HIV/AIDS will also have an increased susceptibility to other infectious diseases[32].

The potential for climate change to intensify or alter flood patterns may become a major additional driver of future health risks associated with flooding.

In tropical Asia, an increase in the frequency and duration of heat waves can be expected. This will increase the risk of mortality among the elderly and within Asia's urban poor population. An increase in respiratory and cardiovascular diseases in arid, semi-arid and tropical Asia can also be expected as a result of global warming.

Global warming will alter the occurrence of vector-borne diseases like malaria and dengue fever. With an increase in temperatures and changes in rainfall patterns, the spread of vectors, such as mosquitoes may also be altered. It is possible that these temperature and rainfall changes will increase vector-borne diseases in temperate and arid Asia, which would have serious human health implications.

Water-borne diseases, such as cholera and the diarrheal diseases caused by organisms such as giardia, salmonella and cryptosporidium, could become more prevalent in many South Asian countries as a result of global warming[33].

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[31] Hartmann, J., K. Ebi, J. McConnell, N. Chan and J.P. Weyant, 2002: Climate suitability: for stable malaria transmission in Zimbabwe under different climate change scenarios. *Global Change and Human Health*, **3**, 42-54.

[32] See for example Holding and Snow, 2001; Utzinger et al., 2001; Malaney et al., 2004., Harrus and Baneth, 2005

[33] See ibid.

1.2.3 Agriculture and Fisheries

Results from various assessments of the impacts of climate change on agriculture based on various climate models and emissions scenarios indicate certain agricultural areas that may undergo negative changes.

Agricultural production, including access to food in many African countries, is projected to become severely compromised by climate change. The areas suitable for agriculture, the length of growing seasons and yield potential, particularly along the semi-arid and arid areas, are all expected to decrease. This would further affect food security and exacerbate malnutrition and, in some countries, yields from rain-fed agriculture could be reduced by up to 50 percent by the year 2020.[34]

It is estimated that, by 2100, parts of the Sahara are likely to emerge as the most vulnerable, showing likely agricultural losses of between 2 percent and 7 percent of the regional GDP. Western and Central African regions are also vulnerable, with impacts on the GDP ranging from 2 percent to 4 percent.

Other assessments have predicted changes in agricultural potential. A significant decrease in suitable rain-fed land and cereal production potential are expected by 2080. The area of arid and semi-arid land in Africa could increase by 5 percent to 8 percent (60 to 90 million hectares) and wheat production is likely to disappear from Africa by 2080[35]. Southern Africa is likely to experience notable reductions in maize production.

Over the last 30 years, food production in most of the sub-Saharan African countries has not kept pace with population increase. Many of these countries rely on food aid. If climate change adversely affects food production, then these countries will become increasingly dependent on external aid, food insecurity will increase and their development goals will be adversely affected.

It is likely that global warming will negatively affect the production of certain crops, such as rice, wheat, corn, beans and potatoes, which are major food crops for many people in Africa.[36] Other crops, such as millet, are resistant to high temperatures and low levels of water, and so may be less affected by future climate change.

In some regions, food production will be affected by flooding caused by the rising sea level. In Guinea, depending on the inundation level considered (between 5m and 6m), approximately 130 km^2 to 235 km^2 of rice fields (17 percent and 30 percent of the existing rice field area) could be lost as a result of permanent flooding by the year 2050.

[34] Climate Change: 2007, Climate Change Impacts, Vulnerability and Adaptation, Summary for Policymakers

[35] Thornton, P.K., P.G. Jones, T.M. Owiyo, R.L. Kruska, M. Herero, P. Kristjanson, A. Notenbaert, N. Bekele and Co-authors, 2006: Mapping Climate Vulnerability and Poverty in Africa. Report to the Department for International Development, ILRI, Nairobi, 200 pp.

[36] Ibid 47

Food-importing countries will be at greater risk, although the impacts may have more to do with changes in world markets than with changes in the local climate and agricultural production.[37]

Global warming will also affect the fishing sector. In some cases, temperature increases will increase productivity. It is projected that a warming of 3°C to 5°C will increase the productivity of the Gambia River by about 13 percent to 21 percent. However, some fish species might be more sensitive to temperatures, and increases of 3°C to 4°C could negatively affect catfish and herring populations, whereas shrimp yields are predicted to increase significantly.

A reduction in annual precipitation will affect range-fed livestock numbers in many African regions. Pastoral livelihoods in the semi-arid zones of Africa are likely to be adversely affected by climate change.

However, not all changes in climate and climate variability will be negative. The growing seasons in certain areas in parts of the Ethiopian highlands and parts of the Southern African region, like Mozambique, may lengthen as the climate continues to change due to a combination of increased temperature and changes in rainfall patterns.

Mild climate scenarios project further benefits across African croplands for irrigated and dryland farms in particular. However, it is worth noting that, even under these favorable scenarios, populated regions of the Mediterranean coastline, Central, Western and Southern African regions are expected to be adversely affected.[38]

Climate change is expected to have a significant impact on agriculture in Asia as well. It may cause a decrease in the supply of water and soil moisture during the dry season, which could exacerbate stress on the available water supplies and increase the need for irrigation. Rice growing areas may also be affected, and the resultant declines in yield would have a significant effect on agricultural trade, economic growth and the development goals of certain Asian countries.

Changes in precipitation and temperature caused by climate change will impair the efficiency of externally applied inputs like fertilizers, and this will have a negative impact on food production. The results from several studies made on the impact of climate change on agriculture in Asia seem to suggest that, in general, mid and high-latitude areas will experience an increase in crop yields, whereas the lower latitude areas will experience declining yields.

It appears that climatic variability and change will seriously endanger sustained agricultural production in Asia in the next decades. The gap between the supply and demand

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[37] Ibid 47

[38] Kurukulasuriya, P. and R. Mendelsohn, 2006a: A Ricardian analysis of the impact of climate change on African cropland. Centre for Environmental Economics and Policy in Africa (CEEPA) Discussion Paper No. 8. University of Pretoria, Pretoria, 58 pp.

of crops, which might arise in certain Asian countries due to climate change, will increase those countries' reliance on food imports.

Climate change may alter the survival rate of pathogens. Cropping areas may also be extended as a result of climate change thus providing more host plants for pathogens. Damage from insects and pathogens may also be more serious as heat-stress conditions may weaken the resistance of host plants.

1.2.4 Ecosystems and Biodiversity

A range of climate change effects on land and water ecosystems has been suggested.

Mangroves and coral reefs, the main coastal ecosystems in Africa, will probably be affected. Endangered species associated with these ecosystems, including manatees and marine turtles, as well as migratory birds, will face higher risk of extinction.

The species sensitivity of African mammals in 141 national parks in sub-Saharan Africa was assessed using two different climate change scenarios. Assuming that the migration of species does not take place, it is forecast that 10 percent to 15 percent of African mammals will fall under the World Conservation Union's list of critically endangered or extinct categories by 2050. This percentage range is likely to increase to 25 percent to 40 percent by 2080. Assuming unlimited species migration, the results are less extreme, with these proportions dropping to approximately 10 percent to 20 percent by 2080.

Climate change is likely to have an effect on the ecosystems and biodiversity of Asia by accelerating damage to freshwater ecosystems such as lakes, marshes and rivers. More than 50,000 hectares of coastal land has been damaged by floods in the past few years, and as precipitation is likely to increase with global warming, there may be increased flooding in the future, increasing the threat to coastal zones.

With a one meter sea level rise, many Asian species, such as Bengal tigers, Indian otters, estuarine crocodiles and mud crabs, will be at risk of extinction. Climate change will have a profound effect on the future distribution, productivity and the health of forests in Asia. The change in climate will affect the boundaries of forest types and areas, species population and migration, the occurrence of pests and diseases and forest regeneration. Forest fires may also increase in number. In Nepal, forest fires in unseasonably high temperatures will threaten the existence of species such as red pandas, leopards, monkeys and other wild animals.

The majority of semi-arid lands in Asia are rangelands, composed mainly of grasses or scrubs. With an increase in temperature of about 2°C to 3°C and a decrease in rainfall (future projections for the arid and semi-arid areas in Asia), grassland productivity will decline by 40 percent to 90 percent. Some rangelands in Nepal are already subject to degradation, and so, climate change will represent an unwelcome additional environmental stress. Climate change will have a negative impact on desert vegetation, especially on the plants with surface root systems that depend on precipitation moisture. These plants will become more vulnerable to reduced water availability. Climate change may also cause a shift in the dryland types in Asia, with semi-arid drylands becoming not only drier but also desertified.[39]

1.2.5 Coastal Zones and Deltas

In Africa, highly productive ecosystems (mangroves, estuaries, deltas, coral reefs), which form the basis for important economic activities such as tourism and fisheries, are located in the coastal zones. The projected rise in sea level will have significant impacts on African coastal cities because of the concentration of poor populations in potentially hazardous areas that may be especially vulnerable to these changes.

In the Gulf of Guinea, sea level rise could induce overtopping and even destruction of the low barrier beaches that limit the coastal lagoons, while changes in precipitation could affect the discharges of rivers feeding them. In Eritrea, a one meter rise in sea level could cause damage of over US$250 million as a result of the submergence of infrastructure and other economic installations in Massawa, one of the country's two port cities.

Coastal zones and low lying delta areas in Asia, such as those in Bangladesh, Myanmar and Cambodia, will be hard hit by the effects of sea level rise and more frequent and severe storms due to climate change.

Deltas and estuaries will increasingly suffer from saltwater intrusion, siltation and land loss. Sea level rise will threaten the rich biodiversity of wetlands as it will decelerate wetland renewal. Mangroves will also be affected by the rise in sea level because it will change the salinity distribution and productivity of those areas. Severe coral bleaching can be expected as a result of warmer seawater and higher solar radiation.

1.2.6 Tourism

Climate change could also place tourism at risk. The economic benefits of tourism in Africa, which according to 2004 statistics accounts for 3 percent of worldwide tourism, may be altered with climate change.[40] However, very few assessments of projected impacts on tourism and climate change are available, particularly those using specific scenarios.

Modeling climate changes as well as human behavior, including personal preferences, choices and other factors, is exceedingly complex. Although scientific evidence is still lacking, it is probable that flood risks and water pollution-related diseases in low-

[39] See ibid.

[40] World Tourism Organization, 2005: *Tourism Vision 2020*. World Trade Organisation, Washington, District of Columbia. http://www.world-tourism.org/facts/wtb.html.

lying regions (coastal areas), as well as coral reef bleaching as a result of climate change, could have a negative impact on tourism.

African and Asian places of interest for tourists, including wildlife areas and parks, may also attract fewer tourists under marked climate changes. Climate change could, for example, lead to a shift of tourist activity towards the poles, as well as a shift from lowland to highland tourism.[41]

1.2.7 Settlements, Industry and Infrastructure

Climate variability, including extreme events such as storms, floods and sustained droughts, have already had marked impacts on settlements and infrastructure[42 43].

The negative impacts of climate change could create a new group of refugees, who may migrate into new settlements to seek new livelihoods, which will create additional demands on infrastructure.[44]

However, few detailed assessments of such impacts using climate as a driving factor have been undertaken in the LDCs. More research is needed, particularly on the impact of climate change on energy, tourism, settlement and infrastructure.

1.3 Conclusions

Despite the uncertainty of the science and the sizeable complexity of the range of issues outlined, initial assessments show that LDCs will suffer a myriad of impacts associated with climate change. Such impacts will further constrain development and the attainment of the MDGs in Africa and Asia. Adaptive capacity thus emerges as a critical area for consideration in these regions.

While it is acknowledged that the emission of greenhouse gasses by LDCs, and therefore their contribution to the problem of global warming, is minute, it should still be an area of interest.

It is estimated that global emissions from tropical deforestation contribute up to 25 percent of the total induced CO_2 emissions. The Congo rainforest is the second largest tropical forest after the Amazon. It is estimated that forest loss and degradation in the Congo River Basin can release more carbon into the atmosphere than any other land

[41] Hamilton, J.M., D.J. Maddison and R.S.J. Tol, 2005: Effects of climate change on international tourism. *Climate Res.*, **29**, 245-254.

[42] Freeman, P. and K. Warner, 2001: Vulnerability of infrastructure to climate variability: how does this affect infrastructure lending policies? Report commissioned by the Disaster Management Facility of the World Bank and the ProVention Consortium, Washington, District of Columbia, 42 pp.

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

[44] McLeman, R. and B. Smit, 2005: Assessing the security implications of climate change-related migration. Preprint, *Human Security and Climate Change: An International Workshop*, Oslo, 20 pp.

use practice in Africa. Rainforest in the Democratic Republic of Congo (DRC) alone contains 8 percent of global carbon stores. It is estimated that forest clearance in the DRC will release up to 34.4 billion tonnes of CO_2 by 2050.

It is imperative, therefore, to find local and global solutions to the risk posed by forest clearance in Africa and other regions.

2. Small Island Developing States

2.1 Climate Change Observations and Projections

Undoubtedly, climate change is affecting the development process in Small Island Developing States. Observational records have shown that sea surface temperatures have been increasing by 0.1ºC per decade in the oceans where most SIDS are located[45]. Studies have also shown that annual and seasonal ocean surface and island air temperatures have increased from 0.6°C to 1.0°C since 1910 throughout a large part of the South Pacific[46].

For the Caribbean, Indian Ocean and Mediterranean regions, analyses show warming trends ranging from 0°C to 0.5°C per decade for the 1971 to 2004 period[47]. There have also been increases in extreme temperatures in the South Pacific and Caribbean regions.

Trends in extreme temperature across the South Pacific for the period 1961 and 2003 show an increase in the annual number of hot days and warm nights, as well as a relative decrease in the annual number of cool days and cold nights; particularly in the years after the onset of El Niño[48].

In the Caribbean, the percentage of days having extremely warm maximum or minimum temperatures have increased considerably since the 1950s, while the percentage of days with cold temperatures have decreased[49].

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[45] Nurse, L., et al, 2001, Small island states, In *Climate Change 2001: Impacts, Adaptation, and Vulnerability*, J.J. McCarthy et al (eds.), Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, pp. 842-975.

[46] Folland, C.K., J.A. Renwick, M.J. Salinger, N. Jiang and N.A. Rayner, 2003: Trends and variations in South Pacific islands and ocean surface temperatures. *J. Climate*, **16**, 2859-2874.

[47] Ibid 11

[48] Manton, M.J., P.M. Dellaa-Marta, M.R. Haylock, K.J. Hennessy, N. Nicholls, L.E. Chambers, D.A. Collins, G. Daw, A. Finet, D. Gunawan, K. Inape, H. Isobe, T.S. Kestin, P. Lefale, C.H. Leyu, T. Lwin, L. Maitrepierre, N. Oprasitwong, C.M. Page, J. Pahalad, N. Plummer, M.J. Salinger, R. Suppiah, V.L. Tran, B. Trewin, I. Tibig and D. Yee, 2001: Trends in extreme daily rainfall and temperature in south east Asia and the south Pacific: 1961-1998. *J. Climatol.*, **21**, 269-284.

[49] Peterson, T.C., M.A. Taylor, R. Demeritte, D.L. Duncombe, S. Burton, F. Thompson, A. Porter, M. Mercedes, E. Villegas, R. Semexant Fils, A. Klein Tank, A. Martis, R.Warner, A. Joyette, W. Mills, L. Alexander and B. Gleason, 2002: Recent changes in climate extremes in the Caribbean region. *J. Geophys. Res.*, **107**, 4601

Changes in rainfall patterns in the Caribbean and the Pacific have also been observed. In the Caribbean specifically, the maximum number of consecutive dry days is decreasing and the number of heavy rainfall events is increasing[50].

Not only are increases in air temperature and changes in rainfall patterns set to continue, but they are also expected to get worse (see tables 5 and 6).

Table 5: Projected increases in air temperature (°C) by region, relative to the 1961–1990 period			
Region	**2010–2039**	**2040–2069**	**2070–2099**
Mediterranean	0.60 to 2.19	0.81 to 3.85	1.20 to 7.07
Caribbean	0.48 to 1.06	0.79 to 2.45	0.94 to 4.18
Indian Ocean	0.51 to 0.98	0.84 to 2.10	1.05 to 3.77
Northern Pacific	0.49 to 1.13	0.81 to 2.48	1.00 to 4.17
Southern Pacific	0.45 to 0.82	0.80 to 1.79	0.99 to 3.11

Table 6: Projected changes in precipitation (%) by region, relative to the 1961–1990 period			
Region	**2010–2039**	**2040–2069**	**2070–2099**
Mediterranean	–35.6 to +55.1	52.6 to +38.3	-61.0 to +6.2
Caribbean	–14.2 to +13.7	–36.3 to +34.2	–49.3 to +28.9
Indian Ocean	–5.4 to +6.0	–6.9 to +12.4	–9.8 to +14.7
Northern Pacific	–6.3 to +9.1	–19.2 to +21.3	–2.7 to +25.8
Southern Pacific	–3.9 to +3.4	–8.23 to +6.7	–14.0 to +14.6

The numbers of tropical cyclones in small island regions are dominated by El Niño Southern Oscillation and decadal variability which result in a redistribution of tropical storms and a disruption of the paths taken by these storms.

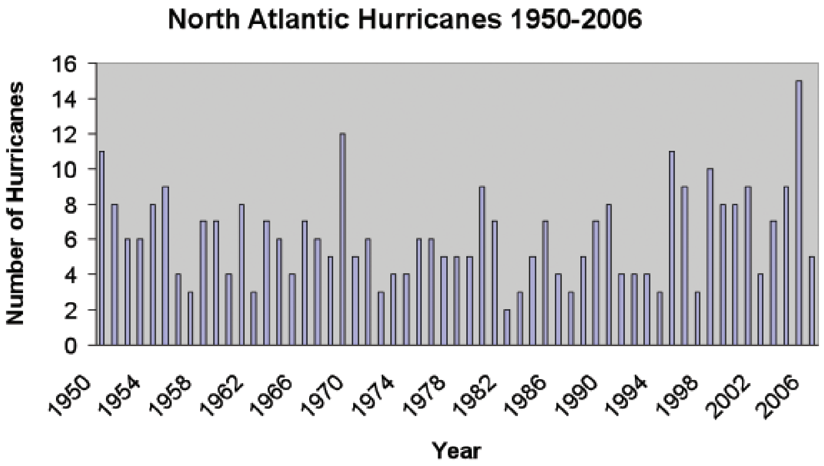
For example, during an El Niño event, the incidence of tropical storms would typically decrease in the Atlantic, far-Western Pacific and Australian regions; increasing in the Central and Eastern Pacific, and vice versa. Evidence exists that the number of storms reaching categories 4 and 5 globally has increased since 1970 owing to increases in their intensity and duration[51].

In the Caribbean, hurricane activity was intense between 1950 and 1960, in comparison with the 1970s and the 1980s. The period 1995 and 2000 saw the highest level of North Atlantic hurricane activity recorded (Figure 1).

[50] Ibid 11

[51] Ibid 11

Figure 1: The Number of Hurricanes per year in the North Atlantic 1950–2006 [52]



Sea level rise is a key concern for SIDS. The overall average sea-level rise around the whole Pacific region is +0.77 mm/yr[53], whereas in the Caribbean, the mean sea-level rise is in the region of 1 mm/yr.

There are some variations due to local conditions. For example, sea level observations along the west coast of Trinidad indicate that in the north of the country sea level is rising at a rate of about 1 mm/yr while in the south, the rate is about 4 mm/year. The difference is attributed to a difference in the response to tectonic movements in the respective regions[54].

In the Indian Ocean, reconstructed records on sea level rise, based on tide gauge data and satellite data from 1950 to 2001 estimate rates of sea-level rise of 1.5, 1.3 and 1.5 mm/yr in Port Louis, Rodrigues, and Cocos Islands respectively[55]. In the Maldives, trends show a sea level rise of about 4 mm/yr[56].

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[52] Data obtained from www.nhc.noaa.gov

[53] Mitchell, W., J. Chittleborough, B. Ronai and G.W. Lennon, 2001: Sea level rise in Australia and the Pacific. Proceedings Science Component: Linking Science and Policy. Pacific Islands Conference on Climate Change, Climate Variability and Sea Level Rise, Rarotonga, Cook Islands. National Tidal Facility, The Flinders University of South Australia, Adelaide, 47-58.

[54] Miller, K., 2005: *Variations in Sea Level on the West Trinidad, Marine Geodesy*, **28**, (3), 219-229.

[55] Church, J.A., N. White and J. Hunter, 2006: Sea level rise at tropical Pacific and Indian Ocean islands. *Global Planet. Change*, **53**, 155-168.

[56] Khan, T.M.A., D.A. Quadir, T.S. Murty, A. Kabir, F.Aktar and M.A. Sarker, 2002: Relative sea level changes in Maldives and vulnerability of land due to abnormal coastal inundation. *Mar. Geod.*, **25**, 133-143.

2.2 Effects and Vulnerabilities

2.2.1 Water Resources

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

Dominica, in the Caribbean, and the Seychelles in the Indian Ocean, for example, are almost entirely dependent on surface water from streams. Rainwater is the primary source of freshwater in several countries in the Pacific like Tuvalu and in the northern atolls of the Cook Islands. Groundwater is the major source of water for many low-lying coral islands such as the Maldives and Barbados and raised atolls such as Nauru, where freshwater lenses can vary in thickness and quality, depending on the rates of extraction and recharge from rainfall.

This dependency on rainfall increases the vulnerability of small islands to future changes and variations in rainfall distributions. Low rainfall can lead to a reduction in the amount of water that can be physically harvested, a reduction in river flow, and a slower rate of recharge of the freshwater lenses, which can result in prolonged droughts.

Since most of the islands are dependent upon surface water catchments for their main water supply, demand cannot be met during periods of low rainfall. On the other hand, during the rainy season, the lack of suitable land areas for dams (e.g. in the Seychelles) and high runoff during stormy seasons (e.g. in Fiji) result in significant losses of surface and stream water to the sea.

The wet and dry cycles associated with El Niño episodes can have serious impacts on water supplies in small islands. The strong El Niño occurrences between 1998 and 2000 were responsible for acute water shortages in many islands in the Indian and Pacific oceans. In the islands of Fiji and the Mauritius, borehole yields decreased by 40 percent during the dry periods, and export crops, including sugarcane, were severely affected. The situation was exacerbated by the lack of adequate infrastructure such as reservoirs and water distribution networks in most islands.

It has been estimated that a 10 percent reduction in average rainfall by the year 2050 could produce a 20 percent reduction in the size of the freshwater lens on Tarawa Atoll, Kiribati. The thickness of the freshwater lens on atolls could be reduced by as much as 29 percent; threatening the structure of freshwater lenses.

2.2.2. Coastal Zones

Naturally, on the islands, coastal zones are of the utmost importance. The coastal zones are often the centre of economic activity since major settlements are located in these areas.

Oftentimes, critical infrastructure, such as schools, electricity generation plants, and hospitals are located in coastal regions. Major economic activities such as tourism also take place in coastal zones.

On the Pacific and Indian Ocean atolls, villages are located on the sand terrace or on the beach itself, and in the Caribbean, more than half of the population lives within 1.5 km of the shoreline.

In many small islands, such as along the north coast of Jamaica and the west and south coasts of Barbados, continuous corridors of development now occupy practically all of the prime coastal lands.

Population growth places additional pressure on coastal settlements, utilities and resources and also creates problems of pollution, waste disposal and housing.

Sea level rise will increase coastal erosion and inundation and increase the susceptibility of vital coastal assets in the islands. The projected increase in the frequency and intensity of hurricanes will also place coastal assets at greater risk.

2.2.3 Biodiversity

Small Islands are home to a significant part of the world's biodiversity. Their relative physical isolation has lead to the formation of many geographically unique species.

The biodiversity of upland and coastal forests, including mangroves, remains threatened by both global change and local factors. For example, more than a quarter of the small island states have a greatly reduced forest cover as a result of the encroachment of infrastructural development or agriculture. Terrestrial and sea ecosystems in most islands are increasingly being subjected to degradation and destruction. For instance, analyses of coral reef surveys over 30 years have revealed that coral cover across reefs in the Caribbean has declined by up to 80 percent, largely as a result of unabated pollution, sedimentation and over-fishing.

Mangrove growth on land may or may not be able to keep pace with the rising sea level depending on the composition of the forest, tidal range and sediment supply. Studies have projected that 3 percent of Cuba's mangrove forests would be lost with a one meter rise in sea level. For the same rise in sea level, a complete collapse of the Port Royal mangrove wetland in Jamaica is predicted since this system has shown little capacity to migrate over the last 300 years.

Biodiversity is threatened by an increase in extreme events which decimate the forests in which the greatest levels of biodiversity are found.

For example, in 1993, 30 percent of the forested area on the Santa Cruz Islands was destroyed in one instance as a result of a cyclone. Samoa lost 92 percent of its plantation estate in the 1990s as a result of cyclones Ofa and Val, with the latter estimated to have caused damage of more than US$300 million.

In 2001, a storm in the Seychelles resulted in the loss of over 1,000 indigenous palms. Coral reefs are continually threatened by rises in sea surface temperatures which lead to coral bleaching. In the past 20 years, a sea surface temperature rise of approximately 1°C above the normal maximum summer temperature has lead to bleaching events. Some studies have predicted that, in the next 30 to 50 years, bleaching events could occur annually in most tropical oceans. Another threat to coral reefs is that of rising CO_2 concentration levels in the oceans – related to rising atmospheric CO_2. Based on projected CO_2 levels, it has been suggested that the calcification rate of corals could decrease by about 14 percent to 30 percent by 2050.[57]

For many SIDS, the importance of coral reefs cannot be overstated. Coral reefs provide key nurseries for important species of fish, play a pivotal role in beach protection, and provide the natural resource base for the tourism industry.

2.2.4 Agriculture and Fisheries

Agriculture has for a long time been the mainstay for survival and economic development in many SIDS. Subsistence agriculture provides local food security, whereas cash crop agriculture has enabled SIDS to earn export revenue and participate in world trade.

Subsistence food production is vital in small islands even within those that have limited arable land. However, arable land for crop agriculture is increasingly in short supply and the likely prospect of land loss and salinization due to climate change and sea-level rise will threaten the sustainability of both subsistence and commercial agriculture. Much of the prime agricultural land is located on the coastal plains that are threatened by sea-level rise.

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

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[57] Nurse, L., et al, 2001, Small island states, In *Climate Change 2001: Impacts, Adaptation, and Vulnerability*, J.J. McCarthy et al (eds.), Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, pp. 842-975.

Economic losses resulting from the negative effects of climate change on agriculture will, however, vary among island states. In the absence of adaptation on a high island such as Viti Levu in Fiji, the cost could be in the range of US$23 to 52 million per year by 2050.

On a low island such as Tarawa, Kiribati, the annual cost is estimated in the order of US$8 to 16 million. These costs would respectively represent 2 percent to 3 percent of Fiji's GDP in 2002 and 17 percent to 18 percent of Kiribati's GDP for the same year[58].

Research has indicated that under conditions of double the atmospheric CO_2, sugar-cane yields would reduce by 29.8 percent as a resulted of a shortening growing season in Guyana. In St. Kitts and Nevis, climatic conditions would be too dry for rain-fed agriculture making it economically unviable. There would be a 20 percent decrease in productivity in St. Vincent and the Grenadines[59].

In many SIDS, fisheries contribute up to 10 percent of the GDP. The socioeconomic implications of climate change effects on fisheries will therefore be significant.

Variations in tuna catches are visible during El Niño and La Nina years. For example, in the Maldives, the El Niño years of 1972–1973, 1976, 1982–83, 1987 and 1992–1994 negatively affected skipjack tuna catches, highlighting the sensitivity of fish stocks to changes in the climate.

Changes in migration patterns and depth of fish stocks are the two main factors affecting the distribution and availability of tuna during such periods and it is expected that changes in climate may cause migratory shifts in tuna aggregations to other locations.

2.2.5 Human Health

A changing climate will have adverse impact on the health of human populations in many small islands. Increases in temperature will increase incidents of heat stress whilst projections for reduced rainfall in the Caribbean[60] will reduce the amount of available freshwater for human use and consumption, leading to the increased risk of disease.

Several cases of dengue have been reported during the period 1980 to 2000 in Barbados, Trinidad and Tobago in relation to the variability in precipitation and temperature. The patterns of reported cases compared closely with the periodicity of ENSO events. Warmer temperatures and less abundance in rainfall also appeared to be influencing dengue epidemics.

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[58] World Bank (2000). *Cities, Seas, and Storms: Managing Change in Pacific Island Economies.* Volume I: Summary Report (draft). Papua New Guinea and Pacific Islands Country Unit. The World Bank. Washington, D.C.

[59] Sem. G (2007), Vulnerability and Adaptation to Climate Change in Small Island Developing States Background paper for the expert meeting on adaptation for small island developing States. United Nations Framework Convention on Climate Change

[60] Arnell, N.W., 2004: Climate change and global water resources: SRES emissions and socio-economic scenarios. *Global Environmental Change*, **14**, 31-52.

2.3 Conclusions

Climate change will impact the social and economic fabric of life in small islands, affecting key sectors such as tourism and agriculture, and placing critical infrastructure at risk. The size and relative isolation of the islands will make them feel the effects of climate change more than other countries. Indeed, climate change will place the viability and very existence of many island states at risk.

ADAPATION AND SUSTAINABLE DEVELOPMENT

Reducing Vulnerability and Enhancing Resilience

With the major greenhouse gas emitters failing to curb emissions, it is clear that CO_2 levels will continue to rise. Even if emission reductions that would limit carbon dioxide levels to their 1990 levels were enacted today, climate change would continue to occur, and further warming would be unavoidable[61]. This rationale has been underscored by the Stern report[62], which examines the economics of climate change.

Adaptation is thus the only option for the Least Developed Countries and Small Island Developing States.

1. Adaptation in the Least Developed Countries

A range of factors including wealth, technology, education, information, skills, infrastructure, access to resources, various psychological factors and management capabilities can modify adaptive capacity.[63] Adaptation is shown to be successful and sustainable when linked to effective governance systems.

Of the emerging range of adaptation practices, the diversification of livelihood activities, institutional architecture (including rules and norms of governance), adjustments in farming operations, income generation projects, sale of labour (e.g., migrating to earn an income) and the move towards non-farm livelihood incomes represent key adaptation options.[64]

Reducing risks with regard to possible future events will depend on the building of stronger livelihoods to ensure resilience to future shocks. Also important is the role of migration as an adaptive measure, particularly as a response to droughts and floods.

Institutions and their effectiveness as well as technology also play a critical role in successful adaptation.

Resilience to droughts may be supported by improvements in existing rain-fed farming systems like improved water-harvesting systems and irrigation.

Improved early warning systems may also reduce vulnerability to future risks associated with climate variability and change. In malaria research, for example, it has been shown

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[61] See Hare, W., and Meinhausen (2004). How much warming are we committed to and how much can be avoided? *PIK Report No. 39, Postdam Institute for Climate Impact Research, Postdam*, pp. 94.

[62] Stern, N., (2007). The Economics of Climate Change – The Stern Review. Cambridge University Press, Cambridge, UK.

[63] See Block, S. and P. Webb, 2001: The dynamics of livelihood diversification in post famine Ethiopia. *Food Policy*, **26**, 333-350., Brooks, N., W.N. Adger and P.M. Kelly, 2005: The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. *Global Environ. Chang.*, **15**, 151-163.

[64] Bryceson, D.F., 2004: Agrarian vista or vortex: African rural livelihood policies. *Review of African Political Economy*, **31**, 617-629.

that while epidemics in the highlands have been associated with rises in temperature, those in the semi-arid areas are mainly associated with excessive rainfall. Using such climate information, it may be possible to give outlooks with lead times of two to six months before the onset of an event. Such lead times provide opportunities for putting interventions in place, thereby preventing excessive morbidity and mortality during malaria epidemics.

In Africa, biotechnology research could also yield tremendous benefits. It could potentially lead to drought-and-pest-resistant rice, drought-tolerant maize and insect-resistant millet, sorghum and cassava, among other crops.

A detailed study of current crop selection as an adaptation strategy to climate change in Africa shows that farmers shift towards more heat-tolerant crops as the weather becomes warmer.[65]

It should be noted that while biotechnology could provide opportunities for adaptation to climate change in Africa, at present, the issue remains contentious due to misgivings about genetically-modified crops.

Other options that could be investigated to enhance resilience to shocks such as droughts include: national grain reserves, grain future markets, weather insurance, the role of food price subsidies, cash transfers and school feeding schemes.

The design and use of proactive rather than reactive strategies would enhance adaptation.

Adaptation costs, constraints and opportunities

Many of the options outlined above come with costs and constraints. However, deriving quantitative estimates of the potential costs of the impacts of climate change and the resource needs for adaptation is difficult.

Limited availability of data and a variety of uncertainties relating to future changes in climate, social and economic conditions, and the responses that will be made to address those changes, frustrate precise cost and economic loss inventories.

Despite these limitations, some economic loss inventories and estimates have been made. In some cases, assessments have attempted to measure costs that may arise with and without adaptation to climate change impacts.

As assessment of the impacts of sea-level rise in coastal states has revealed that the costs of adaptation could amount to 5 percent to 10 percent of GDP. However, if no

[65] Kurukulasuriya, P. and R. Mendelsohn, 2006b: Crop selection: adapting to climate change in Africa. Centre for Environmental Economics and Policy in Africa (CEEPA) Discussion Paper No. 26. University of Pretoria, Pretoria, 28 pp.

adaptation is undertaken, the losses due to climate change could be up to 14 percent of the GDP.

There is also evidence of an erosion of coping and adaptive strategies as a result of varying land-use changes and socio-political and cultural stresses. The interaction of both social (e.g., access to food) and biophysical (e.g. drought) stresses combine to aggravate critical stress periods (e.g., during and after ENSO events). Traditional coping strategies may not be sufficient in this context, either currently or in the future.

The erosion of traditional coping responses not only reduces the level of resilience to the next climatic shock, but also to the full range of shocks and stresses to which the poor are exposed. Limited scientific capacity and other scientific resources are also factors that frustrate adaptation.[66]

The low adaptive capacity of Africa is due largely to the extreme poverty in many countries, the frequent natural disasters such as droughts and floods, agriculture that is heavily dependent on rainfall, and other structural weaknesses. Factors heightening vulnerability to climate change and affecting national-level adaptation have been shown to include issues of local and national governance, civil and political rights and literacy.

At the more local level, the poor often cannot adopt diversification as an adaptive strategy and often have very limited diversification options available to them. Microfinancing and other social safety nets and social welfare grants, as a means to enhance adaptation to current and future shocks and stresses, may be successful in overcoming such constraints if supported by local institutional arrangements on a long-term sustainable basis.[67]

African and Asian regions should focus on increasing their adaptive capacities to climate variability and climate change over the long term. Ad hoc responses (e.g., short-term responses, uncoordinated processes and isolated projects) are only one type of solution. Other solutions could include mainstreaming adaptation into national development processes[68].

There may be several opportunities that link disaster risk reduction, poverty and development (see, for example, existing calls for such action, such as the Hyogo Declaration)[69]. In places where communities live with various risks, coupling risk reduction and development activities can provide additional adaptation benefits.

Unprecedented efforts by governments, humanitarian and development agencies to collaborate in order to find ways to move away from reliance on short-term emergency

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[66] Washington, R., M. Harrison and D. Conway, 2004: African climate report. Report commissioned by the UK Government to review African climate science, policy and options for action, 45 pp.

[67] Chigwada, J., 2005: Climate proofing infrastructure and diversifying livelihoods in Zimbabwe. *IDS Bull*, **36**, S103-S116.

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

[69] See http://www.unisdr.org/wcdr/intergover/official-doc/L-docs/Hyo-go-declaration- english.pdf)

responses to food insecurity to longer term development-oriented strategies that involve closer partnerships with governments are also increasing.

The African and Asian continents alike have always battled the vagaries of the weather and climate. These struggles, however, are increasingly waged alongside a range of other stresses, such as HIV/AIDS, as well as territorial conflicts.

Despite good economic growth in some sectors and countries in Africa and Asia, large inequalities still persist, and the hopes of reaching the MDGs by 2015 are slim.[70] While climate change may not have featured directly in the setting of the MDGs, it is clear from the evidence presented here that climate change and variability may be an additional impediment to achieving them. A challenge exists, therefore, in attempting to shape and manage development that also builds resilience to shocks, including to the ones resulting from climate change and variability[71 72].

It is generally agreed that effective adaptation strategies should show an ability to reduce present as well as future vulnerabilities to climate change. Adaptation measures can contribute to equitable and sustainable policies and to the present development decision frameworks by reducing present day risks from climate variability and by being relevant to immediate national development priorities.[73] This strategy has been referred to as a "no regrets" adaptation strategy. Reducing present vulnerability to climatic hazards should help to prepare for the potential future impacts of climate change.

For the most vulnerable groups, adaptation strategies are vital as failure to adapt to climate change could lead to "significant deprivation, social disruption and population displacement, and even morbidity and mortality".

The problem is in identifying those adaptations that favour the most vulnerable groups. Many adaptation strategies, such as large-scale agriculture, irrigation and hydroelectric development, will benefit large groups or national interests but may harm the local, indigenous and poor population.

2. Adaptation in the Small Island Developing States

Many SIDS have already started to implement adaptation strategies on a local scale, often in an ad hoc manner. For example, placing concrete blocks on the top of zinc

[70] UNDP, 2004: *Reducing Disaster Risk: a Challenge for Development.* UNDP Bureau for Crisis Prevention and Recovery, New York, 161 pp.

[71] See 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., and Hulme, M., R. Doherty, T. Ngara and M. New, 2005: Global warming and African climate change. *Climate Change and Africa*, P.S Low, Ed., Cambridge University Press, Cambridge, 29-40.

[72] 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.

[73] Ibid 92

roofs to prevent the roofs from being blown away during hurricanes has become common practice in Jamaica since Hurricane Ivan.

In Vanuatu, the South Pacific Regional Environmental Programme, with funding from the Canadian government, has moved 100 villagers living in the Lateu settlement to higher ground 600m from the coast and 15m above current sea level as frequent flooding and erosion made the original location of the settlement uninhabitable.

Using traditional knowledge is key in many SIDS for enhancing resilience and finding strategies to cope with the changing climate.

For example, on Timor Island, farmers have developed their own varieties of major staple crops to adapt to erratic rainfall and cyclones and to ensure food security.

Practices for coping with coastal erosion can be useful in adapting to rising sea level. For example, at Playa Rosaria, Havana Province, Cuba, the community has been relocated five kilometers inland as a result of coastal erosion. Other less disruptive activities such as reconstructing groynes, building sand dune fences, and planting trees along the coast can also reduce the impact of coastal erosion on communities.

With the predicted decrease in water resources, island specific actions for adaptation to enhance water resources should include: incentives to encourage the use of water saving devices; selecting appropriate drought tolerant vegetation; establishing river buffer zones to enhance the resilience of the river and catchments area; updating national water policies and improving water resources management.

In the area of water resource management, revising building codes to increase opportunities for rainwater catchments and storage would be advantageous. A few other profitable water resource management options will include preparing water resource master plans for the islands; assessing and improving the water supply systems; rainwater harvesting; water demand management; provision of water storage and water efficient household appliances; flood risk analyses with land zoning and flood mitigation actions.

Biodiversity-centered frameworks also need to be established in order to promote less destructive environmental practices. Training fishermen and women in sustainable fishing practices is another possible adaptation strategy.

As far as land management is concerned, creating land use plans and corresponding enforcement strategies, strengthening institutional capacity to enforce land zoning restrictions and the application of beach setbacks for construction are all viable adaptation strategies.

Adaptation can also occur through the prevention and removal of maladaptive practices. Maladaptation has been defined by the IPCC as “any changes in natural or human systems that inadvertently increase vulnerability to climatic stimuli.” An alternate definition for maladaptation is: “an adaptation that does not succeed in reducing vulnerability but increases it instead." Examples of laws and practices that can inadvertently increase vulnerability include: policies that lead to the destruction of mangroves; the relaxation of coastal setback regulations; laws preventing the use of recycled water by hotels and an absence of comprehensive coastal zone management and planning. Individuals can carry out maladaptive practices by deliberately ignoring the risks posed by climate change (such as repeatedly rebuilding property in a vulnerable zone)[74].

Adaptation options must be selected carefully, depending on the uniqueness and the specificity of the issue which is to be addressed. In most cases, however, small island states lack the capacity and resources to integrate climate change concerns in development activities and to undertake the adaptation actions required.

3. Adaptation within the context of the UNFCCC

During the 1990s, a large portion of the scientific research and negotiations concentrated on mitigation. This resulted in the formulation of the Kyoto Protocol in 1997. There was a divergence between the priorities of the developed countries (to reduce greenhouse gas concentrations) and those of the small island and least developed countries (to reduce their vulnerabilities to climate change).

The reduction of greenhouse gas concentrations has also been the main objective of the UNFCCC. However, in the last few years, the scientific community has increasingly realized the importance of adaptation, especially for the developing countries and particularly the LDCs, which are the most vulnerable countries to climate change.

This recognition is given in Article 4, paragraph 9, of the UNFCCC, which states that "parties shall take full account of the specific needs and special situations of the least developed countries in their actions with regard to funding and transfer of technology."

As part of the Marrakech Accords, the Conference of the Parties to the UNFCCC (COP) in its decision established the LDC Expert Group and a work programme for the Least Developed Countries.

The Least Developed Countries Expert Group (LEG) has been tasked, amongst other obligations, with assisting LDCs in preparing their national adaptation programmes of action (NAPA).

NAPA is a process which identifies the urgent and immediate needs of LDCs for adaptation to climate change and an action plan to implement adaptation. At least 40 of the 49 LDCs have completed NAPAs.[75]

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[74] Ibid 28

[75] As of 31 August 2009. See UNFCC website: http://unfccc.int/cooperation_support/least_developed_countries_portal/submitted_napas/items/4585.php

In November 2006, the 12th Conference of Parties (COP 12) of the UNFCCC adopted the Nairobi Work Programme (NWP) on impacts, vulnerability and adaptation to climate change. The objectives of the five-year programme are two fold:

1. To assist countries, in particular developing countries, including the least developed countries and small island developing States, to improve their understanding and assessment of impacts, vulnerability and adaptation; and
2. To assist countries in making informed decisions on practical adaptation actions and measures to respond to climate change on a sound, scientific, technical and socio-economic basis, taking into account current and future climate change and variability.

It is important that the implementation of the Nairobi Work Programme and similar initiatives prioritise the adaptation needs of the LDCs and SIDS.

National Adaptation Programmes

In a number of Least Developed Countries, some adaptation projects are being implemented through the National Adaptation Programmes of Action to enhance resilience and adaptive capacity. They mostly cover the areas of water resources, food security and agriculture, disaster preparedness and risk management, coastal zone management and infrastructure, natural resources management and community level adaptation.

Resources for adaptation projects are being provided through the Least Developed Countries Fund (LDCF). Adaptation projects being supported through the LDCF include[76]:

a. **Bangladesh:** Community based adaptation to climate change through coastal deforestation – US$3 million
b. **Bhutan:** Reduction of the climate change-induced risks and vulnerabilities from glacial lake outbursts in the Punakha-Wangdi and Chamkar Valleys – US$3.64 million
c. **Cambodia:** Building capacities to integrate water resources planning into agricultural development – US$1.8 million
d. **Djibouti:** Reduction of the impacts and vulnerability of coastal productive systems in Djibouti – US$2 million
e. **Eritrea:** Integration of the climate change risks into community based livestock management in the north western lowlands – US$3 million
f. **Malawi:** Climate Change adaptation for rural livelihood and agriculture – US$3 million

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[76] Biagini, B. 2007. NAPA Implementation in Practice – current status of the LDCF portfolio, a paper presented at the *LEG Stocktaking Meeting on NAPA*, Bangkok, Thailand, 3-5 September 2007.

g. **Mauritania:** Reduction of the climate change vulnerability of arid zones through improved water shed management – US$1.3 million

h. **Niger:** Building resilience and adaptive capacity of the agricultural sector to climate change – US$2 million

i. **Samoa:** Integrated climate change adaptation – US$2 million

j. **Sudan:** Building resilience in the water and agricultural sectors to the adverse impacts of climate change – US$3 million

Table 7: Examples of adaptation projects from national adaptation programmes of action in selected Least Developed Countries

Country	Climate Change Vulnerabilities	Adaptation Actions	Outcomes
Bangladesh	• Sea Level Rise and salt water intrusion into agricultural lands • Increased frequency of storms and floods in coastal zones	• Pilots at community level • Mangrove/wetland restoration • Innovative ways of securing potable water • Promotion of alternative livelihoods • Improvement of institutional and technical capacity, including early warning systems	• Reduced risk of hunger and conflict • Reduced loss of life and infrastructure from climate-induced disasters
Bhutan	• Glacial outbursts causing massive floods in river valleys	• Increased disaster risk management capacity • Artificial lowering of water level in glacial lakes • Creation of an early warning system for glacial floods	• Reduced risk of massive destruction from flooding • Limitation of human and economic losses
Cambodia	• Increased drought and/or flooding poses risk to agricultural sector and food security	• Training of adaptation experts in extension teams • Implementation of pilot projects in local communities, i.e. rainwater harvesting, measures to reduce soil erosion, changes to the design of reservoirs and irrigation channels to prevent risks from peak flows • Dissemination of lessons learned at the national and international levels	• Increased food security and sustainable agricultural development • Reduced risks of climate-induced disasters

Djibouti	• Decreasing the availability of freshwater from decreased rainfall and salt water intrusion • Increasing risk of coastal inundation • Increasing frequency of flash floods	• Rehabilitate coastal buffers • Strengthen early warning system and improve disaster management capacity • Strengthen institutional capacity to implement integrated coastal zone management	• Reduced risk of climate-induced disasters • Reduced impacts of climate change on productivity and food security in coastal communities
Eritrea	• Increasing frequency of seasonal and multi-year droughts resulting in reduced productivity of pastoralist systems affecting food security	• Improved water and forage management • Improved dissemination of short to medium term climate forecasts to pastoral communities • Promotion of alternative and/or supplemental livelihoods • Capacity-building for agricultural extension services to incorporate climate change issues into water and forage management	• Increased food security and sustainable development • Reduced competition for water resources between agriculturalists and pastoralists – reducing the potential for conflict
Malawi	• Drought and rainfall variability pose risks to agricultural sector and food security	• Crop diversification • Improved cropping sequences • Conservation tillage • Irrigation and efficient use of water • Food storage • Creation of an enabling environment for climate risk management, i.e., policy development and implementation, institutional coordination and generation of knowledge and awareness raising	• Increased food security and sustainable development
Mauritania	• Decreasing rainfall and poor water management leading to the low quantities of water	• Run-off dikes to capture rainfall • Promote water use efficient technologies • Dissemination of drip irrigation techniques • Building codes to prevent building on the ground water recharge zones • Policy and institutional support	• Sustainable availability of water for agriculture, domestic use and tourism

Niger	• Decreasing annual rainfall • Increasing temperature variability	• Improved water harvesting, storage, and small-scale irrigation techniques • Introduction of new heat and drought tolerant plant varieties • Planting wind barriers/ breaks and tees along irrigation canals • Rehabilitation of vegetation cover and rangelands • Improved early warning system, and capacity-building at local and national levels	• Increased food security and sustainable agricultural development
Samoa	• Sea Level Rise, loss of land, intrusion of salt water into freshwater affecting livelihoods • Increased storminess, flooding, loss of life, crops and infrastructure • Increasing climate-related health problems • Increased intensity of rainfall and drought	• Improvement of capacity in health sector • Improving and disseminating seasonal forecast • Improvement of early warning systems	• Decreased loss of life and prevention of tropical diseases • Increased food and water security • Decreased loss of life and livelihood from climate-induced disasters
Sudan	• Decreasing annual rainfall • Increasing rainfall variability and temperatures	• Improved water harvesting, storage, and small-scale irrigation techniques • Introduction of new heat and drought tolerant plant varieties • Planting wind barriers/ breaks and trees along irrigation canals • Rehabilitation of vegetation cover and rangelands • Improved early warning systems, and capacity-building at local and national levels	• Increased food security and sustainable agricultural development

In the Small Island Developing States, a number of projects have been developed to build adaptive capacities and provide further options for adaptation. These projects not only involve strengthening institutions, policies and regulations, but also ground-level tasks such as water storage and drought resistant crops. Many are acting in synergy with projects on the mainstreaming of adaptation.

These programmes are being implemented within the framework of UNFCCC with the support of bilateral development assistance agencies, multilateral financial institutions and UN agencies, especially those that serve as Global Environment Facility (GEF) implementing agencies.

The adaptation programmes vary in scope. Some projects provide support for multiple countries, including the GEF-UNDP project "Piloting Climate Change Adaptation to Protect Human Health" and the GEF-World Bank project on Mainstreaming Adaptation to Climate Change in the Caribbean region (MACC).

Table 8 lists some of the main adaptation projects involving SIDS. For SIDS that are also LDCs, such projects are complemented by the National Adaptation Programmes of Actis.

Table 8: Selected climate change adaptation projects in SIDS

Project	Region
Implementation of Pilot Adaptation Measures in coastal areas of Dominica, St. Lucia and St. Vincent and the Grenadines, Regional (2006–2010)	Caribbean
Kiribati Adaptation Program, Phase II (2006–2009)	Pacific (National)
Mainstreaming Adaptation to Climate Change, Regional (2002–2007)	Caribbean
Coastal Resilience to Climate Change: Developing a Generalized Method for Assessing Vulnerability and Adaptation of Mangroves and Associated Ecosystems	Global
Adaptation to Climate Change in the Tourism sector in Fiji Islands	Pacific
Pacific Islands Adaptation to Climate Change Project	Pacific
Piloting Climate Change Adaptation to Protect Human Health	Global
Wise Practices for coping with Climate Change in Mauritius (2006)	Indian Ocean (National)
Assessments of Impacts and Adaptations to Climate Change (AIACC) in Multiple Regions and Sectors, 2001–2006	Global
Capacity building for Stage II adaptation to climate change (2003–2005)	Caribbean
South Pacific Sea Level and Climate Monitoring Project (SPSLCM), 2000–2005	Pacific
Capacity building for the development of adaptation measures in the Pacific island Countries (CBDAMPIC), 2002–2005	Pacific
Adaptation to Climate Change in the Caribbean (ACCC), 2001–2004	Caribbean
Caribbean Planning for Adaptation to Climate Change (CPACC), 1997–2001	Caribbean
Climate Adaptation in the Pacific, 2001–2003	Pacific
Pacific Islands Climate Change Assistance Programme (PICCAP), 1997–2000	Pacific

Many of the adaptation projects and programmes have assisted in the enhancement of national and regional capacity as it relates to climate change adaptation. This has been demonstrated in the Caribbean where the Caribbean Planning for Adaptation to Climate Change project has led to the establishment of the Caribbean Climate Change Centre to help address climate change concerns within the region.

Despite such projects, the need to develop adaptation capacity remains high. Adaptation to climate change cannot be addressed in isolation but needs to be incorporated into developmental activities. Enhancing adaptive capacity will only be successful when it is integrated with other policies such as disaster preparedness, land-use planning, environmental conservation, coastal planning, and national plans for sustainable development.[77]

[77] Sutherland, K., B. Smit, V. Wulf and T. Nakalevu, 2005: Vulnerability to climate change and adaptive capacity in Samoa: the case of Saoluafata village. *Tiempo*, **54**, 11-15.

INTERNATIONAL COOPERATION

1. Mitigation

Climate change is a matter of future viability or even survival for many Least Developed Countries and Small Island Developing States. While the greenhouse gas emission levels by LDCs and SIDS are insignificant, emissions by other countries have a disproportionate effect on them as discussed earlier. As well as adaptation, therefore, getting other countries to reduce their greenhouse gas emissions is a priority for LDCs and SIDS.

At the international level, LDCs and SIDS are members of the Group of 77 and China (G77/China), a negotiating bloc of developing countries. However, the G77/China also has some of largest greenhouse gas emitters among developing countries.

The dilemma for LDCs and SIDS is that they are members of the same negotiating group with countries whose emissions levels are continuously increasing. These same countries are reluctant to reduce greenhouse gas emissions because of their development objectives.

Members of the Organization of Petroleum Exporting Countries (OPEC) are also G77/China constituents. Burning fossil fuels is one of the main contributors to greenhouse gas emissions. Cutting greenhouse gas emissions may not be in their short-term economic interests.

The large developing country emitters, who are members of G77/China, often refer to the principle of common but differentiated responsibilities, as a justification for not taking action to reduce their respective greenhouse gas emissions.

As a consequence, SIDS and LDCs are at variance with their developing country negotiating partners with regard to greenhouse gas emission reductions. SIDS and LDCs will need to convince their partners to take on the responsibility of reducing their greenhouse gas emissions.

2. Adaptation

Given that the emission levels of SIDS and LDCs are extremely low, their policy actions are largely restricted to adaptation.

On their own, SIDS and LDCs cannot afford the costs of adaptation. Studies have estimated the cost of protecting the coasts of Jamaica from a sea-level rise of one metre at US$462 million[78]. Adaptation costs have been estimated at US$71 million in Antigua and US$50 million in St Kitts and Nevis.

The World Bank has estimated that between US$10 billion and US$40 billion will be required for adaptation in developing countries. At the global level, there have been

[78] Government of Jamaica, Jamaica's First National Communication to the UNFCCC (Government of Jamaica 1999)

some global funds which have been established to assist groups of countries such as SIDS and LDCs with the costs associated with adaptation.

One of these funds, the Adaptation Fund, obtains its resources through a 2 percent levy on the Clean Development Mechanism projects mandated by the Kyoto Protocol. Some estimates have established that the fund could provide between US $270 million and US $600 million[79] for adaptation projects. Clearly, this is not enough to meet even just the current adaptation needs.

The Global Environment Facility (GEF), as an entity entrusted with operating the financial mechanism of the UNFCCC, established the Strategic Priority on Adaptation (SPA) under its Trust Fund.

The objective of the SPA is to reduce vulnerability while increasing adaptive capacities to the adverse effects of climate change. The SPA supports pilot and demonstration projects that address local adaptation issues whilst generating global environmental benefits simultaneously.

The Special Climate Change Fund (SCCF) aims at supporting activities in the following areas: (i) adaptation; (ii) technology transfer; (iii) energy, transport, industry, agriculture, forestry and waste management; and (iv) economic diversification. Adaptation activities to address the adverse effects of climate change have top priority for funding under the SCCF.

The Least Developed Countries Fund established under the UNFCCC provides funding for adaptation activities in LDCs. The fund has provided financial support to over 40 National Adaptation Programmes of Action. As of August 28, 2007 total available resources of the Least Developed Countries Fund, including new contributions and pledges, had reached US $150 million of which US $10 million was spent on the preparation of NAPAs.

There is no specific fund which addresses the concerns of SIDS, yet SIDS, along with LDCs, are the most vulnerable to climate change.

In the context of the current negotiations on climate change, special consideration needs to be given to funding adaptation needs in SIDS. Priority access for SIDS to the current Adaptation Fund is one element, whereas the establishment of a special fund to address the adaptation needs of SIDS should be considered an option.

In addition to international agreements on climate change, there is a need to integrate climate change concerns in other development programmes at the global level. With regard to the Least Developed Countries, the Fourth United Nations Conference on the Least Developed Countries planned for 2011 will be an opportunity to mainstream adaptation needs in the broader development agenda for the LDCs.

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[79] See Muller B, (2006) Climate of Distrust: The 2006 Bonn Climate Change Adaptation Fund Negotiations. http://www.oxfordenergy.org/pdfs/comment_0606-1.pdf

CONCLUSIONS AND RECOMMENDATIONS

The Least Developed Countries and Small Island Developing States are at the frontline of climate change effects, but they remain on the margins of the current debate on climate change. Given that their contribution to greenhouse gas emissions is minute, and that climate change would continue even with the most optimistic global reductions in greenhouse gas emissions, the priority focus of LDCs and SIDS is, rightly, adaptation.

Adaptation to climate change in LDCs and SIDS is not only a sustainable development challenge but also, in some cases, a survival issue. For adaptation to be successful, a number of actions are required at both national and international levels:

a. In order to make better and informed decisions about climate change impacts, it is important to improve the understanding of multiple stresses at all levels – local, national and global. Thus more research is needed to understand the impact of climate change on LDCs and SIDS and options for adaptation in view of their structural weaknesses.

b. National Adaptation Programmes of Action prepared by the LDCs are an important step in enhancing adaptive capacity. However, most of the current adaptation programmes focus on one or two sectors. There is need for such programmes to be more comprehensive. Indeed, adaptation needs should be mainstreamed in national development plans and strategies.

c. LDCs and SIDS have neither the financial resources nor the technical capacities to meet their adaptation needs. The international community needs to provide stronger financial and technical support to the LDCs and SIDS, both through the special funds such as the Least Developed Countries Fund and other international frameworks, including the Brussels Programme of Action for the LDCs and the Barbados Programme of Action for SIDS. In the case of SIDS, consideration should be given to establishing a special fund for them along the lines of the LDC fund.

d. LDCs and SIDS can significantly enhance their adaptation capacity through regional arrangements and pooling of resources. For example, it might be more efficient to establish and manage early warning systems at regional rather than national levels.

e. LDCs and SIDS need to bring their influence to bear within the G77/China to gain support for significant reductions in global greenhouse gas emissions.

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