

Adaptation to Climate Change: A Vulnerability Assessment for Sudan

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Executive Summary

Sudan is typical of other least developed countries in Africa in being highly vulnerable to climate change and climate variability. The interaction of multiple stresses—endemic poverty, ecosystem degradation, complex disasters and conflicts, and limited access to capital, markets, infrastructure and technology—have all weakened people’s ability to adapt to changes in climate.

This study assesses Sudan’s vulnerability to climate change. By overlaying maps of population distribution, poverty, rainfall distribution and variability, and incidence of environmental hazards, it has been possible to identify the states which are most vulnerable to climate change. It also outlines some of the actions being taken to help the country to adapt to a changing climate, and makes recommendations for how such actions could become more effective. For example:

- Adaptation activities need to be implemented in an integrated way and take a long-term view, rather than involving short-term, stand-alone projects.
- Institutions working on environmental issues should be better co-ordinated.
- A national sustainable development strategy is needed to co-ordinate and build on synergies among the recommendations of the National Adaptation Programme of Action (NAPA), the National Action Plan on Desertification (NAP) and the National Biodiversity Action Programme (NBSAP).
- Adaptation work should involve vulnerable communities at the local level and take a bottom-up approach to project planning.
- Water resource laws need to be reformed, particularly those that govern the cost and distribution of water and the use of money generated from water projects in vulnerable communities in arid and semi-arid lands.
- Climate monitoring and early warning systems would help to reduce the very high impact of climate-related disasters.

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Introduction

In recent times, human activities have caused, and are continuing to cause, great changes to the composition of the atmosphere. The major concern of both scientific and public communities is the enhanced greenhouse effect caused by anthropogenic activities. The findings of the Intergovernmental Panel on Climate Change (IPCC) have shown that climate change is already having strong impacts on human societies and the natural world, and is expected to do so for decades to come (IPCC, 2007).

Sudan is a least developed country in Africa—one of the most vulnerable continents to climate change and climate variability. This situation is aggravated by the interaction of multiple stresses occurring at various levels, such as endemic poverty; institutional weaknesses; limited access to capital, including markets, infrastructure and technology; ecosystem degradation; complex disasters and conflicts. These in turn have weakened people's adaptive capacity, increasing their vulnerability to projected climate change (Box 1; and IPCC, 2007).

This paper assesses Sudan's vulnerability to climate change and outlines some of the actions being taken to help the country to adapt to a changing climate. The author is an active participant in national climate change activities and is also actively engaged with NGOs and co-ordinating Sudan's role in Community-based Adaptation in Africa (CBAA; see below).

Sudan: a country of contrasts

Sudan is the largest country in Africa, covering over 250 million hectares. The country extends gradually from the desert in the north, with its hot dry climate and almost no vegetation cover, to the African sahel zone in the centre (dry to semi-dry climate) with its light and dense savanna, to the sub-tropical region in the south with heavier rains and dense tree cover. The south western parts of Sudan have a sub-humid to humid climate.

BOX 1. DEFINITIONS: VULNERABILITY AND ADAPTATION

Vulnerability is the potential to be adversely affected by an event or a change and the ability to cope with or recover from its impacts. The extent to which climate change may damage or harm a system depends on the system's sensitivity and ability to adapt to new conditions. Physical vulnerability refers to exposure to stress and crises resulting from physical hazards, while social vulnerability refers to the inability of individuals and communities to respond to physical impacts. Vulnerability may be considered at many levels, including the individual, household, national or regional level.

Adaptation is the adjustment in natural or human systems in response to actual or expected climatic change or their effects, to reduce harm or exploit beneficial opportunities. Adaptation involves changing processes, practices or structures, either automatic or planned, by individuals, households, governments and other stakeholders. The capacity to adapt depends largely on access to assets (including natural resources; and human, technological, social, physical and financial capital) and how well these are used.

Source: Oriandi and Zakieldeen, 2006.

A variable and unpredictable climate

Sudan is one of the driest but also the most variable countries in Africa in terms of rainfall. Extreme years (either good or bad) are more common than average years (Zakieldeen, 2007). Rainfall, on which the overwhelming majority of the country's agricultural activity depends, is erratic and varies significantly from the north to the south of the country (Figure 1). The unreliable nature of the rainfall, together with its concentration into short growing seasons, heightens the vulnerability of Sudan's rainfed agricultural systems.

Mean annual temperatures vary between 26°C and 32°C across the country. The most extreme temperatures are found in the far north, where summer temperatures can often exceed 43°C and sandstorms blow across the Sahara from April to September. These regions typically experience virtually no rainfall, while in the southern regions, climatic conditions are more equatorial with average annual rainfall over 1,000 mm/year (Fadel-El Moula, 2005; NAPA, 2007).

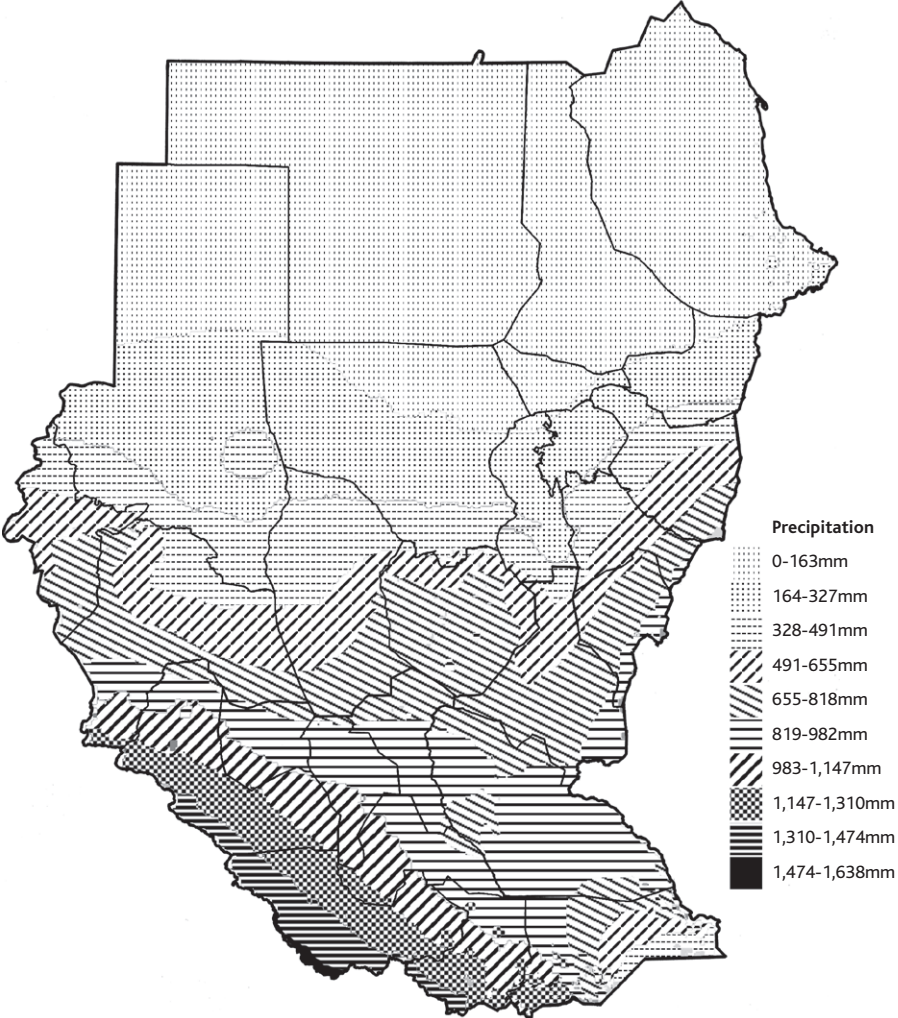
Rainfall is also very variable, and is becoming increasingly unpredictable. The coefficient of rainfall variability (CV, or the percentage deviation from the norm), measures the uncertainty of rainfall: the higher the CV percentage the more uncertain the rainfall. In Sudan the CV decreases from north to south (190% to less than 15%, Figure 2). The CV seemed to increase between 1941 and 2000 according to data from some weather stations (Elfasher, Kassala, Karima; Figure 3). Average rainfall also declined over the same period (Figure 4). Declining and uncertain rainfall makes life very difficult for traditional farmers and herders and severely affects their livelihoods.

The people

In 2007, Sudan's population was estimated at over 37 million, with one of the highest annual growth rates in the world (2.6%). Though population density is about 10 people

per square kilometre, densities in areas with arable and cultivated land are considerably higher (63 and 370 people per square kilometre respectively; NAPA, 2007).¹ This means that much of the population is clustered in central Sudan and along the Nile River.

FIGURE 1. ANNUAL RAINFALL DISTRIBUTION IN SUDAN, 2004.
SOURCE: AWHERE DATABASE (REDRAWN)



¹ Arable land is defined as land suitable for cultivation, but not necessarily cultivated.

FIGURE 2. SUDAN RAINFALL COEFFICIENT OF VARIABILITY (%), 1971-2000.
 SOURCE: FADEL-EL MOULA, 2005

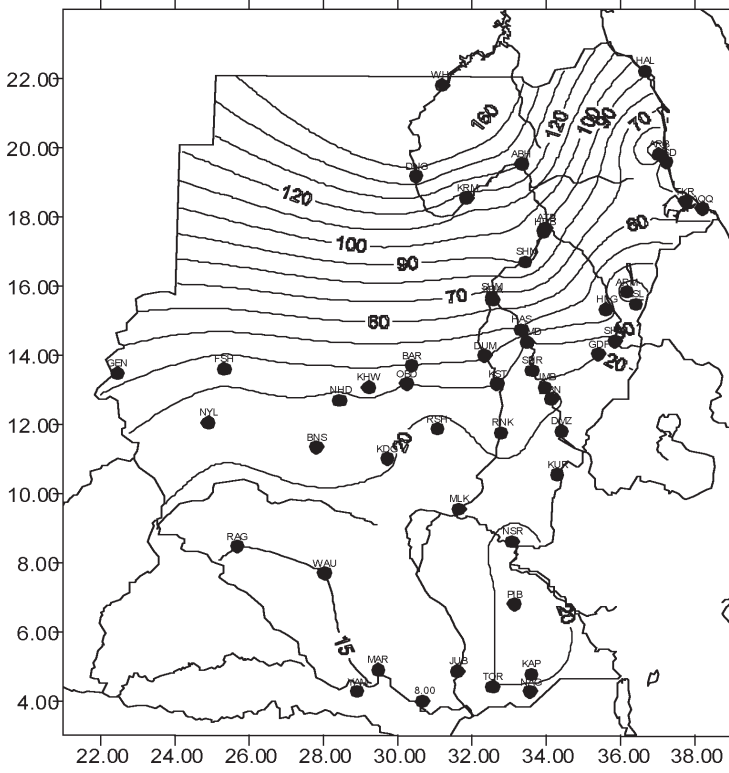


FIGURE 3. THE COEFFICIENT OF VARIABILITY OF RAINFALL FOR FIVE DIFFERENT WEATHER STATIONS IN EAST, NORTH AND WEST SUDAN, 1941-2000.
 SOURCE: ADAPTED FROM FADEL-EL MOULA, 2005

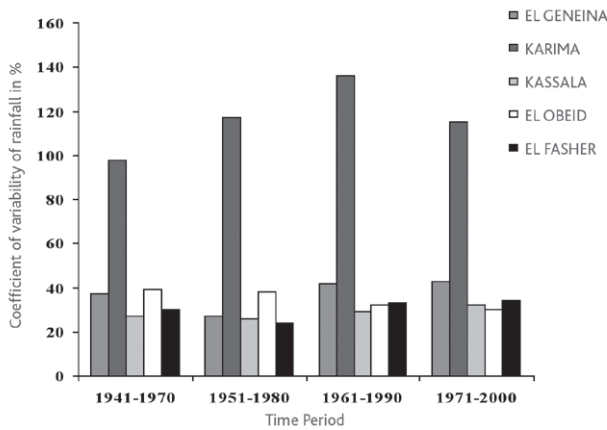
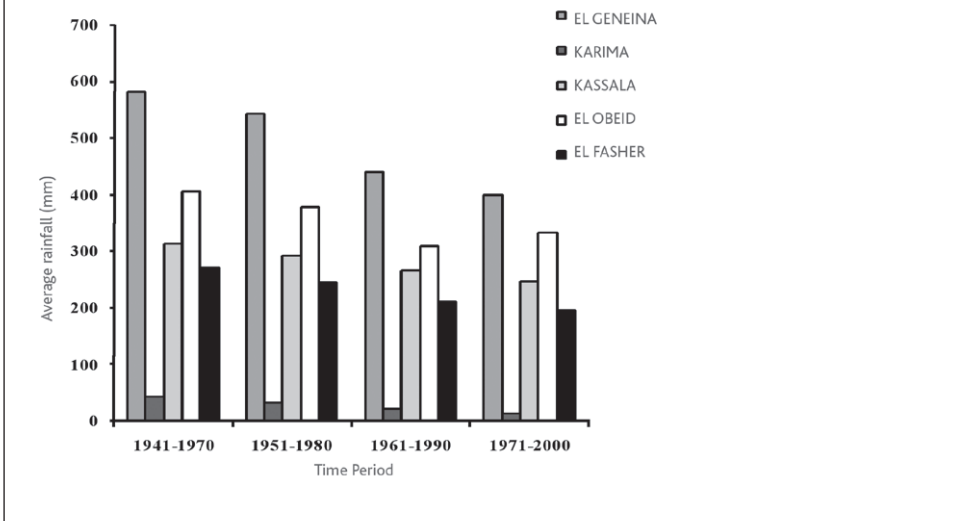


FIGURE 4. AVERAGE RAINFALL TRENDS (MM) FOR SOME AREAS OF SUDAN, 1941-2000
 SOURCE: ADAPTED FROM FADEL-EL MOULA, 2005



The vast majority of the population is poor, with an average per capita income of less than US\$400 a year. However, this low level masks wide regional disparities in economic and social development. Certain states are below the national rural poverty average (Figure 5: Kordofan, Blue Nile, Kassala and Red Sea states). Educational levels in these states are low and the burden of disease is heavy and widespread. Infrastructure (roads, river traffic, railways power, water, telecommunications as well as irrigation facilities) is either non-existent or underdeveloped and inadequate; the little that exists is run down due to prolonged neglect (PRSP, 2004).

The Sudanese Poverty Reduction Strategy (PRSP) involved several surveys for poverty analysis, including a Multiple Indicators Cluster Survey; Poverty Reduction Survey; and the Safe Motherhood Survey (PRSP, 2004). These surveys show, among other things:

- That poverty is increasing, especially in rural areas due to the neglect of the rural sector.
- That there are only small disparities among states.
- That more than one factor is contributing to the increase in poverty levels (weak rural development, civil war, natural calamities etc.).

Table 1 compares Sudan's basic poverty indicators with other developing country groupings.

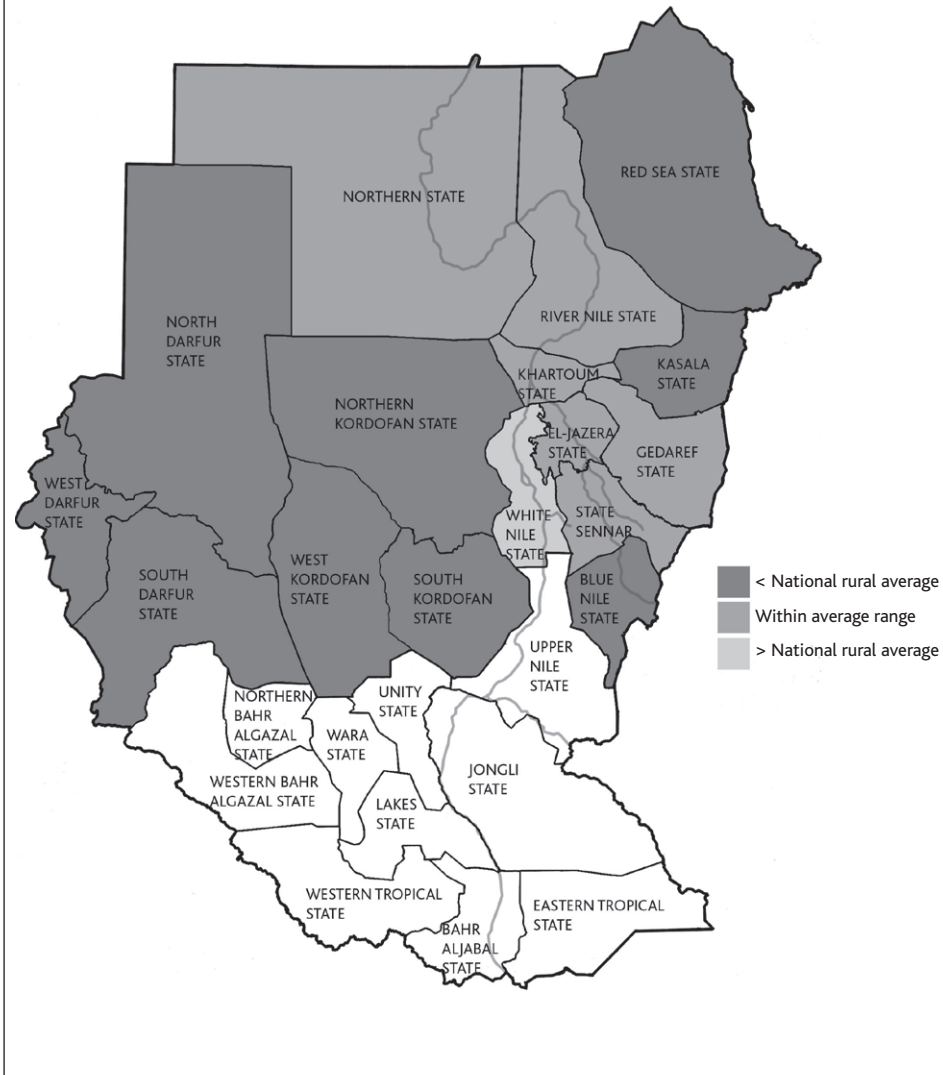
Sudan's actions to tackle climate change

Sudan has been actively engaged in climate change activities and negotiations. The country is party to both the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. Currently Sudan is leading the biggest negotiating group, the group of 77 and China, in the climate change negotiations to formulate new commitments post-2012 and to enhance the implementation of the convention.

TABLE 1. BASIC POVERTY INDICATORS FOR SUDAN COMPARED TO OTHER LEAST DEVELOPED COUNTRIES (LDCS) AND ARAB COUNTRIES, 2000					
Indicators	Sudan %	Future target based on expected available budget	LDCS %	Arab countries %	Developing countries %
Basic education					
Basic education enrolment rate	75.2%	90%	60.4%	86.4%	85.7%
Literacy rate	50.1%	41.1	59.1%	59.7%	28.3%
Health					
Infant mortality rate	68/1,000	65/1,000	103/1,000	55/1,000	64/1,000
Child mortality rate	103/100,000	96/100,000	161/100,000	72/100,000	93/100,000
Maternal mortality rate	509/100,000	478/100,000	na	na	na
Malaria rate	25%	22%	37.3%	19%	na
AIDS rate	1.6%	1.12%	4.13%	0.16%	10.18%
Water					
Drinking water provision	60%	64.5%	64%	83%	72%
Sanitation coverage	60%	66%	40%	77%	44%

Source: PRSP (2004)

FIGURE 5. RURAL POVERTY IN SUDAN (COMPARISONS BASED ON A NATIONAL RURAL AVERAGE) SOURCE: PRSP (2004) (REDRAWN)



Sudan has succeeded in meeting all its commitments under the convention, and has submitted its First National Communication to the UNFCCC. It is currently working on its Second National Communication, and also completed its National Adaptation Programme of Action (NAPA) in 2007. The aim of a NAPA is to identify a country's most urgent and immediate needs for adaptation to climate change across its different ecological zones. According to the United Nations Development Program, this initiative is a process that builds on the synergies between climate change adaptation and existing national action plans for promoting sustainable development, such as the United Nations Framework Convention on Climate Change, United Nations Convention on Biodiversity

(UNCBD) and United Nations Convention on Combating Desertification (UNCCD). Many national plans and programmes have been prepared in Sudan under these conventions in order to fulfil the country's commitments. However, to date Sudan has no strategy for sustainable development, although the relevant institutions are currently working towards developing one.

Furthermore, despite the fact that the NAPA was prepared two years ago, no project has been implemented on the ground. Currently only one out of 32 projects identified by the NAPA is being considered for funding by the Global Environment Facility. This project will be multi-regional and multi-sectoral. The NAPA targeted five different ecological zones in Sudan and focused on three sectors (agriculture, water resources and health). This project will implement adaptation activities in these three sectors across the five ecological zones. The funding for the rest of the projects will depend on the financial mechanisms of the UNFCCC and the outcome of the United Nations Climate Change Conference (COP 15) in Copenhagen in December 2009.

Sudan is also involved in a regional non-government project involving eight African countries (Kenya, Sudan, Tanzania, Uganda, Malawi, South Africa, Zambia and Zimbabwe).² Known as Community Based Adaptation in Africa (CBAA), its objective is to help vulnerable communities to adapt to climate change and share lessons learned from project activities with key stakeholders at local, national, regional and international levels to elicit their support for climate change adaptation. The CBAA is using a methodology called LOCATE (Local Options for Communities to Adapt and Technologies to Enhance Capacity) (Mozaharul Alam, 2009). Vulnerability assessment is an integral part of the LOCATE methodology, to help select priority communities for the implementation of CBAA projects. The assessment takes into account a number of elements, including poverty, climatic factors, hazards and extreme events.

Unlike the NAPA, the CBAA does not automatically target the most vulnerable area. Instead, it targets an area (in this case, Northern Kordofan) which is vulnerable to climate change but which also meets other criteria, such as the existence of a suitable partner (a national or international NGO), and a secure and conflict-free environment.

Assessing vulnerability to climate change in Sudan

The CBAA project conducted an assessment of vulnerability to climate change in Sudan at the beginning of 2009. To assess climate change vulnerability we overlaid the various maps presented in this paper (population distribution, poverty, rainfall distribution, CV, environmental hazards and others) to identify the most vulnerable states to climate change. We used an AWhere Mapping programme (Version 3.8) to overlay the maps.

² The project also has some non-African partners: the UK (IIED), Bangladesh (Bangladesh Centre for Advance Studies BCAS), and Sweden (the Stockholm Environment Institute). In Sudan the project is hosted by the Sudanese Environment Conservation Society (SECS).

Climatic vulnerability

Least developed countries (LDCs) like Sudan are particularly vulnerable to climate change because of the overwhelming dependence of their economies on natural resources, and their low adaptive capacity. Most land in Sudan is quite sensitive to changes in temperature and precipitation. Food security is mainly determined by rainfall, with more than 70% of Sudan's people directly dependent on climate sensitive resources for their livelihoods. Forested areas have already been degraded, with forest cover falling from between 36 to 43% of the country's total area in 1958, to 19% in 1990 (Zakieldeen, 2007).

Sudan has a range of ecosystems and agricultural systems (NBSAP, 2004). Throughout much of the country, water resources are limited, soil fertility is low, and drought is common. These underlying conditions are exacerbated by various human pressures. Thus, Sudan is already highly vulnerable to climatic shocks and unless adaptive measures are taken, will become even more vulnerable in the face of future climate change (NAPA, 2007). Sudan's National Adaptation Programme of Action states that the major climate-related hazards associated with climate change are droughts and extreme flooding events (Table 2). Floods in Sudan can either be localised—caused by exceptionally heavy rainfall—or more widespread, caused by the overflow of the River Nile and its tributaries.

Other climate-related phenomena—such as dust storms, thunderstorms, and heat waves—also pose a serious threat to local livelihoods, though they occur less frequently. Climate change is expected to see these hazards intensify, and the frequency of extreme events in Sudan has already increased in the last 20 years (Fadel-El Moula, 2005; NAPA, 2007).

Climate scenario analyses conducted by Sudan's First National Communication (SFNC) to the UNFCCC indicate that average temperatures are expected to rise significantly relative to the baseline (1961-1990). By 2060, average temperatures are expected to rise from between 1.5°C and 3.1°C above the baseline during August, and from between 1.1°C to 2.1°C during January. Climate change is also projected to reduce average rainfall by about 6mm per month during the rainy season. Such changes in temperature and precipitation are likely to undermine the development progress that is occurring in many sectors in Sudan.

Sudan is part of the Sudano-Sahel Region, which has been exposed to a series of recurring dry years and droughts in recent times. Demand for land has increased and the spread of cash-crop farming has been to the detriment of subsistence farming and rangelands used by nomadic people. The most vulnerable people are the farmers in western, central and eastern Sudan, whose livelihoods are exposed to the severity of drought and variability of rainfall (in terms of amount, distribution and frequency). Drought threatens approximately 12 million hectares of rainfed land, particularly in the northern Kordofan and Darfur states. Between 1971 and 2001, over ten million people in Sudan were affected by drought. In 2000, drought reduced food stocks and caused prices to rise three-fold compared to the same period in the previous year (Zakieldeen, 2007).

TABLE 2. EXTREME WEATHER AND CLIMATE EVENTS IN SUDAN: TYPES, FREQUENCY, SECTORS AFFECTED AND IMPACTS				
Event	Occurrence	Vulnerable areas	Sectors	Impacts
Drought	Frequent	North & Western Sudan (North Kordofan and Farfur), Kassala State and some parts of the rain-fed areas in central Sudan.	Agriculture, livestock, water resources and health.	Loss of crops and livestock (food shortage), decline in the hydroelectric power, displacement, wildfire
Floods	Frequent	Areas within the River Nile basin and low areas from extreme South to far North. Mountain areas along Red Sea.	Agriculture, livestock, water resources and health.	Loss of life, crops, livestock; insects & plant diseases, epidemic/vector diseases, decline in hydro power; damage to infrastructure & settlement areas
Dust storms	Frequent	Central and northern parts of Sudan	Transport (aviation and land traffic)	Air and land traffic accidents and health
Thunderstorms	Infrequent	Rain-fed areas throughout all Sudan	Aviation	Loss of lives and properties
Heatwaves	Rare	Northern, central parts of Sudan besides the Red Sea State.	Health, agriculture & livestock	Loss of life, livestock and crops
Wind-storms	Rare	Central and north central Sudan	Settlements and service infrastructure	Loss of life, property; damage to infrastructure (electricity and telephone lines)

Source: NAPA (2007)

Vulnerable sectors

Sudan's NAPA and its First National Communication to the UNFCCC both identified agriculture, water resources and health as the three sectors most vulnerable to climate change.

Agriculture

The NAPA (2007) assessed the likely impacts of future climate change on agriculture. It states that, combined with growing socioeconomic pressures, climate variability and climate change are likely to intensify the desertification of arable areas. It also predicts that the humid agro-climatic zones are likely to shift southward, rendering areas of the north increasingly unsuitable for agriculture. In addition, crop production is predicted to decline substantially for both millet and sorghum, because of decreasing rainfall and increasing variability in its distribution. The areas suitable for arable land, as well as the important gum Arabic belt, are also expected to decrease in size, with negative impacts for both local incomes and food security.

The goal of the agriculture and forestry vulnerability and adaptation assessment done by the First National Communication (SFNC) was to identify and measure the severity of climate change impacts and suggest possible adaptation options for traditional agriculture (sorghum and millet) and gum Arabic production in the Kordofan region. It suggested there would be a significant decrease in Kordofan's agricultural productivity and a reduction in gum Arabic, the state's primary cash crop (SFNC, 2002). It also suggested that the agriculture and forestry sectors, and the nation as a whole, may be hard hit by even the modest changes in temperature and precipitation which it forecast (see above).

Water resources

Climate change is expected to affect Sudan's water resources through reduced groundwater recharge brought about by decreased precipitation and/or increased temperatures and evaporation. It has been shown that soil moisture is also likely to decline under future climate change. When coupled with increased water consumption, population growth and high rainfall variability, these effects mean that the country could face a serious water crisis (SFNC, 2002; NAPA, 2007).

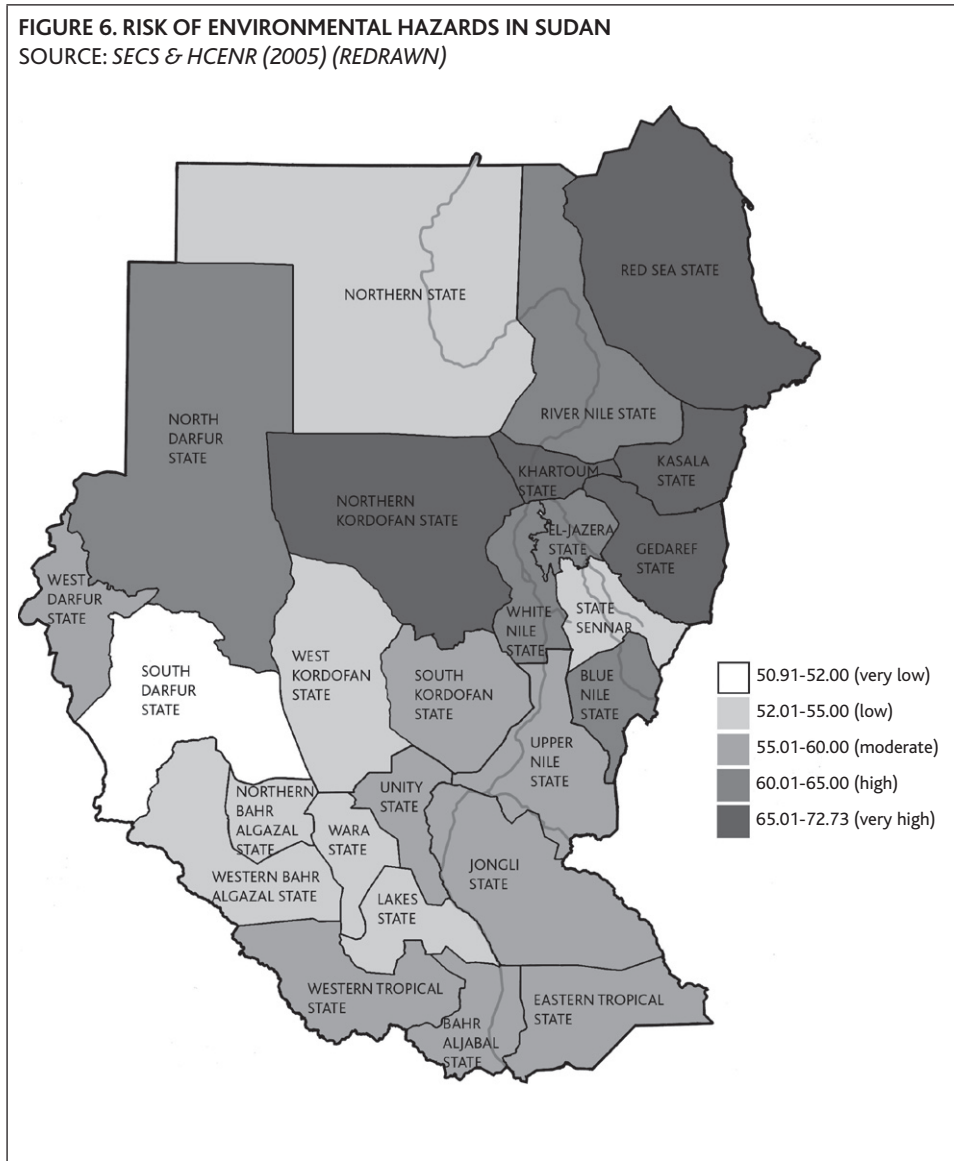
Public health

Communities in Sudan are likely to be exposed to a significantly increased risk of malaria under climate change (NAPA, 2007). Studies in Kordofan State, for example, have shown that the risk of transmission potential could increase substantially by 2060 (SFNC, 2002). This could put the already overburdened health care system under extreme stress and the disease would take a heavy toll.

Vulnerability to environmental hazards

Our study included other environmental hazards because their impacts, in conjunction with climate change, are likely to exacerbate people's vulnerability by weakening coping capacities and reducing options for adaptation. We analysed an environmental hazards map that had been drawn up for Sudan (HCENR & SECS, 2005; Figure 6). It included 11 indicators that have negative impacts on the welfare of communities in Sudan: human diseases, industrial pollution, overgrazing, deforestation, desertification, shortage of domestic water, unsafe domestic water, lack of safe sanitation, conflicts, urban problems and the effect of agrochemicals.

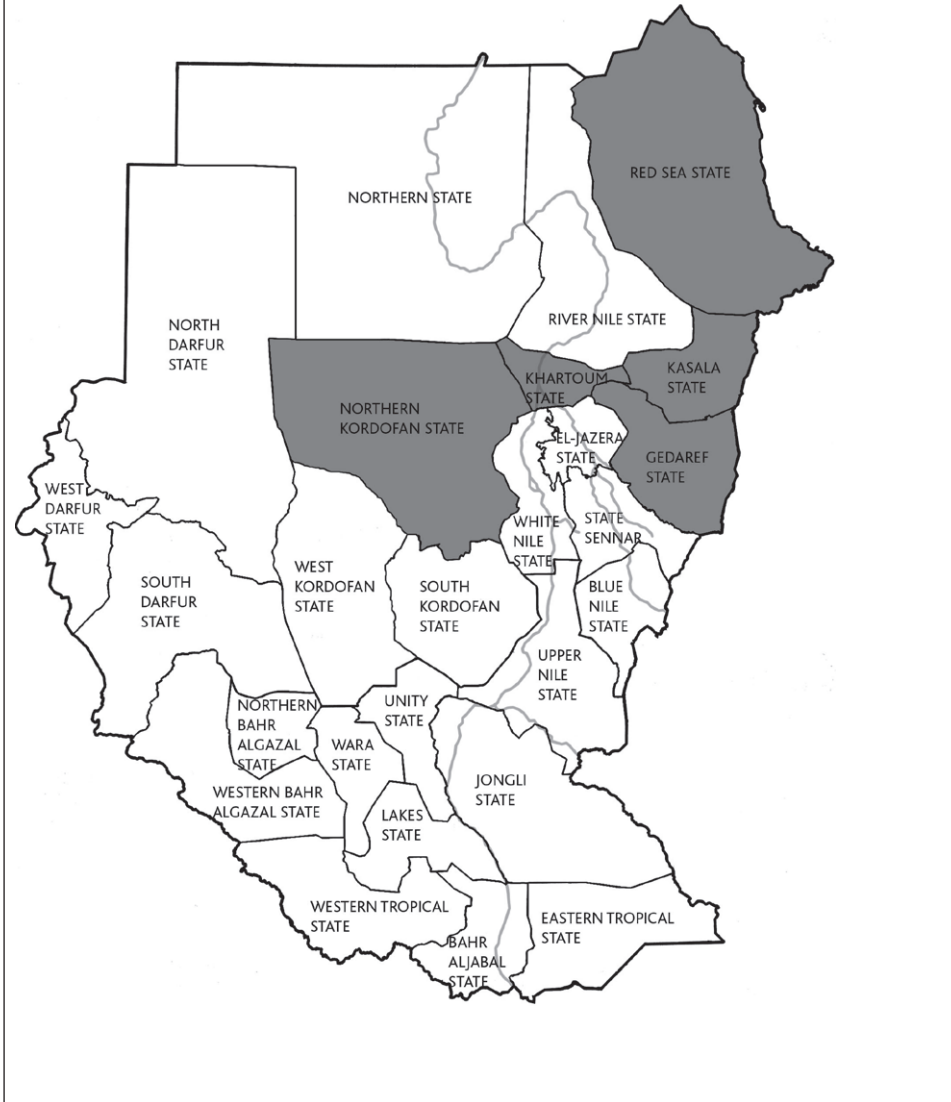
The analysis showed that certain states are at very high risk of environmental hazards (Red Sea, Kassala, North Kordofan, and Khartoum states; see Figure 6).



Identifying the most vulnerable states

Our mapping analysis shows that some states are repeatedly classified as vulnerable based on the following criteria: average rainfall and coefficient of variability; population distribution; poverty; extreme events (drought, floods); and other environmental hazards (Figure 7).

FIGURE 7. AREAS MOST VULNERABLE TO CLIMATE CHANGE



For example, certain states are poorer than the national average: Kordofan, Blue Nile, Kassala and Red Sea (Figure 5), and coupled with that, also had a very high, and increasing, rainfall CV between 1971 and 2000 (Figure 2) along with decreasing average rainfall. These factors are likely to threaten all rainfall-dependent livelihoods. Furthermore, the analysis showed that these areas are frequently affected by drought and/or floods; findings which were also confirmed in the NAPA (Table 2). The SFNC (2002) assessment indicated that Kordofan State was particularly vulnerable in certain sectors (water, agriculture, forestry and health). Finally Figure 6 confirms the vulnerability of states such as Red Sea, Kassala, Northern Kordofan and Khartoum to environmental hazards.

Recommendations

The NAPA involved a comprehensive analysis of, and stakeholder consultation on, policies and institutions. The objective was to recommend an enabling environment for implementing adaptation options in the water, agriculture and health sectors. In this section we integrate some of the participants' recommendations with some of our own:

- **Integrate and co-ordinate approaches.** Adaptation activities need to be implemented in an integrated way and take a long-term view, rather than involving short-term, stand-alone projects. There is also a clear need for a national sustainable development strategy to implement the activities and target all the interests and recommendations in the National Action Plan on Desertification, the National Biodiversity Action Programme (NBSAP) and the National Adaptation Programme of Action (NAPA). All these plans contain many activities that could have significant positive impacts on the country's natural resources. There are many synergies between these programmes, and they could be integrated in a comprehensive manner for greater effect (Box 2). It's also important to ensure co-ordination amongst institutions working on environmental issues (agriculture, water, physical planning etc.). Activating and/or establishing state councils for environment and natural resources, and for co-ordinating related work, would also help.

BOX 2. SYNERGIES IN ADDRESSING CLIMATE CHANGE, DESERTIFICATION AND BIODIVERSITY LOSS IN KORDOFAN

In a region like Kordofan, any efforts to combat desertification will eventually lead to the enhancement/ restoration of biodiversity and will also in many ways help to increase the resilience of vulnerable communities in their struggle against the negative impacts of climate change. For example, a community-based adaptation project implemented in Bara (Northern Kordofan State) was found to significantly enhance biodiversity and combat desertification in the region.

Source: Zakieldeen and Hanafi, 2004.

- **Work with vulnerable communities at the local level and take a bottom-up approach to project planning.** This is very important and can generate valuable lessons, not only for adaptation success but also for sharing knowledge/experiences with vulnerable communities outside Sudan. Community-based adaptation projects (e.g. those generated and implemented by the NAPA and the CBAA project etc.) are likely to raise a lot of recommendations, particularly on the policies and institutions required. Practical experiences from local communities in Sudan reveal the value of a bottom-up approach for sharing decisions and prioritising needs. For example, in western Sudan (Kordofan) studies showed that local institutions (traditional administration, NGOs etc.) can give a lot of support to adaptation projects. Involving such institutions gives local communities a sense of ownership of a project and a greater stake in ensuring it succeeds (Zakieldeen and Hanafi, 2004). In the same vein it is important to ensure the effective participation of women in projects that target adaptation to climate change (NAPA projects) and to encourage and support civil society organisations working for environmental protection.

- **Amend water policies.** Many local communities are calling for the amendment of some water resource laws, particularly those that govern the cost and distribution of water and the use of money generated from water projects in vulnerable communities in arid and semi-arid lands. In many parts of the country people suffering from water shortages and scarcity are forced to drink with their animals from ponds because it is less expensive (though they still have to pay for this water). At the moment people have to buy *hafeer* and well water.³ All the money is transferred to the national water corporation, but there are no standard regulations governing the distribution of benefits. Before 2002 the communities used to have a reasonable share of the money (60%, which was then reduced to 40%). However a law issued in 2002 eliminated their right to a share of the money (Zakieldeen and Hanafi, 2004).
- **Establish monitoring and early warning systems.** The impact of climate-related disasters is very high; the provision of timely early warning by the Meteorological Authority could help reduce these impacts.
- **Make land use laws consistent with customary laws.** Current land use policies allocate land to various development projects, even when that land has already been allocated to tribes by customary laws. This is likely to aggravate resource conflicts—tribes will be forced to compete for shrinking resources which are already affected by extreme weather events.
- **Introduce climate change information into educational curricula** in schools, universities, mosques etc.
- **Amend and/or develop funding policies which suit the conditions of the poor.** The increase in extreme events due to climate change is likely to undermine livelihoods. Vulnerable people will need to adapt their livelihoods, such as by adopting income-generating activities. However, the poor or vulnerable often have less access to income-generating activities. For example, experiences from the Bara project in western Sudan clearly illustrate that there is gender and wealth bias in access to loans. This was justified by the need to guarantee that recipients were able to repay the loan.
- Ensure that project planning for all the affected sectors takes into account climate change and its impacts.

If these recommendations are considered in planning and in a comprehensive national sustainable development strategy, then the process of integrating adaptation is more likely to be effective.

³ A *hafeer* is a huge pond dug for water storage for use during the dry part of the year. *Hafeer* are commonly used in arid and semi-arid parts of Sudan.

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