Zakieldeen *et al*., Sudan Academy of Sciences Journal-Special Issue (Climate Change), Vol. 11, 2015, 217-233
ISSN 1816-8272

Climate Change Impacts, Vulnerability and Adaptation in Sudan

Sumaya A. Zakieldeen[1] and Nagmeldin G. Elhassan[2]

Abstract

The Intergovernmental Panel on Climate Change (IPCC) clearly confirmed that past Green House Gases (GHGs) emissions result in unavoidable warming regardless of the global mitigation efforts. Wide ranges of impacts and vulnerabilities are associated with this warming. Adaptation is, however, the only available response waiting for the global community to undertake mitigation actions that lead to stabilization of GHGs in the atmosphere to prevent dangerous anthropogenic interference with the climate system. Sudan as an African least developed country is extremely vulnerable to the adverse impacts of climate change. Its vulnerability is an outcome of the interaction between climatic and non-climatic factors. Previous studies have indicated that the temperature increase, rainfall variability, southwards movement of isohyets, increase of frequency of drought and floods and sea level rise as the climatic factors causing vulnerability. The country is also facing a number of non-climatic factors, which aggravate its vulnerability such as poverty, lack of income diversity and mismanagement of resources. Studies conducted by the Higher Council for Environment and Natural Resources (INC, AIACC, NAPA, NAP, SNC) on Sudan's vulnerability to climate change, identified the water, agriculture, costal zone and health sectors as the most vulnerable. In Sudan, climate change represents a reality and a burden impeding the achievement of food security and sustainable development. Accordingly, Sudan climate change strategy aims at promoting sustainable development that improves adaptive capacity and limit growth of GHGs emissions through integration of climate change issues and concerns into national polices, strategies and development plans. In line with its national strategy for climate change, the country implemented a number of adaptation projects and programs such as AIACC, NAPA and NAP with the objective of identifying adaptation measures that address the vulnerabilities of the major sectors in the country. While AIACC is for development of information base for adaptation planning, in addition to building technical capacity among experts, NAPA is the one that identified and implemented urgent and immediate adaptation needs to address climate variability and changes within the context of the country's economic development. On the other hand, NAP is a comprehensive mid and long-term adaptation planning process with the objectives of building adaptive capacity and resilience and facilitating the integration of climate change adaptation into development plans for all relevant sectors in all the states of Sudan. Both NAPA and NAP followed bottom up approaches in which the communities from different parts of the country have participated.

Keywords: climate change, vulnerability, adaptation, water, agriculture, health.

[1] Institute of Environmental Studies, University of Khartoum.
[2] Higher Council for Environment and Natural Resources.

Scientific and Policy Context

It is well established now by scientific community that historical accumulation of the Greenhouse Gases (GHGs) will cause climatic changes no matter what we do. The Intergovernmental Panel on Climate Change (IPCC) in its Fourth Assessment Report (AR4, 2007) concluded that past emissions are estimated to involve some unavoidable warming (about a further 0.6°C by the end of the century relative to 1980-1999) even if atmospheric greenhouse gas concentrations remain at 2000 levels. IPCC also concluded in its AR4 that there are some impacts for which adaptation (Box 1) is the only available and appropriate response. In other words for those unavoidable impacts, reduction (mitigation) of the GHGs will not help humankind to avoid them and it is simply too late because the atmosphere is already responding to these historical accumulations of GHGs. The IPCC AR4 included very alarming findings with regard to the impacts of climate change on the African countries, particularly the Sahel and sub-Saharan Africa. It stated, "Agricultural production, including access to food, in many African countries and regions is projected to be severely compromised by climate variability and change". The area suitable for agriculture, the length of growing season and yield potential, particularly along the margins of semiarid and arid areas are expected to decrease. This would further adversely affect food security and exacerbate malnutrition in the continent. In some countries, yields from rainfed agriculture could be reduced by up to 50% by 2020. These findings have been confirmed by the results of the vulnerability and adaptation assessment conducted in the larger region of Kordofan during the preparation of Sudan's Initial National Communication (INC, 2003).

In climate change science, global average temperature is correlated to the concentrations of GHGs in the atmosphere. The IPCC in the AR4 stated, "Impacts are expected to increase with increases in global average temperature" if the current scenario of global GHGs emissions continued in the same manner. IPCC AR4 also stated, "Although many early impacts of climate change can be effectively addressed through adaptation, the options for successful adaptation diminish and the associated costs increase with increasing climate change". This is a clear warning signal from the IPCC which indicates the need, in addition to undertaking urgent adaptation actions for the global community to undertake urgent mitigation actions to avoid future impacts with larger magnitude that diminishes our ability to adapt both in terms of resources required and factors of success of actions taken. It is, therefore, very important that climate change policies and planning, at global as well as national level, respond simultaneously to both the need for urgent adaptation and the need to avoid future impacts through effective GHGs mitigation actions.

The global policy framework for addressing both climate change mitigation and adaptation is the United Nations Framework Convention on Climate Change (UNFCCC), which is adopted in 1992. The UNFCCC objective as enshrined in its Article 2 is "to achieve stabilization of GHGs concentrations in the atmosphere at levels that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change to ensure that food production is

ISSN 1816-8272

not threatened and to enable economic development to proceed in a sustainable manner".

In the implementation of the Convention, the concept of stabilization of GHGs concentrations in the atmosphere is translated into a temperature increases goal that is assumed (as the limit) to prevent occurrence of dangerous climate change (irreversible impacts) (UNEP, 2013). The Parties to the UNFCCC currently adopted a "stabilization goal" of reducing global GHGs emissions to the level that holds the increase in global average temperature to below 2°C above pre-industrial levels. The second part of the UNFCCC objective refers to adaptation; it recognizes that the priority of developing countries to achieve food security and sustainable economic development should be ensured, because adaptation needs are correlated with the impacts associated with global average temperature levels. However, so far, in the implementation of the convention, adaptation has not been addressed in a comprehensive manner that take into consideration the link between adaptation needs and the different GHGs stabilization levels adopted or achieved by the global community to hold temperature increases to save levels. The recently adopted IPCC AR5 (2014) stated that "the globally averaged combined land and ocean surface temperature data as calculated by a linear trend show a warming of 0.85 [0.65 to 1.06] °C over the period 1880 to 2012. The total increase between the average of the 1850–1900 period and the 2003–2012 period is 0.78 [0.72 to 0.85] °C". This simply means that, with all the devastating impacts of climate change already being witnessed in all regions of the globe including Africa and Sudan, we still live in a world of a global average temperature increase of about 0.85 °C, and we are yet to reach the agreed 2°C stabilization target. This gloomy picture necessitates a more serious and urgent global and national efforts to address adaptation planning and implementation.

IPCC in its AR4 provided different options of GHGs stabilization scenarios for achieving the ultimate goal of the Convention (see Table 1) and stated that "delayed emissions reductions significantly constrain the opportunities to achieve lower stabilization levels and increase the risk (Box 1) of more severe climate change impacts". It is worth noting that according to the World Meteorological Organization (WMO), observed concentrations of CO_2 in the atmosphere have exceeded the symbolic 400 ppm thresholds at several stations of the WMO's Global Atmosphere Watch Network by May 2013 (http://www.wmo.int/ pages/ mediacentre/news/documents/400ppm.final.pdf).

Table 1. Characteristics of stabilization scenarios

Stabilization level (ppm CO_2-eq)	Global mean temp. increase (ºC)	Year CO_2 needs to peak*
445 – 490	2.0 – 2.4	2000-2015
490 – 535	2.4 – 2.8	2000-2020
535 – 590	2.8 – 3.2	2010-2030
590 – 710	3.2 – 4.0	2020-2060

Source: IPCC AR4 (2007)

*In order to stabilize the concentration of GHGs in the atmosphere, emissions would need to peak and decline thereafter. The lower the stabilization level, the more quickly this peak and decline would need to occur

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Box 1 definitions

Climate change refers to a change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forces such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or inland use.

In the context of the climate convention, climate change is defined as "Climate change" means a change of climate, which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods (Article 1 of the UNFCCC).

Exposure: The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected.

Risk: The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Climate change risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur. Risk results from the interaction of vulnerability, exposure, and hazard.

Vulnerability: The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.

Impacts: Effects on natural and human systems of extreme weather and climate events and of climate change. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes. The impacts of climate change on geophysical systems, including floods, droughts, and sea-level rise, are a subset of impacts called physical impacts.

Adaptation: The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.

Resilience: The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation.

Climate Change Impacts and Vulnerability of Sudan

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 such as 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 (Zakieldeen,

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2009; AIACC WP No. 42, 2005). The vulnerability of the country is an outcome of interaction of both climatic and non-climatic factors (NAPA, 2007).

Climatic Factors

Climate scenario analyses conducted by Sudan's Initial National Communication (INC, 2003) 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^{o}C and 3.1^{o}C above the baseline during August and from between 1.1^{o}C to 2.1^{o}C during January. Climate change is also projected to reduce average rainfall by about 6 mm per month during the rainy season. Such changes in temperature and precipitation are likely to undermine the development process that is occurring in many sectors in Sudan.

For the current situation, the findings of the Sudan's Second National Communication (SSNC, 2013) illustrated that air temperatures have been steadily increasing in Sudan over the period 1960-2009. The most affected areas were semiarid parts of the country (Northern, River Nile, and Red Sea States). The increase in temperature was found to be between 0.2°C and 0.4°C per decade during both the March through June and June through September periods. However, it was also stated that when averaged across all seasons, temperatures in the 2000-2009 periods are roughly between 0.8°C and 1.6°C warmer than they were in the 1960-1969 period.

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 (Zakieldeen, 2009), indicating that rainfall is highly variable in time and space (temporal and spatial variability). During the period (1981-2012), the rainfall in the whole country was significantly lower as compared to the 1971-2000 period. This was very clear in the central and northern parts of the country, while the southern parts experienced less decrease. There was an area in the southern parts of central Sudan, where the rainfall increases during the last ten years.

Studies also illustrated that the rainfall isohyets shifted southwards (Fig. 1) in two climatic means (1941-1971) and (1971-2000). The 100 mm isohyet was found to shift by 100 to 150 km, while the 700 mm isohyet retreated about 150 to 250 km to the south (Elhassan *et al.*, 2013). The findings of the Second national communication also confirmed the high variability, as well as decrease of rainfall amount over the past decades. The findings of the studies conducted for the current NAP process (2014) show that in addition to the variability in the amount and distribution of rainfall, variability in the length of the rainy season was found to become unpredictable and generally shorter in all States. The following has also been reported in almost all the States:

- Decrease in annual rainfall.
- Change in number of rainy days.
- Delay in the start of rainy season.
- Increase in dry spells during the rainy season.

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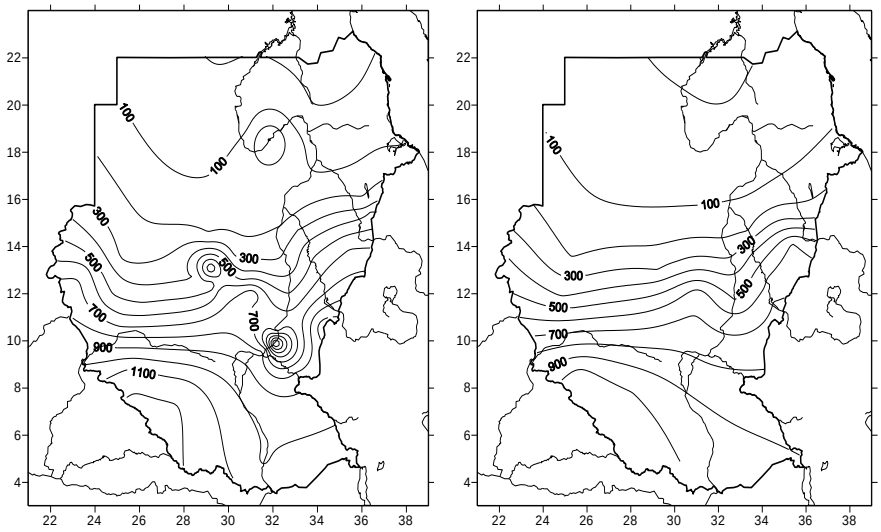

Figure (1): Comparison of the rainfall climate normal for the period: 1941-1970/1971-2000
Source: A. K. Abdalla, Sudan Meteorological Authority (2011)

Both the SSNC (2013) and the NAP (2014) illustrated that the frequency of extreme climatic shocks is increasing, particularly drought and floods. The former used to be a rare phenomenon that used to occur once every 30 years. Drought is now one of the most important and frequently recurring challenges that Sudan faces. Future drought threatens about 19 million hectares of rain-fed mechanized and traditional farms, as well as the livelihoods of many pastoral and nomadic groups. Floods in Sudan can either be localized caused by exceptionally heavy rainfall or more widespread, caused by the overflow of the River Nile and its tributaries (NAPA, 2007). During the past five decades, there has been a 6-fold increase in flood frequency. The most vulnerable groups are the thousands of communities who live in low lands and along the riverbanks of the River Nile and its tributaries (SSNC, 2013).

Non-Climatic Factors

Beside the climatic factors, the country is facing a large number of non-climatic factors that contribute to the vulnerability of communities in different parts of Sudan including the following:

i. **Poverty:** Much of the population in Sudan lives in poverty. Overall, almost 51% live below the poverty line. In the northern part of the territory, this is somewhat lower at 47%. Socioeconomic factors affecting human wellbeing e.g. wealth, distribution of income, gender equity, access to resources, clean water and sanitation
ii. **Resources mismanagement:** combination of severe climatic conditions and land mismanagement (overgrazing, over-cropping, deforestation, deterioration of soil fertility) have caused vegetation cover degradation in different parts of

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the country that has led in many instances to loss of many endemic species (woody, rangeland species) that were once dominant. In the region that borders the desert zone, there is a persistent threat associated with shifting sand dunes and desertification.

iii. **Lack of income diversity:** due to high rates of poverty, poor human skills and high illiteracy rates, vulnerable communities are not able to diversify their income resources.

Vulnerable Sectors

The national studies and documents identified the following as the most vulnerable sectors to the negative impacts of climate change:

(i) Water: Water supply and demand in Sudan are highly dependent on future changes of temperatures that may adversely affect evapotranspiration rates at water storage location, as well as changes in rainfall patterns that may adversely affect surface water quantities flowing in the Blue Nile and White Nile, as well as leading to drought in areas that practice rainfed agriculture. The SNC estimated future climatic change over the watersheds of major rivers and Wadis in Sudan (SSNC, 2013). A comprehensive analysis was conducted based on the three emissions scenarios and downscaling of nine global circulation models (Abdalla, 2011). The future water demand was projected for 2050 and 2090 climate conditions in both the No population growth and 2% growth scenarios. The analysis targeted the monthly average temperature for baseline (1961-2000) and forecasted (2050 and 2090) periods in Upper Nile regions. It also assessed the annual rainfall for the baseline and forecasted periods in the Upper Nile regions.

The analysis of the monthly average temperature for the baseline (1961-2000) and forecasted (2050-2090) periods in Upper Nile regions anticipated incremental warming throughout the 21st century, in the watershed of the Upper Blue Nile; monthly temperatures are expected to rise between 1.5°C and 3.0°C by 2050 and approximately between 2.9°C and 5.8°C by 2090. In the Upper White Nile watershed, changes are similar; monthly temperatures are expected to rise between 1.0°C and 2.8°C by 2050 and approximately between 3.5°C and 4.5°C by 2090. For the annual rainfall for the baseline (1961-2000) and forecasted (2050-2090) periods in Upper Nile regions, the study findings showed tendency for drier conditions over the Upper Blue Nile Basin and wetter conditions over the White Nile Basin.

The anticipated joint effects of warmer, as well as drier conditions suggested by the study findings poses serious concerns regarding increased evapotranspiration over water storage areas that could lead to lower flows in the River Nile and decrease of hydropower generation (Table 2).

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Table 2. Forecasted future (2050-2090) climate change impacts on water resources in the upper Blue Nile as compared to baseline (1961-2000).

	Impacts of climate change
Water demand	Water demand will increase considerably. For 2050 and 2090 climatic conditions, water demand is expected to increase by up to 11% relative to baseline conditions.
Water flow in the river Nile	For the main *Nile below Merowe*, there are more scenarios with greater flows under 2050 conditions than 2090 conditions. Peak annual flows are about 20% less than historic levels under 2090 climatic conditions. For the *Blue Nile at Khartoum* on average peak annual flows are approximately 30% less than historic levels under 2090 climatic conditions.
Impacts on water storage	Water storage will decrease considerably in Sudan, by about 40% starting around the year 2030.
Hydropower generation	Hydropower generation will decrease considerably in Sudan. This will adversely impact national electrification efforts that seek to use a once-available non-GHG emitting resource

Source: SSNC (2013)

Both the bottom-up (consultations) and top-down (scenarios) approaches of the current National Adaptation Planning (2011) also showed similar findings for both present and future climate change impacts on water resources. The synthesis of vulnerability across all the Sudanese States showed that both surface and ground water are negatively affected due to decrease/high variability of rainfall as well as increase of temperature. These were found to lead to:

- Scarcity of water sources (irrigation, drinking and domestic uses)
- Decrease of water quality
- Increase in prices of water during summer (70% of income spent on water purchase)
- Fluctuation of the flow of the Nile water, its tributaries and the seasonal streams has adverse impacts on irrigated agriculture.
- Increase in frequency of floods leading to loss of property, infrastructure, irrigation channels, negative impacts on water services spread of water-borne diseases

(ii) Agriculture: Agriculture, including both crop and livestock production, is the main sector of the Sudan's economy. It is the main livelihood source for more than 70-80% of the population and about 80% of the labor force is employed in agriculture and related activities. It contributes about 30-35% to the GDP.

The national studies showed that agriculture is one of the most vulnerable sectors to the negative impacts of climate change. It has been demonstrated that the sector is extremely vulnerable to all the above-indicated climatic factors (Rainfall variability and distribution, drought, flood, temperature). The first national communication anticipated that both agriculture (millet, sorghum) and forestry (gum Arabic) production will be significantly affected by negative impacts of

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climate change (warmer and drier conditions) in the medium and long term (INC, 2003). The NAPA (2007) also demonstrated the high vulnerability of the agricultural sector in five different ecological zones and identified urgent and immediate measures for addressing adaptation needs in this important sector. The NAP (2014) project also assessed the vulnerability of the agriculture sector in all the Sudanese States. The analysis used both bottom-up and top down approaches to conduct comprehensive analysis of present, as well as medium and long-term vulnerabilities. The synthesis of climate change impacts in agriculture in Sudan (Table 3) showed that the sector is even currently gravely affected and facing serious challenges.

Table 3. Some of climate change impacts on agricultural sector

Impacts on Crop production	**Impacts on Grazing and animal production**	**Impacts on Forests**
- Deterioration in crop production (decrease in production per unit area) - Crop failure - Expansion and increase of cultivated areas in marginal lands at the expense of rangelands and forest cover - Spread of pests and diseases - Negative impacts of increase of temperature on winter crops - Cultivation of local crop varieties that are early maturing but of low yield and quality - Deterioration of horticultural production - Change in livelihoods	- Deterioration of carrying capacity - Shrinkage of rangelands - Lack of drinking water for grazing animals - Scarcity and gaps in fodders (e.g. estimated by 1.5 million tons in White Nile State) - Changes in amount and types of rangelands' species (disappearance of palatable species and appearance of unpalatable ones) and decrease in biodiversity of rangeland species - Spread of animal diseases - Deterioration of animals production (quality and quantity) - Risks to agro-pastoral life (Migration from rural to urban areas) - Change in type of animals (e.g. cattle are sensitive, goats are survivor)	- Decrease of areas covered by forests - Impact on natural regeneration and succession of trees - Decrease of fodder trees - Deterioration of gum Arabic belt - Deforestation - Disappearance of trees (Tamarind, Ebony)
General impacts: - Conflicts over scarce resources - Changes in prices and income - Loss of livelihoods - Food insecurity - Increase of poverty		

(iii) Coastal zone: The UNFCCC (2010) identified the slow onset events to include "sea level rise, increasing temperatures, ocean acidification, glacial retreat and related impacts, salinization, land and forest degradation, loss of biodiversity

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and desertification. The Red Sea zone is highly vulnerable to the negative impacts of slow onset events of climate change.

Sea level rise: The IPCC's Fourth Assessment Report (2007) posits 0.59 meters rise by 2100. Continued melting of certain glacial types could lead to sea level rise in excess of 10 meters in the period after 2100 (IPCC, 2007). Rapid sea-level rise constitutes a major potential problem facing coastal zones in Sudan. The second national communication showed that there has been a gradual increase in sea level, about 10-20 cm during the past century in Port Sudan area based on data from Permanent Service for Mean Sea Level.

Sea-surface temperatures: are warming due to increased concentrations of GHGs in the atmosphere. Scenarios anticipated that the increase in temperature could reach up to 3°C by 2100, changing the *density* and thus *volume* of the oceans. Increased sea-surface temperature could also lead to higher peaks of storm surges, increased cyclone intensity, and a greater risk of *coastal disasters* (IPCC, 2007).

Salinity: The IPCC (2007) also stated that tropical and sub-tropical regions have become and will continue to become slightly more saline. Such changes pose hazards to aquatic plants and animals in Sudan's coastal lagoons that do not tolerate high salinity

Intensification of storm surges: The Red Sea area itself is not currently an area of cyclone activity and is not recognized as a region currently vulnerable to cyclone activity. In Sudan, storm surges would lead to damaging flood conditions all along its coastline, particularly in high population areas like Port Sudan, as well as adjoining low-lying areas like the Tokar Delta agricultural areas.

The Red sea zone is characterized by unique fauna and flora and, as well as outstanding ecosystems such as Coral Reefs, Mangroves, Salt Marshes and Sea grass. The studies showed the current and potential impacts of these ecosystems to slow onset events (Table 4).

(iv) Health sector: Health is one of the most vulnerable sectors to the negative impacts of climate change. The first National Communication anticipated the increase of the risk of malaria under climate change. It has been illustrated that malaria transmission potential could increase substantially by 2030 and 2060 in Kordofan State (INC, 2003). The vulnerability assessment of health sector to current climate change impacts was conducted by both the NAPA and NAP. The findings confirmed the correlation between temperature and precipitation patterns and malaria, meningitis, and leishmaniasis diseases that afflict millions of people throughout the country (NAPA, 2007). While the NAPA consultation process confirmed that malaria is a major concern, the other diseases were also prioritized for adaptive measures. Besides confirming the findings of the NAPA, the NAP also showed that changes in climate might alter the distribution of important vector species and increase the spread of diseases to new areas. For instance, highland populations that fall outside areas of stable endemic malaria transmission may be particularly vulnerable to increases in malaria due to climate warming. In addition to that, it was demonstrated that not only will climate change worsen various current health problems, it may, however, also bring new and unexpected ones. The NAP results synthesized from all the Sudanese States analysis, showed

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spread of waterborne diseases (malaria, bilharzia, Kalzar), as well as diseases that spread because of lack of water (trachoma, skin diseases). For most of the States, the spread of malnutrition was also identified as an outcome of food deficiency caused by climate changes.

Table 4. Current and potential vulnerabilities of natural and physical environments to the climate change impacts (slow onset event) in Red Sea zone

Impacts on different ecosystems	**Sea level rise**	**Changes in seawater temperature and salinity**	**Storm surge intensification**
Coral Reefs		Corals are vulnerable to thermal stress and have low adaptive capacity. Corals in the Red Sea are expected to have reached their upper physiological temperature limit	
Mangroves	root systems will be unable to take in oxygen and new trees will be unable to establish root as seeds float in higher water		any increase in extreme storms may induce erosion damage to the system
Salt Marshes	Flooding could remobilize the fine sediments, increasing coastal turbidity and affect coral reefs, sea grass, and other marine biota lack of reef and altitude allows sea water to move inland during high tide, storm surges, and even more so with future sea-level increases	*The inundation* of coastal salt marshes could create an extremely shallow sea along the coast, would be susceptible to strong *heating and cooling*.	
Sea Grass	A change in mean *level*, as it contributes to increased water depth, would lead to a subsequent reduction in light available for sea grass growth resulting in reduction of 30±40% in its growth and productivity	A change in sea-surface temperatures could lead to altered growth rates, geographic distribution, and impair physiological functions of the plants	
Built Environment	Inundation of built environment		

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Climate Change Adaptation in Sudan

In its INC (INC, 2003), Sudan stated that the contributions of developing and least developed countries in global efforts to fight climate change and its consequences should be closely linked to their national development priorities. The objective of the Climate Change Convention has clearly recognized the needs of developing and least developed countries to address problems of food security, poverty and pursue sustainable development. Accordingly, the commitments of developed and developing countries in the implementation of the convention, as defined in its Article 4, have been based upon the principles of common but differentiated responsibilities and equity.

Sudan is considered among the most vulnerable countries to the impacts of climate change. Therefore, adaptation is the highest and overriding priority in its effort to combat climate change. The vulnerability of Sudan has been confirmed in the findings of a number of studies on assessment of impacts and adaptation at different regions of Sudan conducted by the HCENR (INC, 2003; AIACC AF14, 2004; NAPA, 2007; SNC, 2012; NAP, 2014).

Sudan's INC to the UNFCCC set the context for Sudan's response to its obligations and challenges under the climate change convention. The INC included a general framework for a national implementation strategy for the climate change in Sudan, called "towards a national implementation strategy". In this strategy, Sudan stated that the overall objective is "to promote sustainable development paths that improve Sudan's adaptive capacity and limit its growth in GHGs emissions through integration of climate change issues and concerns into national policies, strategies and development plans". The specific objectives of the implementation strategy include:

- To improve scientific knowledge and understanding of climate change and its potential consequences in Sudan,
- To build an enabling environment to integrate climate change issues and concerns into national development (capacity building, institutional infrastructure),
- To raise awareness,
- To identify and build synergies with other conventions and agreements (coordination),
- To develop a national adaptation program, and
- To develop a national GHGs mitigation program.

Following the completion of the INC, Sudan participated in an umbrella project called Assessment of Impacts and Adaptation to Climate Change in Multiple Sectors and Regions (AIACC), the main objective was to identify suitable options for the adaptation planning in Sudan. The AIACC project was funded primarily by the Global Environment Facility (GEF), the U.S. Agency for International Development, the Canadian International Development Agency and the U.S. Environmental Protection Agency also provided additional funding for the project. The project was co-executed on behalf of the United Nations Environment Program by the Global Change System for Analysis, Research and Training (START) and the Third World Academy of Sciences. AIACC aims to

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enhance capabilities in the developing world for responding to climate change by building scientific and technical capacity, advancing scientific knowledge, and linking scientific knowledge to development and adaptation planning. AIACC supported 24 regional assessments based on case studies in Africa, Asia, Latin America and Small Island States with funding, mentoring, training and technical support.

Sudan's participation in AIACC was motivated by its need to develop information base for adaptation planning in addition to building technical capacity among Sudanese experts. Three case studies were considered in this study, in Arbaat area in the Red Sea State, Bara area in North Kordofan State and Dar Assalam area in North Darfur State. The purpose was to show that certain sustainable livelihoods (SL) measures operate as climate change adaptation options and that such measures can be integrated into the planning of national adaptation strategies (AIACC WP No. 18, 2005). The Sustainable Livelihood Assessment Approach was used to measure the impact of a package of measures (interventions) on a community's coping/adaptive capacity. The approach aimed at examining the condition of available livelihood assets (natural, physical, financial, human and social) before and after the intervention in order to assess the capacity of communities to adapt to future climate variability and change. Different types of adaptation options were covered by the case studies, some are considered as being developed spontaneously, or autonomously, as a regular part of on-going resource and risk management, and others that are consciously and specifically planned in light of specific climate-related risks (AIACC WP No. 42, 2005).

Actual adaptation planning in Sudan started with the preparation of the National Adaptation Programme of Action (NAPA, 2007), which was prepared in line with the requirements under the Least Developed Countries (LDCs) work programme of the UNFCCC. NAPA is the first adaptation plan prepared to enable Sudan to access funds made available through the Least Developed Countries Fund (LDCF) to implement real adaptation actions on ground. The overall goal of the NAPA preparation process was to identify urgent and immediate activities to address climate variability and climate change within the context of the country's economic development priorities. The three highest priority sectors were identified through the NAPA consultation process included agriculture, water, and public health. NAPA project was funded by GEF, UNDP and the Government of Sudan and implemented by HCENR in collaboration with five States representing the ecological zones of Sudan; North Kordofan, South Darfur, River Nile, Gedarif and Central Equatoria at that time, before the separation of South Sudan. The NAPA started by establishing institutions (a focal point and technical committees) at each of the selected States to coordinate NAPA activities at the State level including data collection, assessment of vulnerability and adaptation, consultations, etc. Then it launches a comprehensive consultative and participatory process in line with the NAPA guidelines developed by the Least Developed Countries Expert Group (LEG). An initial step in the design of the NAPA consultation process was to identify and assess communities and areas within each of the five ecological zones of Sudan where people may be acutely vulnerable to climatic shocks. The groups that have been identified as most

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vulnerable to climate risks were the traditional rainfed farmers and pastoralists. During past climatic shocks such as drought, rainfed farmers and pastoralists are found typically the least able to cope with climate-related shocks in Sudan. This has been due primarily to a combination of their extreme poverty levels, as well as to household income-generating activities that are highly limited. These factors, together with other specific non-climatic factors contributed to increased vulnerability of these local communities during climatic shock (NAPA, 2007).

The NAPA followed a project-based approach in the identification of the intervention needed to reduce vulnerability and build resilience (Box 1) among the targeted communities. About 32 projects identified in the five States addressing urgent and immediate needs for adaptation in the water, agriculture and food security and human health sectors (NAPA, 2007). The NAPA projects of each State have been ranked in an order of priority to the state, this has been done in consultation with relevant stakeholders using agreed criteria. The selected projects are considered as pilot interventions that can be replicated within similar areas in these zones. The NAPA also included recommendations for improving current policies and the institutional framework to facilitate the integration and implementation of adaptation measures. NAPA projects were identified on the basis that they respond to urgent and immediate needs of the most vulnerable groups, improve their adaptive capacity, remove barriers to development caused by the impacts of climate change and in this sense they are not development projects *per se*, but enable and complement the development process.

NAPA is relatively very successful plan in term of implementation compared to other plans and strategies prepared in response to Sudan's obligations under other multilateral environmental agreements such as biodiversity, desertification, etc. The first support for NAPA implementation was received shortly after the NAPA endorsement by the government of Sudan. Despite the fact that NAPA is project-based plan, its implementation started by a programmatic intervention covering two sectors in multiple regions addressing the highest priority in each of the NAPA States. The first NAPA implementation activities have been very successful in responding to the needs of the vulnerable groups in the targeted areas and generated a number of good lessons and best practices that motivated the State's governments to replicate them and attracted other donors to provide additional funding for scaling up these successful interventions. Other three NAPA implementation projects are now under different stages of their development and implementation (Table 5). Total funding accessed for NAPA implementation so far is about 21 millions USD.

In 2011, Sudan launched a process for a National Adaptation Plan (NAP) in line with its national implementation strategy (INC, 2003) and in response the UNFCCC decisions reach in 2010, the Cancun Adaptation Framework (CAF), which call for the development of National Adaptation Plans (NAP) in least developed countries. The NAP project was based on cooperation agreement between UNEP and HCENR, funded by DIFD as part of the UNEP-Sudan umbrella project (SIEP) and has been implemented in collaboration with the Governments of the 18 States of Sudan.

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Table 5. Projects of National Adaptation Programme of Action (NAPA), states covered, implementation status and source of funding

Project	States covered	Implementation status	Funding
Implementing NAPA Priority Interventions to Build Resilience in the Agriculture and Water Sectors to the Adverse Impacts of Climate Change in Sudan	North Kordofan, South Darfur, River Nile and Gedarif	Completed by mid 2014 and; The scale-up phase started in 2014	GEF/UNDP and Sudan's Government CIDA (Canada)
Climate risk finance for sustainable and climate resilient rain-fed farming and pastoral systems	North Kordofan, South Darfur, River Nile, Gedarif, Kassala and White Nile	Full project under GEF council approval	GEF/UNDP and Sudan's Government
Enhancing the resilience of communities living in climate change vulnerable areas of Sudan using Ecosystem Based approaches to Adaptation (EbA)	White Nile State	Project concept (PIF) under GEF approval	GEF/UNEP and Sudan's Government
Livestock and Rangeland Resilience Program	West Kordofan, North Kordofan, White Nile, Sennar and Blue Nile	Full project under GEF council approval	GEF/IFAD and Sudan's Government

NAP is a comprehensive adaptation planning process covering longer timeframe (mid and long-term) compared to the NAPA, which is mainly for identification of urgent and immediate adaptation needs. NAP aims to reduce vulnerability to the impacts of climate change, by building adaptive capacity and resilience and to facilitate the integration of climate change adaptation into development planning processes within all relevant sectors and at different levels involving all the States of Sudan. NAP process benefited from the experience with NAPA preparation and from the institutions established in the four NAPA States. NAP established similar institutions in all the States with focal points and technical teams of experts from related government, research, academia and civil society organization. The capacity of these institutions has been strengthened through targeted training sessions; learning-by-doing programs; and the establishment of networks to exchange knowledge and experience. The State's institutions have been tasked with coordination of the NAP process at the State level, including data collection, vulnerability assessment, adaptation strategy formulation, policy and institutional review, and the consultation that led to the identification of the adaptation initiatives to be included in the NAP. NAP process includes assessment of vulnerability and adaptation in all the States, covering the main development sectors, such as water, agriculture, health and coastal zone. In addition to a

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number of studies on vulnerability hotspot mapping, climate proofing of existing development programs and projects, development of climate scenarios, adequacy of national research and systematic observations and adaptation finance and investment. The outcome of these assessments and studies, informed the programs and activities included the NAP.

The NAP shifted the adaptation planning to a more programmatic approach compared to the NAPA. The emphasis in the NAP process turned from a project-based approach seeking to identify and implement urgent and immediate adaptation interventions, to programme-level process for integration of adaptation into medium and long-term development planning.

NAPs represent the core and strategic adaptation planning processes at the country level, through which developing countries can identify their needs for support and be able to access funding. According to the UNFCCC guidelines, NAP is a dynamic process that should evolve over time and be reviewed every five years based on development of scientific knowledge and understanding of climate impacts, vulnerability and adaptation. This is implying that Sudan's NAP process should continue to:

- Build technical and institutional capacity and strengthen the States' NAP institutions and the national NAP network that link all the States and HCENR
- Improve knowledge, understanding and develop information database of current and future vulnerabilities of Sudan to climate and its adaptation needs through additional research and studies (e.g. applying advanced methods and tools such as climate scenarios and impact modeling)
- Facilitate integration of adaptation into policies and development planning at all levels, through building capacities and awareness and involving relevant stakeholders and solicit government (national and State) commitment and support to the NAP process
- Elaborate and develop the NAP programs and initiatives and prepare good quality project proposals of priority adaptation options for financing
- Facilitate fund raising to support NAP integration and implementation, targeting government, UNFCCC funds, other multilateral and bilateral sources of funding.

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