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AFRICAN DEVELOPMENT BANK

NATIONAL CLIMATE CHANGE PROFILE

PRODUCED IN COLLABORATION WITH:

African Climate & Development Initiative, University of Cape Town;
Climate Systems Analysis Group, University of Cape Town;
Energy Research Centre, University of Cape Town; Cirrus Group.

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ACKNOWLEDGEMENT

This national climate change profile, one in a series of 25 national-level assessments, is the product of the African Development Bank-led project "Enhancing the capacity of African countries to use climate information to inform decision-making and implement NDCs", sponsored by the Africa Climate Change Fund (bit.ly/AfDB-ACCF). The profiles were developed by a diverse group of experts from the University of Cape Town including the African Climate & Development Initiative (www.acdi.uct.ac.za), the Climate System Analysis Group (www.csag.uct.ac.za) and the Energy Research Centre (www.erc.uct.ac.za)) and the Cirrus Group. In addition, these profiles have benefited from the suggestions and inputs of multiple reviewers over the course of project development, and we would like to recognize and appreciate their efforts.

1. BACKGROUND

1.1. Geographic and socio-economic context

The Republic of the Sudan (henceforth, 'Sudan', shown below in Table 1-1), also known as North Sudan since South Sudan's independence, is a country in Northern Africa. As the third-largest country in Africa, Sudan's landscape includes several distinct biogeographic regions and features, including the coastline of the Red Sea, the inland catchment and plains of the Nile River, savanna woodlands in the south and extensive semi-desert and desert in the central and northern interior. The majority of the country is classified as semi-arid or desert climate. Sudan's neighbouring countries include Egypt to the north, Eritrea and Ethiopia to the east, South Sudan to the south, the Central African Republic to the southwest, Chad to the west and Libya to the northwest. Petroleum resources are the main contributor to Sudan's economy (~USD 95.6 billion, 6th largest in Africa), which supports a relatively high standard of living in terms of GDP per capita (~USD 2,415 per capita, 15th highest in Africa). However, Sudan is also faced with diverse challenges related to social equality and gender equity (15th least gender-equitable country in Africa). In terms of vulnerability to climate-related hazards and natural disasters, Sudan is a hyper-arid country, which frequently experiences the negative impacts of droughts and water shortages (~6.1 million people affected by drought in the period 1996–2016). Sudan is also affected by floods, particularly in low-lying river basins below catchment areas, which are estimated to have affected ~4.1 million people in the period 1996–2016. Sudan's ND-GAIN index is 30.6, one of the lowest in Africa. This index summarizes the country's vulnerability to climate change and other global challenges in combination with its readiness to improve resilience. In the case of Sudan, this index is composed of a very low readiness score and a very high vulnerability score, indicating that the country has both a great need for investment and innovations to improve readiness and a great urgency for action. Key socio-economic and demographic indicators are further presented and summarised in Table 1-1, below.

Figure 1-1: Map of Sudan

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Table 1-1: Socio-Economic Context of Sudan (reference year ranges from 2014 - 2017)

VARIABLE		SCORE/TOTAL	UNIT	RANK (OUT OF 54)
Geography, Socio-Economy and Demographics				
Population[1]		42,166,323	people	8
Population growth rate[1]		2.4	% population. yr-1	30
Population density[1]		24	People/km2	39
Land area[1]		1,764,281	km2	4
% Urban population[1]		32.7	% population	38
% Urbanisation rate[2]		3.0	% population. yr-1	37
Economy: total GDP[2]		95.6	USD billions. yr-1	6
Economy: GDP by PPP[2]		187	billion international dollars. yr-1	7
Economy: GDP/capita[2]		2,415	USD per capita/yr.	15
Population below the poverty line[3]		14.9	% below USD 1.90 per day	40
Gender Inequality Index[4]		59.1		15
GINI co-efficient[3]		35.4		39
HDI[5]		0.49		32
Access to electricity[6]		44.9	% population	26
Summary indicators of climate change vulnerability				
Workforce in agriculture[7]		44.6	% workforce	24
Number of people affected by drought[8]		6,160,000	people	11
Number of people affected by flood events[8]		4,155,741	people	4
Population living within 100 km of coast[9]		1,256,614	people	28
Population living in informal settlements[6]		91.6	% urban population	3
Incidence of malaria[10]		37	cases per 1000 population at risk	37
ND-Gain Vulnerability Index[11]	Total	30.6		48
	Readiness	0.27		46
	Vulnerability	0.66		6

2. CLIMATE AND WEATHER

The climate of Sudan varies significantly from north to south. The northern parts have a hyper-arid climate shifting to semi-arid and then to tropical savannah to the south. The rainy season is short, occurring primarily from July to August. The two primary river catchments, the Blue and White Nile, extend far beyond the border of Sudan; the Blue Nile catchment within the Western Highlands of Ethiopia has high annual total rainfall of around 1500mm/year occurring in a single rainy season from around May to October. The catchment of the White Nile extends into South Sudan, Uganda and beyond and the rainfall increases to the south and shifts to occurring all year round with two peaks during the long and short rains (March – May and November).

Climate variation within the region is large, and four sub-regions are distinguished here, only two falling within the border of Sudan. The Sudan regions are illustrated in **Figures 2-1** and **2-2**, below, and summary descriptions can be found in **Table 2-1** below.

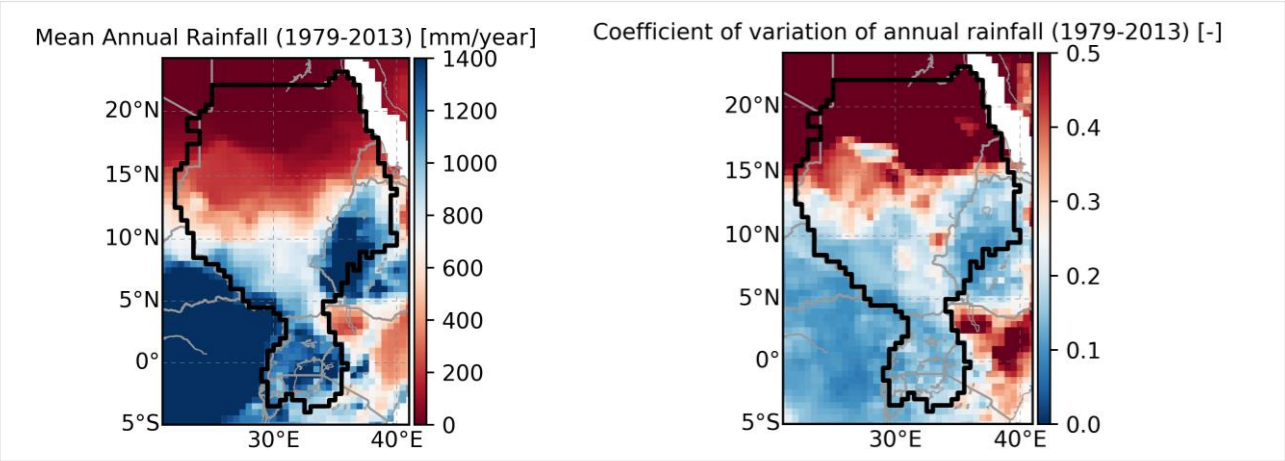
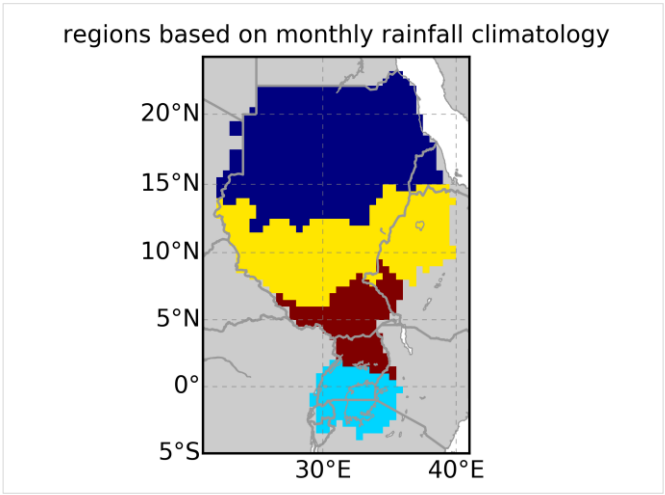


Figure 2-1: Main characteristics (magnitude and variability) of rainfall in Sudan and its region



Coloured regions on the map (above) correspond to the colours used in rainfall and temperature graphs (below)

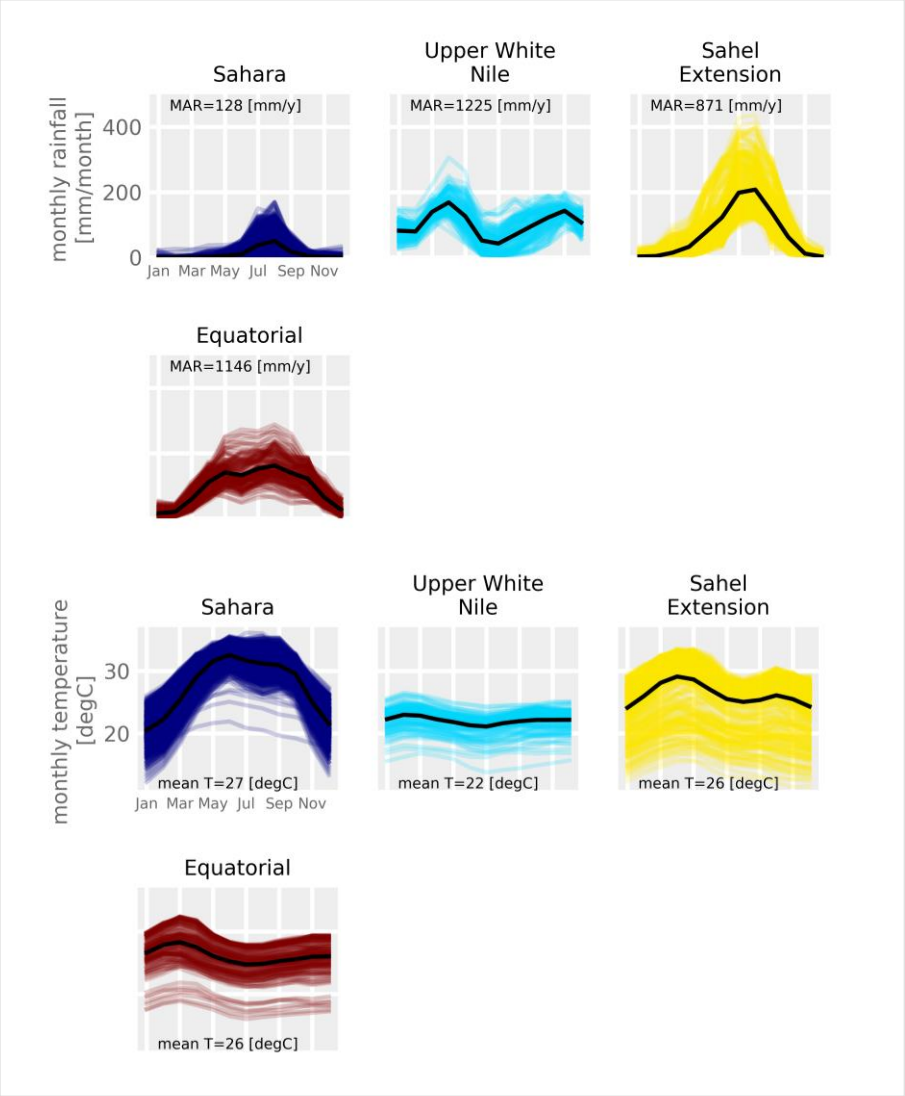


Figure 2-2: Rainfall regions of Sudan based on similarity of standardised rainfall climatology, and their rainfall and temperature climatologies

Table 2-1: Main characteristics of rainfall of Sudan region

SAHARA	A very dry region with mean annual rainfall of 130 mm/year with values decreasing from the south to the north. Rainfall is unpredictable illustrated by the high coefficient of variation of annual total rainfall. What rainfall does occur falls primarily during boreal summer (July – August). The daily mean temperature averages 27° C with a seasonal range of roughly 12° C. Warmest temperatures occur during boreal summer and coolest temperatures during winter.
SAHEL EXTENSION	A spatially heterogeneous rainfall region with a mean annual total of 870 mm/year. Rainfall is highest over the Western Highlands of Ethiopia and along the western border of this region and lowest over the northern parts. The variability from year to year is highest over the drier parts and lowest over the wettest parts. Rainfall occurs primarily during the boreal summer (June – August) with a clearly defined dry season from December to February). The daily mean temperature averages 26° C with a seasonal range of roughly 6° C. Warmest temperatures occur during boreal summer, with a peak just before and after the core rainy season, and coolest temperatures during winter.
EQUATORIAL	A wet region with mean annual rainfall of around 1150 mm/year. Rainfall is highest over the parts of the region within south-west Ethiopia and along the Democratic Republic of Congo border. Rainfall variability from year to year is relatively low. Rainfall occurs during one long rainy season from March to November, peaking with around 180 mm/month from May – October. The daily mean temperature averages 26° C with a seasonal range of 4° C. Warmest temperatures occur around March-April (just before the core rainy season) and temperatures remain relatively stable during the rest of the year.
UPPER WHITE NILE	A wet region with a mean annual rainfall of just under 1230 mm/year. Rainfall is generally highest around Lake Victoria with relatively low year to year variability. Rainfall in this region falls throughout the year, but peaks at around 180 mm/month during two core rainy seasons; the long rains from March to May and the short rains during November. The daily mean temperature averages 22° C with very little seasonal variations (<3° C). Warmest temperatures occur just before the core rainy season in February-March.

2.1 Observed historical climate variations and climate change trends

The Sahara region of Sudan experiences very high rainfall variability on an inter-annual basis. The Sahel Extension region experiences low to high inter-annual variability inversely correlated to the magnitude of rainfall. The other more southern regions experience low inter-annual variability. On **decadal time scales** Sudan also experiences **significant variability** especially over the Sahel Extension region, with some decades being relatively drier or wetter than others. This variability can be seen in the supporting evidence plots provided in the supplementary Appendix **(Figures A-1 to A-4).**

Long term trends across the region show **increasing temperatures** over the period 1979 – 2015, although that trend appears to be weaker in the second half of that period. Long term trends in total annual rainfall are generally not detectable over the regions, with the exception of the Upper White Nile, and to a lesser extent the Sahara region which show non-statistically significant upward trends. Trends in rainfall frequency are generally not statistically significant, with the exception of the Sahel Extension region which shows a negative trend in all rain days, but a positive trend in the frequency of extreme rainfall events. Long term trends and variability in the Sudan regions are summarized in **Table 2-2** below and illustrated further in the supplementary Appendix **(Figures A-1 to A-4).**

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Table 2-2: Summary of trends in rainfall and temperature attributes in Sudan (1979 - 2015)

REGION	MEAN T [DEG C/DECADE]	TOTAL RAINFALL [MM/DECADE]	EXTREME RAINY DAYS [DAYS/DECADE]	RAINY DAYS [DAYS/DECADE]
Sahara	+0.40	slight upward	not detectable	slight downward
Sahel Extension	+0.30	not detectable	+1.4	-4.5
Equatorial	+0.40	not detectable	not detectable	slight upward
Upper White Nile	+0.46	upward	+1.2	not detectable

2.2 Projected (future) climate change trends, including temperature, precipitation and seasonality

Projected changes in main attributes of climate for the Sudan region are summarized in Table 2-3, below, and described in Sections 2.2.1 and 2.2.1. Additional analysis and visualisation of projections be found in **Figures A-5 to A-8** in the supplementary Appendix.

2.2.1 PROJECTED CHANGES IN PRECIPITATION FROM PRESENT TO 2100

Rainfall projections across the Sudan region show a pattern of **potential increased rainfall** emerging during the second half of the century. That pattern appears to be consistent across the majority of CMIP5 models in the ensemble. Relative magnitudes of potential increased rainfall in the Upper White Nile region could potentially reach about 500mm/year wetter by 2100 which equates to 40% of the baseline normal. The rainfall over the much drier Sahara region could potentially increase by up to 100% above the baseline normal. **The increase in rainfall** seems to be strongly associated with **increase in all rainfall events** and also **high intensity rainfall events**. It must be noted that these results are derived from GCM projections which may not accurately represent changes in extreme rainfall dynamics. They are, however, consistent with the increased convective rainfall intensity (e.g. thunderstorm-related rainfall) expected in a warmer climate.

2.2.2 PROJECTED CHANGES IN TEMPERATURE FROM PRESENT TO 2100

Air temperature is projected to be between 1.5˚C and 3˚C warmer in the Sudan water region by the 2050s. By 2100 the range of projected temperatures is greater with Saharan region showing projected increases of 3˚C to 7˚C.

Table 2-3: Summary of projected climate changes across regions of Sudan for key climate variables by 2050

REGION	AVERAGE TEMPERATURE [˚C]	TOTAL ANNUAL RAINFALL [MM/YEAR]	NUMBER OF HEAVY RAINFALL [DAYS/YEAR]	RAINY DAYS [DAYS/YEAR]
Sahara	**Increasing** +2˚C to +3˚C by 2050s but changes evident in next decades	**Normal to increasing,** ranging from no change to an increase of up to 100% by 2100. Change could become evident after 2020s	**Normal to increasing,** could become evident in the 2060s	**Normal to increasing,** ranging from no change to an increase of up to 60% by 2100. Change could become evident in the 2060s

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REGION	AVERAGE TEMPERATURE [˚C]	TOTAL ANNUAL RAINFALL [MM/YEAR]	NUMBER OF HEAVY RAINFALL [DAYS/YEAR]	RAINY DAYS [DAYS/YEAR]
Sahel Extension	**Increasing** +1.5˚C to +3 ˚C by 2050s but changes evident in next decades	**Normal to increasing,** ranging from no change to an increase of up to 30% by 2100. Change could become evident after 2060s	**Normal to increasing,** could become evident in the 2040s	**Normal to increasing,** could become evident in the 2060s
Equatorial	**Increasing** +1.5˚C to +2.5 ˚C by 2050s but changes evident in next decades	**Normal to increasing,** ranging from no change to an increase of up to 25% by 2100. Change could become evident after 2060s	**Increasing,** could become evident in the 2050s	**Normal to increasing,** could become evident in the 2060s
Upper White Nile	**Increasing** +1.5˚C to +2.5˚C by 2050s but changes evident in next decades	**Normal to increasing,** ranging from no change to an increase of up to 40% by 2100. Change could become evident after 2070s	**Increasing,** could become evident in the 2050s	No consistent sign in projections

2.3 Expected climate vulnerabilities

NOTE: Determining vulnerability of different sectors to climate variations or change is extremely challenging as there are many factors involved in vulnerability and different approaches can yield different results. The vulnerabilities presented here based on UNFCCC reporting documents such as national communications or national adaptation plans of action where available, and other literature where UNFCCC documents are not available.

Though with several distinct biogeographic regions and features Sudan is by and large deemed to be a hyper-arid country. The increasing temperature trend is likely to increase the pressure on water resources despite indications that rainfall trends may be normal to increasing into the future, and the possible increase in extreme rainfall events and increasing temperatures is likely to further complicate access to safe drinking water. While the overall contribution of agriculture to the GDP is decreasing, the climate sensitive sector still plays a reasonably large role. The rain-fed agricultural activities, practiced in all areas except along the Nile, is particularly vulnerable to the impacts of increasing temperatures and more extreme rainfall. Already prone to the impact of floods, particularly in low-lying river basins, a potential increase in extreme rainfall events is a reason for concern. While the GDP per capita is high, so is social inequality, and thus people's capacity to adapt to increasing temperatures and more extreme rainfall varies widely.

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Table 2-4: Broad scale sectoral vulnerabilities and potential climate change impacts in Sudan

SECTOR	IMPACTS
Agriculture	- Desertification and loss of agricultural and grazing land - Crop loss and reduced yields owing to increased temperatures and changing rainfall patterns - Increased potential for conflict between farmers and pastoralists - Decreased water and fodder availability for livestock - Increased death and heatstroke in livestock
Fisheries	- Loss of habitat and breeding grounds, especially mangroves and coral reefs - Decreased fish populations and biodiversity owing to reduced river flow and drying of wetlands - Reduced aquatic diversity owing to increased water temperatures
Water resources	- Reduced availability of water resources, owing to increased temperatures and changing rainfall patterns - Increased potential for conflict over limited natural resources - **Decreased water quality, especially during droughts and floods** - Increased salinization of coastal aquifers - **Reduced water storage, negatively affecting hydropower production** - Increased demand for irrigation water
Built infrastructure and human settlements	- Damage to or destruction of coastal infrastructure owing to sea level rise and increased storm intensity - Damage to or destruction of inland infrastructure due to extreme events, especially flooding - Increased potential for damage to infrastructure from extreme temperatures
Human health	- Potential for changes in the prevalence of vector-borne diseases such as malaria - **Increased potential for malnutrition and stunting, especially during drought** - **Increased incidence of water-borne diseases, especially during floods and droughts** - Increased potential for death and disease owing to conflict

3. CLIMATE CHANGE MITIGATION, GREENHOUSE GAS EMISSIONS AND ENERGY USE

The major carriers of Sudan's energy mix, and the energy demands of major economic sectors, are summarised in Section 3.1, below. The major sources of GHG emissions, described by fuel source and sector, are described in Section 3.2. The latter section also includes summarised statistics on Sudan's agriculture sector, historical land use change and vegetation cover.

3.1 National energy production and consumption

Sudan's energy sector is characterised by a split between a well-developed and economically important fossil fuel industry (Sudan is Africa's third-largest oil producer) and a large impoverished rural population that is largely reliant on biomass for domestic energy needs. As a result of this split, the largest contributors to national energy production are biofuels (~58%) and oil (~37%) (IEA, 2014) (Table 3-1, below). Electricity is mostly generated by hydroelectricity (~78% of total electricity production) and oil (~21%) (IEA, 2014; World Bank, 2013). The split between Sudan's formal and informal energy sectors is further reflected in the distribution of total energy consumption between various sectors (Table 3-3, below). The sector that accounts for the majority of national energy consumption is the residential sector (44% of total, ~4.4 MTOE per year), which primarily consumes biomass fuel for cooking, food-processing and heating water. Transport, industry and commercial/public services are responsible for the next largest consumption of energy, respectively consuming 2.6, 1.4 and 1.4 MTOE per year (IEA, 2014). The total annual GHGs emitted by the abovementioned sectors and fuel carriers are described further in Section 3.2.

Unless stated otherwise, all energy figures are derived from UN Stats (2014) [10]; World Energy Council (2016); [11]; and the World Resources Institute (2013) [12]. Agriculture & forestry-related emissions are also reported from Food and Agriculture Organisation (2014-2017) [14] and Global Forest Watch. (2015-2017) [15].

The tables and figures below describe Sudan's energy sector, including total national energy production, primary energy supply and national energy consumption by fuel carrier and sector.

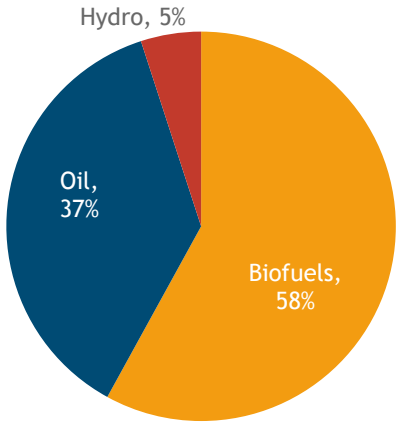

Figure 3-1: Distribution of Sudan's national energy production between major energy carriers (2014-2016)

Table 3-1: National energy and electricity production in Sudan (2014-2016)

NATIONAL ENERGY PRODUCTION		
Source	**Total (MTOE)[1]**	**% of total energy production**
Oil[12]	6.1	37.4
Hydro[12]	0.8	4.7
Biofuels[12]	9.5	57.9
Total national energy production	16.3	
Electricity[6]	Non-Hydro renewable	78.3
	Oil	21.7

[1] *Energy is expressed in 'Megatonnes of Oil Equivalent', where 1 Tonne Oil Equivalent = 11,630 KiloWatt hours (KWh)*

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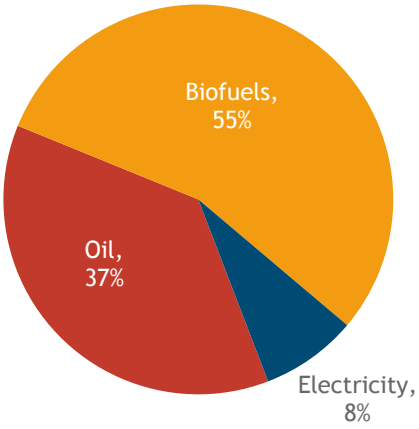

Figure 3-2: Distribution of Sudan's national energy consumption by major energy carriers

Table 3-2: Sudan's national energy consumption by energy source

CONSUMPTION BY ENERGY SOURCE[12]	
Source	**Total (MTOE)**
Oil	3.9
Biofuels	5.7
Electricity	0.8
Total national energy consumption by source	10.4

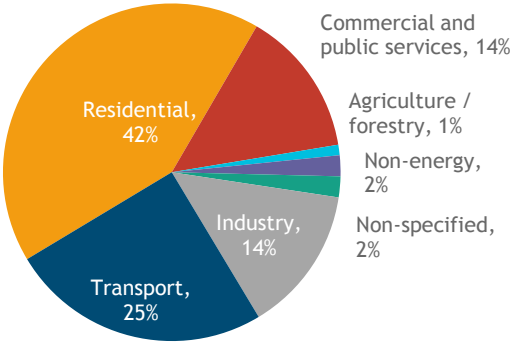

Figure 3-3: Distribution of Sudan's national energy consumption by sector (2014-2016)

Table 3-3: Sudan's national energy consumption by sector (2014-2016)

CONSUMPTION BY SECTOR[12]	
Source	**Total (MTOE)**
Industry	1.4
Transport	2.6
Residential	4.4
Commercial and public services	1.4
Agriculture / forestry	0.1
Non-specified	0.2
Non-energy use	0.2
Total national energy consumption by sector	10.4

Table 3-4: Sudan's national total primary energy supply (estimated for 2014-2016)

TOTAL PRIMARY ENERGY SUPPLY[12]		
Source		**Total (MTOE)**
Oil	Crude Oil	4.3
	Oil Products	0.5
Biofuels		0.8
Electricity		9.5
Total primary energy supply		15.0

3.2 National greenhouse gas emissions by source and sector

Oil is the only contributor to Sudan's greenhouse gas (GHG) emissions from fuel combustion (~13.6 MT CO_2e), excluding consideration of biofuels (IEA, 2013). The sectors that account for the largest proportion of national GHG emissions from fuel combustion are transport, which is almost all by road (8.2 MT CO_2e), electricity and heat production (2-2.1 MT CO_2e), residential (0.5 MT CO_2e) and other uses within the energy sector (IEA, 2013). Despite the large contribution of fossil fuels to Sudan's energy consumption and resultant GHG emissions, the largest sources of GHG emissions from all sources of primary energy consumption are Land Use Change and Forestry (LUCF) (166.7 MT CO_2e out of a total of ~208 MT CO_2e) - it is likely that the majority of LUCF emissions can be attributed to the use of biomass fuel (CAIT, 2013).

Section 3.2.1, below, describes GHG emissions from fuel combustion – these figures include direct combustion of fuels as a primary energy carrier as well as conversion to other forms of energy (e.g. as electricity). The latter figures are based on statistics from the International Energy Agency (IEA). Section 3.2.2, further below, describes GHG emissions from all sectors of national energy consumption, which therefore includes emissions from fuel combustion, industrial/manufacturing processes, household-level energy consumption and AFOLU (Agriculture, Forestry and Other Land Use). The latter figures are compiled by the World Resources Institute's Climate Access Indicator Tools (CAIT), which employs different methodologies and reporting standards to the IEA. Therefore, while there is some resultant duplication between the two datasets, each provides slightly different approaches to categorisation of major GHG emitting sectors and are both included for consideration. Section 3.2.3 provides additional details on Sudan's Land Use and Land Use Change sector, including detailed summaries of emissions from the agriculture sector and historical land use changes.

3.2.1 GHG EMISSIONS FROM FUEL COMBUSTION, BY SOURCE AND SECTOR

Table 3-5: Sudan's national greenhouse gas emissions from fuel combustion

NATIONAL GHG EMISSIONS FROM FUEL COMBUSTION BY FUEL SOURCE AND SECTOR [13]		
Source / Sector		**Total emissions (MT CO_2e)**
Oil		13.6
Total fuel source emissions		13.6
Electricity and heat production		2.0
Other energy industry own use*		0.2
Manufacturing industries and construction		1.7
Transport	Road	8.2
	Other	0.1
	Total	8.3
Other	Residential	0.5
	Non-residential	0.9
	Total	1.5
Total sector emissions		13.6

** Includes emissions from own use in petroleum refining, the manufacture of solid fuels, coal mining, oil and gas extraction and other energy-producing industries.*

3.2.2 GHG EMISSIONS FROM PRIMARY ENERGY CONSUMPTION, BY SOURCE AND SECTOR

Table 3-6: Sudan's national greenhouse gas emissions from primary energy consumption (estimated for 2014-2016)

NATIONAL GHG EMISSIONS FROM PRIMARY ENERGY CONSUMPTION BY SOURCE AND SECTOR[14]		
Source / Sector		Total emissions (MT CO_2e)
Energy	Electricity and heat	8.2
	Manufacturing and construction	0.1
	Transport	8.3
	Other fuel combustion	0.5
	Fugitive emissions	0.9
	Energy sub-total	1.5
Waste		1.5
Land use change and forestry (LUCF)		166.7
Total emissions (including LUCF)		207.6

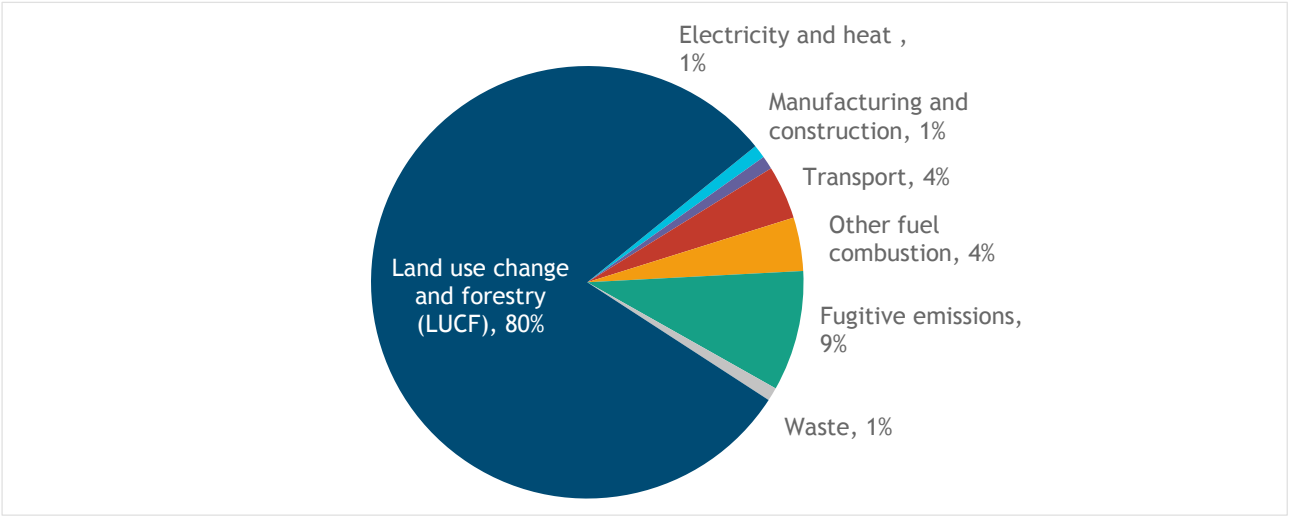

Figure 3-4: Distribution of Sudan's GHG emissions by major sectors

3.2.3 GHG EMISSIONS FROM AGRICULTURAL PRACTICES

Table 3-7, overleaf, summarises GHG emissions from Sudan's agriculture sector (derived from Food and Agriculture Organisation statistics). Although there are multiple agricultural practices which contribute to GHG emissions, in the case of Sudan the livestock production sector is by far the largest contributor to agricultural GHG emissions. In particular, enteric fermentation and manure left on pastures contributes ~86% (~63 out of a total of 72 MT CO_2e) of total GHG emissions from this sector.

Table 3-7: National annual greenhouse gas emissions from agricultural practices, forestry and other land use in Sudan (estimated for 2014-2017)

VARIABLE		ANNUAL EMISSIONS (MT CO_2E)
Annual GHG emission from agricultural practices [15]	Burning - crop residues	0.02
	Burning - savanna	4.1
	Crop residues	0.9
	Enteric fermentation	37.9
	Manure management	1.6
	Manure applied to soils	0.9
	Manure left on pasture	24.7
	Rice cultivation	0.05
	Synthetic fertilizers	2.3
Total emissions		72.5

Table 3-8, below, summarises the recent historical changes in land use in Sudan through analysis of land use change. Statistics derived from the Global Forest Watch database were used to summarise the total area of wooded vegetation in various categories of canopy cover density (where 10-30% canopy cover can be considered as savanna, 30-50% cover can be considered woodland and 50-100% cover can be considered dense forest), as well as the historical rates of change in each vegetation category. Sudan is largely characterised by arid semi-desert and desert and as a result total national tree cover is only ~2.3% - the majority of wooded vegetation occurs in a narrow extent of Sudanian savanna at the south of the country. Global Forest Watch reports the total aboveground carbon stock of Sudan's forest biomass as ~153 million tonnes.

Table 3-8: Vegetation cover and land use change in Sudan (estimated for 2015)

VARIABLE		TOTAL (HECTARES)	TOTAL (% OF LAND AREA)	UNIT
Total tree cover [16]	10-30% canopy cover	4,219,387	2.25	% of total land area
	30-50% canopy cover	71,661	0.0	
	50-100% canopy cover	1,108	0.0	
	Total	4,292,155	2.3	
Land use change and agricultural expansion	Historical annual rate of deforestation[17]	10-30% canopy cover	0.0	% of previous year
		30-50% canopy cover	0.1	
		50-100% canopy cover	0.5	

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4. SUMMARISED NATIONAL PRIORITIES FOR CLIMATE CHANGE ADAPTATION AND MITIGATION

Sudan's main priority actions related to climate change are described in the country's submissions to the UNFCCC through the Intended Nationally Determined Contributions (NDC) document. This document includes detailed descriptions of Sudan's major commitments and priorities related to GHG mitigations (Table 4-2, below) as well as major priorities related to adaptation, derived from the draft National Adaptation Plan (NAP) (Table 4-3, further below).

Sudan intends to pursue implementing low carbon development interventions in three sectors of energy, forestry and waste in line with the country's national development priorities, objectives and circumstances. The NDC contains both mitigation and adaptation aspects that Sudan aims to undertake towards achieving the objective of the Convention and its national development priorities.

Sudan's NDC estimates that the total international support required to implement the intended contribution in terms of finance, technology and capacity building, over a cycle of contributions of 5-10 years, amounts to ~12.88 USD billion of which 1.2 billion USD is allocated for adaptation and 11.68 billion for mitigation (including USD 7.55 billion for the energy sector, USD 3.2 billion for AFOLU, and USD 930 million for the waste sector).

Table 4-1, below, gives details on Sudan's GHG reduction targets outlined in the country's NDC, with information on target gases and sectors, the use of international markets in achieving targets (e.g. the use of carbon credits), and accounting methods used to quantify GHG emissions (e.g. inclusion of land use and land use change).

Table 4-1: Summary of Sudan's NDC commitments for reduction of GHG emissions

GHG EMISSIONS REPORTED IN NDC (MT CO2E/YR)	BASE LEVEL	REDUCTION TARGET	TARGET YEAR	SECTORS AND GASES	USE OF INTERNATIONAL MARKETS	LAND-USE INCLUSION / ACCOUNTING METHOD
177.35	N/A	A series of four conditional policy measures on GHG inventories to reduce emissions in multiple sectors	N/A	Renewable energy, ethanol, and HFC/PFC/SF_6 phase-out	Does not exclude using market-based-mechanisms in implementing its contributions if access is granted	N/A

4.1 National priorities for climate change mitigation

Sudan's major priorities for actions and investments related to climate change mitigation are summarised in Table 4-2, below, categorised according to sector. Proposed activities and investments within each sector are further categorised according to 'Technology Type', based on the categories of technologies listed by the Green Climate Fund's (GCF) impact indicators for mitigation projects (key for technology types provided below Table 4-2). The below-mentioned technology types and specific actions represent Sudan's immediate national priorities for investments in climate change mitigation and reflect recent and ongoing policy-level measures to reduce GHG emissions and increase energy efficiency.

National priorities for mitigation of GHG emissions are identified for the sectors of Energy, AFOLU and Waster, respectively. Priorities related to Energy sector are strongly focused on increasing the generation of electricity through renewable energy, including several detailed and ambitious targets inter alia increasing share of renewables in the energy mix to 20% by 2030 through promotion of wind (1,000 MW), solar CSP (100 MW) and solar PV power

(1,000 MW). Other low-carbon energy technologies identified in Sudan's NDC include promotion of biomass, geothermal, waste-to-energy and small hydroelectricity systems. Energy access in 'off-grid' rural areas will be increased through promotion of household-level solar electrification systems, aiming to reach over 1,000,000 households by 2030. Sudan's NDC identifies multiple measures for reduced emissions through increased efficiency of energy transmission, from household- to national-level actions. In the AFOLU sector, Sudan's priority actions are comparatively less detailed but include inter alia afforestation/reforestation, reduced use of woodfuels through LPG substitution, increased forest conservation and sustainable forest management, and various measures to increase sustainability of natural resource use (such as gum Arabic, woodfuels and livestock production). Sudan's NDC also proposes the development of a national REDD+ strategy. In the Waste sector, the NDC of Sudan includes actions to reduce the volume of urban waste in landfill sites, as well as generate gas and electricity through energy recovery at landfill sites.

Table 4-2: Mitigation priorities in Sudan's NDC

PRIORITY SECTOR	SECTOR-SPECIFIC ACTION	TECHNOLOGY TYPE[2]
Energy	Integration of renewable energy for electricity, target of 20% by 2030	1
	Promotion of wind energy, up to 1000 MW to be connected to grid	1, 3, 7
	Promotion of solar PV energy: 1000 MW in different states within Sudan (on - and off - grid)	1, 3, 7
	Promotion of solar CSP technology: up to 100 MW to be connected to the grid in the northern part of Sudan	1, 3, 7
	Waste to Energy: 80 MW (grid connected) will be applicable in several intended sites	1, 4, 5
	Biomass Potential: 80 MW (grid connected); e.g. the sugar industry	1, 3
	Geothermal Potential: 300 MW in different states of Sudan	1, 3
	Small Hydro Plants: 50 MW (grid connected)/ especially in combination with irrigation-sites, small hydro plant projects	1, 3
	Solar rural electrification through installation of 1.1 million Solar Home Systems (SHSs) up to 2030	1, 3
	Reduction of loss in transmission and distribution networks	1
	Rehabilitation of the cooling system in Hydroelectric stations	1
	Increase the readiness of the power station – matrix turbines	1

[2] *GCF Technology Type Key (derived from GCF's Results Framework for mitigation)*

1. Reduced emissions through increased lower emission energy access and power generation.

2. Reduced emissions through increased access to low-emission transport.

3. Reduced emissions from buildings, cities, industries and appliances.

4. Reduced emissions from land use, deforestation, forest degradation, and through sustainable management of forests and conservation and enhancement of forest carbon stocks.

5. Strengthened institutional and regulatory systems for low-emission planning and development.

6. Increased number of small, medium and large low-emission power suppliers.

7. Lower energy intensity of buildings, cities, industries, and appliances.

8. Increased use of low-carbon transport.

9. Improved management of land or forest areas contributing to emissions reductions.

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PRIORITY SECTOR	SECTOR-SPECIFIC ACTION	TECHNOLOGY TYPE[3]
Energy (cont)	Reduction of the costs of producing electricity and auxiliary consumption from thermal power plants	1, 6
	Improvement of specific fuel consumption in thermal power plants	1, 6
	Replacement of incandescent lamps by CFL and LED lamps in residential sector	3, 5, 7
	Establishment of the labelling system for electrical appliances	1, 5
	Production of 2300 MW using natural gas in different areas in the country	1
AFOLU	Afforestation/reforestation through official planting. Community planting and Planting in irrigated agricultural areas	4, 9
	National REDD+ strategy	4, 5, 9
	The carbon balance and incentives for energy substitution to LPG	4, 5, 9
	Incentives for using sustainable charcoal, firewood efficiency, increased gum Arabic production, forest conservation and sustainable forest management, reforestation, forest plantations and more balanced livestock production	4, 5, 9
	Reconciliation of conflicting policies of rival economic sectors and streamlining of activities of supporting sectors such as education and research	4, 5, 9
Waste	Adoption of sanitary landfill sites with treatment facilities, gas collection and capture system	4,9
	Composting of organic component in municipal waste	4, 9
	Sorting and recycling of recyclable items such as plastic and paper	4, 9
	Use of non-recyclable items as a fuel for cement factories	4, 9
	Energy Recovery by generation of electricity or gas from waste	1, 4, 9

[3] *GCF Technology Type Key (derived from GCF's Results Framework for mitigation)*

1. Reduced emissions through increased lower emission energy access and power generation.

2. Reduced emissions through increased access to low-emission transport.

3. Reduced emissions from buildings, cities, industries and appliances.

4. Reduced emissions from land use, deforestation, forest degradation, and through sustainable management of forests and conservation and enhancement of forest carbon stocks.

5. Strengthened institutional and regulatory systems for low-emission planning and development.

6. Increased number of small, medium and large low-emission power suppliers.

7. Lower energy intensity of buildings, cities, industries, and appliances.

8. Increased use of low-carbon transport.

9. Improved management of land or forest areas contributing to emissions reductions.

4.2 National priorities for climate change adaptation

In terms of climate change adaptation, Sudan's NDC includes detailed national priorities for sectors including AFOLU, Water, Coastal Zones and Human Health. Sudan's proposed activities and investments related to adaptation are categorised according to 'Technology Type', based on the categories of technologies listed by the Green Climate Fund's (GCF) impact indicators for adaptation projects (key for technology types provided below Table 4-3). In the AFOLU sector, Sudan's priorities include a strong focus on empowering and increasing the adaptive capacity of vulnerable communities, including through enhancing the participation of women and youth in activities related to adaptation and environmental conservation, creation of an enabling environment and increasing access to information in climate-vulnerable areas. Adaptation priorities related to crop production focus on crop diversification and introduction of improved drought-resistant varieties/early maturing varieties (both field and horticultural crops) in areas affected by decreased/variable rainfall. Sudan's adaptation priorities for the AFOLU sector also include a focus on restoration and sustainable management of natural resources such as rangelands and gum Arabic woodlands. Adaptation priorities for the livestock sector include improved veterinary services, monitoring of livestock disease, and management of grazing resources.

In the water sector, Sudan's adaptation priorities include *inter alia* detailed measures for integrated water resource management, development of small-scale water harvesting and storage infrastructure, and increased access to water supply facilities for vulnerable households (hand pumps and construction of water-networks in rural areas for provisions of drinking-water and achieving water security). In the coastal zone, Sudan's adaptation priorities focus on the implementation of a framework for integrated coastal management (an integrated approach to land use planning, creation of ecological buffer zones, establishing protected inland zones to accommodate salt marsh, mangrove and sea grass) combined with multiple measures to increase awareness and adaptive capacity at the community level. Adaptation priorities in Sudan's Health sectors are mainly focused on increasing the capacity of public health systems to monitor and control disease vectors, improved community sanitation and increased public awareness of specific health risks associated with climate change hazards (such as increased prevalence of insects and disease vectors. Specific measures to reduce the incidence of diseases such as malaria, meningitis and leishmaniasis include inter alia introduction of early diagnosis and treatment programmes, control of primary insect vectors, and improved community sanitation and medical services for diagnosis and treatment of diseases.

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Table 4-3: Adaptation priorities in Sudan's NDC

PRIORITY SECTOR	SECTOR-SPECIFIC ACTION	TECHNOLOGY TYPE[4]
AFOLU	Crop diversification and introduction of improved drought-resistant varieties/early maturing varieties (both field and horticultural crops) in areas affected by rainfall decease/ variability	1, 2
	Rehabilitation of the meteorological networks to enhance early warning system activities	6
	Diversification of income generating activities of vulnerable farmers	1, 2
	Strengthening of enabling environment/activities to empower vulnerable communities including through: establishment of markets in vulnerable areas, awareness and access to information by vulnerable groups/communities etc	1, 2, 8
	Introduction of agroforestry in areas vulnerable to climate change to enhance agriculture production as well as empower vulnerable communities through their involvement in community forests activities/products	1, 2
	Establishment of women cooperative societies in order to empower them and increase their resilience	1, 2
	Enhancing the participation of women and youth in activities related to adaptation and environmental conservation	1, 7
	Climate-proofing of some of the existing developmental project to increase their resilience for current and future climatic changes	5, 7
	Planting shelterbelts, introduction of high economic value trees and rehabilitation of the Gum Arabic gardens through engagement in a range of forestry activities	1, 4
	Regular surveillance of animal diseases through improved monitoring	4, 6
	Establishment of range's enclosures/ranches to increase resilience of vulnerable communities	1, 2
	Advance research on various areas related to climate change impacts on rangelands (e.g. plants and animals species, communities etc.) and response measures	4, 5
	Joint management of natural resources for comprehensive consideration of climate change impacts	4, 7
	Sustainable management of grazing areas and rangelands	1, 4
	Restocking animal herds in areas affected by climate change	1, 2

[4] **GCF Technology Type Key (derived from GCF's Results Framework for adaptation)*

1. Increased resilience and enhanced livelihoods of the most vulnerable people, communities, and regions.

2. Increased resilience of health and wellbeing, and food and water security

3. Increased resilience of infrastructure and the built environment to climate change threats

4. Improved resilience of ecosystems and ecosystem services

5. Strengthened institutional and regulatory systems for climate responsive planning and development

6. Increased generation and use of climate information in decision making

7. Strengthened adaptive capacity and reduced exposure to climate risks

8. Strengthened awareness of climate threats and risk reduction processes

PRIORITY SECTOR	SECTOR-SPECIFIC ACTION	TECHNOLOGY TYPE[5]
AFOLU (cont)	Improving animal productivity and animal breeds to increase resilience to climate change	1, 7
	Replanting and rehabilitating of vulnerable areas with palatable range species and management of animal routes	1, 4
	Improving veterinary services (including, mobile clinics provision of vaccines etc.) to enhance the adaptive capacity in vulnerable areas	1, 7
Water	Integrated Management of water resources to meet the current and future challenges/needs	2, 7
	Water harvesting (dams, hafirs, terraces, etc.) to assist vulnerable communities to adapt and build their resilience facing increasing vulnerability of water sources/resources	1, 2, 7
	Establishment and rehabilitation of hand pumps and construction of water-networks in rural areas for provisions of drinking-water and achieving water security in order to discourage communities' migration from vulnerable areas	1, 2
	Advance research related to climate change impacts on water sector e.g. Undertaking geophysical studies of the aquifers for sustainable ground water utilization	2, 6
	Establishment of rain gauge stations to monitor and provide hydrological information	6
	Introduction of a revolving micro-credit fund to support implementation of small water harvesting projects	2
Coastal zone	New information systems: Enhancing monitoring programs in natural and urban settings to detect biological, physical, and chemical changes and responses due to direct and indirect effects of climate change	6
	Implement integrated coastal zone management: an integrated approach to land use planning, creation of ecological buffer zones, establishing protected inland zones to accommodate salt marsh, mangrove and sea grass	4
	Building awareness: This involves enhancing the awareness of coastal developers through national and international activities, technical assistance, and capacity-building	7, 8

[5] **GCF Technology Type Key (derived from GCF's Results Framework for adaptation)*

1. Increased resilience and enhanced livelihoods of the most vulnerable people, communities, and regions.

2. Increased resilience of health and wellbeing, and food and water security

3. Increased resilience of infrastructure and the built environment to climate change threats

4. Improved resilience of ecosystems and ecosystem services

5. Strengthened institutional and regulatory systems for climate responsive planning and development

6. Increased generation and use of climate information in decision making

7. Strengthened adaptive capacity and reduced exposure to climate risks

8. Strengthened awareness of climate threats and risk reduction processes

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PRIORITY SECTOR	SECTOR-SPECIFIC ACTION	TECHNOLOGY TYPE[6]
Health	Introduction of early disease diagnosis and treatment programmes for malaria, meningitis, and leishmaniasis	7
	Raising the health awareness of communities in vulnerable areas to climate change related diseases in order to increase their adaptive capacities	7, 8
	Building the capacities of the health cadres and improvement of health services to meet the evolving and increasing challenges of climate change	1, 7
	Increasing health resilience to climate change related diseases and reducing the associated mortality by supporting family's and school's health programmes	1, 7
	Control of Endemic and epidemic diseases induced by Climate Change through Combating vectors and insects borne diseases	7
	Controlling of diseases shared between humans and animals	7
	Improve community sanitation and medical services, including capacities for diagnosis and treatment	1, 7

[6] *GCF Technology Type Key (derived from GCF's Results Framework for adaptation)*

1. Increased resilience and enhanced livelihoods of the most vulnerable people, communities, and regions.

2. Increased resilience of health and wellbeing, and food and water security

3. Increased resilience of infrastructure and the built environment to climate change threats

4. Improved resilience of ecosystems and ecosystem services

5. Strengthened institutional and regulatory systems for climate responsive planning and development

6. Increased generation and use of climate information in decision making

7. Strengthened adaptive capacity and reduced exposure to climate risks

8. Strengthened awareness of climate threats and risk reduction processes

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5. ASSUMPTIONS, GAPS IN INFORMATION AND DATA, DISCLAIMERS

The observed and projected climate trends described in Section 2 'Climate and Weather' are derived from a combination of publicly-available observational data and CMIP5 climate models. Detailed information is included in Section 6. Appendix 1, including '6.1.b. Historical Trends and Variability Analysis' and '6.1.c. Climate Projections Visualisations'.

Unless stated otherwise, all statistics reported in Section 1 ('Geographic and Socio-Economic Context' and Section 3 'Climate change mitigation, greenhouse gas emissions and energy use') are derived from databases of publicly available datasets managed by international or multilateral agencies including inter alia The World Bank Group, the United Nations, World Resources Institute and International Energy Agency.

Unless stated otherwise, all energy and greenhouse gas emission figures are derived from UN Stats (2014); World Energy Council (2016); the World Resources Institute (2013), and the International Energy Agency (2016). Agriculture & forestry-related emissions are also reported from Food and Agriculture Organisation (2014-2017) and Global Forest Watch. (2015-2017). Full references are provided as a supplementary appendix.

As a result of the use of standardised methodologies and data sources across the 25 countries included in this AfDB Climate Change Profile, statistics and estimates reported herein may differ from other publicly available datasets or national estimates. Readers are advised to always check for updated publications and newly released national datasets.

This AfDB Climate Change Profile series is intended to provide a brief touch-stone reference for climate change practitioners, project managers and researchers working in African countries. The figures and estimates provided herein are intended to inform the reader of the main climate-related challenges and priorities, however these should be used to inform a process of additional research and in-country consultations. The University of Cape Town, the African Development Bank and its Boards of Directors do not guarantee the accuracy of figures and statements included in this work and accept no responsibility for any consequences of its use.

6. APPENDIX 1

1.a Supporting evidence

The climate projections detailed in Chapter 2 (above) are supported by rigorous analysis of observed and model projections data. More details of this analysis and supporting figures can be found below.

1.b Historical trends and variability analysis

The analysis of historical trends and variability of key climate variables is presented below. This analysis uses the WATCH Climate Forcing dataset which has been selected as the most broadly representative of station observations across Sudan. Long term (1979 to 2013) trends as well as inter-annual variability (decade to decade) has been analysed for total annual rainfall, number of rainfall days, number of extreme rainfall days, and daily mean temperatures for each of the four climate regions across Sudan. The plots below detail **inter-annual variability** (dotted lines), **decadal variability** (smooth bold solid curves) and **long-term trends** (thin straight lines) for each region and statistic. This allows for comparison of different types of variability against the long-term trend. It can be seen that for rainfall statistics, inter-annual and decadal variability are typically fairly large compared to long term trends. For example, for total annual rainfall, the Sahel region has very high inter-annual (700mm in some years to 900mm in other years) and moderate decadal variability (800mm in some decades to 950mm in other decades). The long-term trend is not statistically significant but could be around 15mm over the 30-year period.

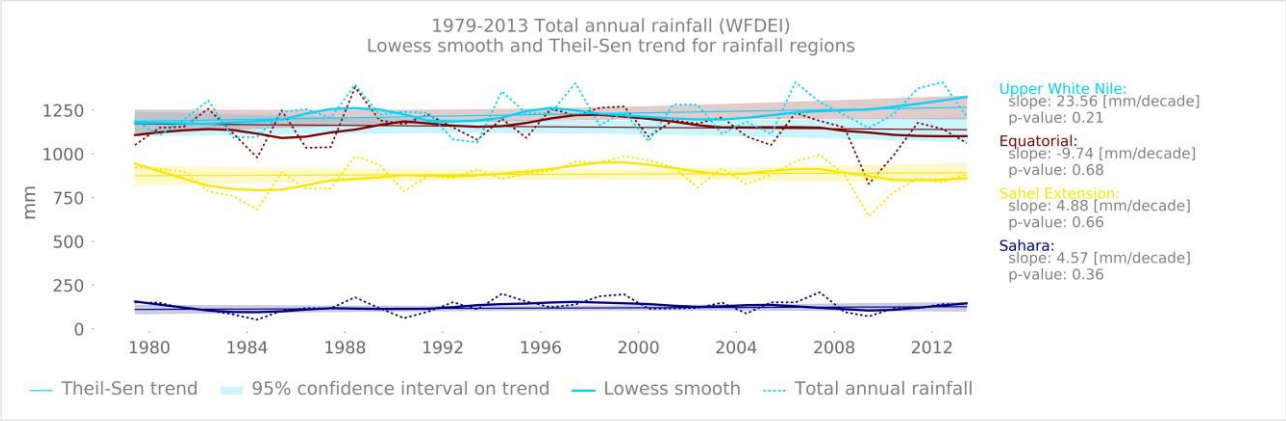

Figure A-1: Long term trends and variability in total annual rainfall for rainfall regions

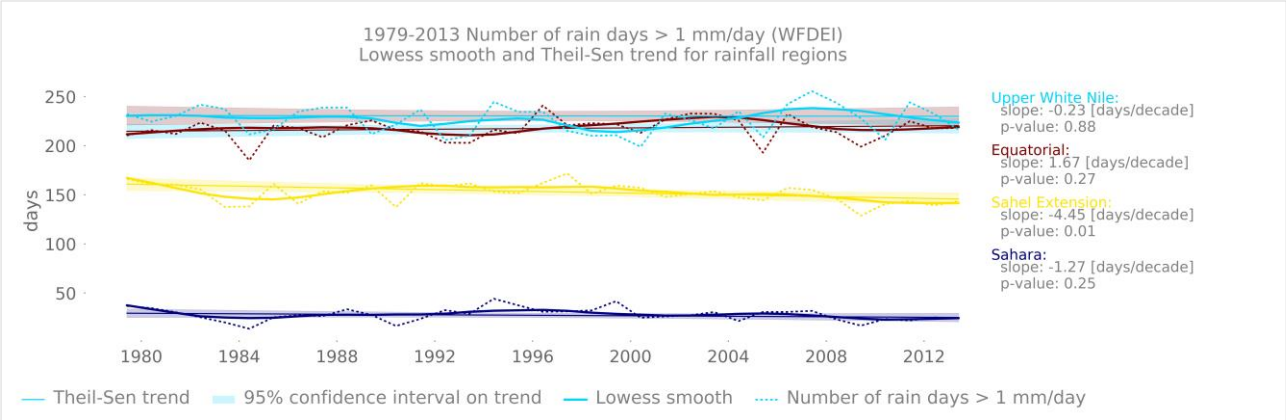

Figure A-2: Long term trends and variability in frequency of rainfall events for rainfall regions

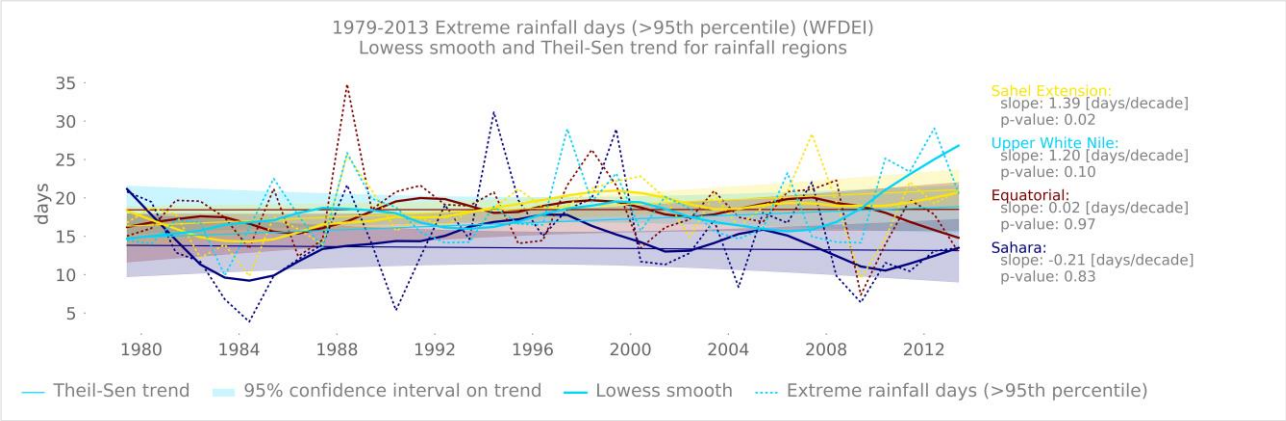

Figure A-3: Long term trends and variability in extreme rainfall events for rainfall regions

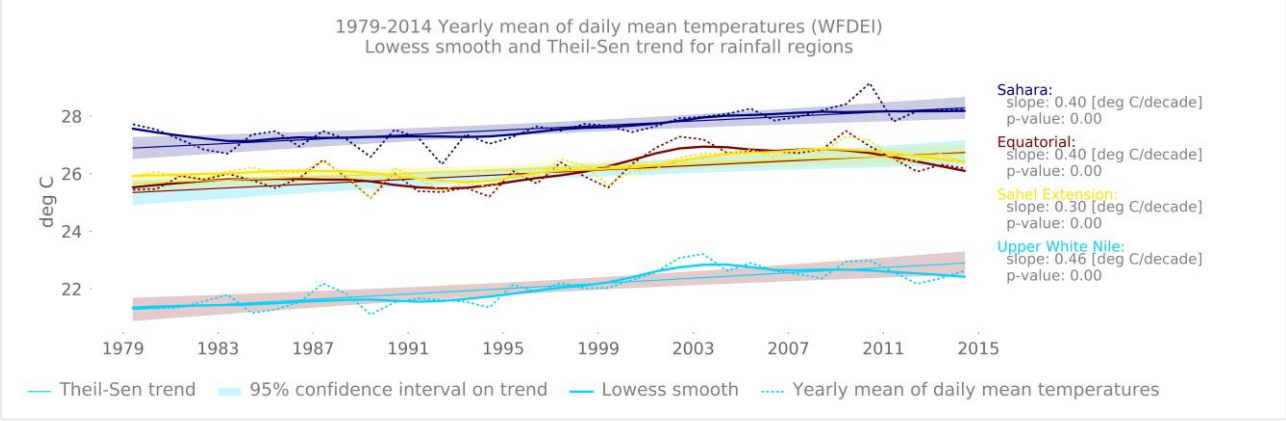

Figure A-4: Long term trends and variability in daily mean air temperatures for rainfall regions

1.c Climate projections visualizations

The plots below (Figures A-5 – A-8) are called plume plots and they are used to represent the different long-term projections across the multiple climate models in the CMIP5 model archive used to inform the IPCC AR5 report. The plots show projected variations in different variables averaged over the climate regions. The blue colours indicate variations that would be considered within the range of natural variability, so in other words, not necessarily the result of climate change. The orange colours indicate projection time series where the changes would be considered outside of the range of natural variability and so likely a response to climate change. It is important to note that these are global climate model projections and so likely do not capture local scale features such as topography and land ocean boundary dynamics. They also may not capture small scale features such as severe thunderstorms that can have important societal impacts. Finally, these projections are averages over relatively large spatial areas and it is possible that different messages would be obtained at small spatial scales and if various forms of downscaling are performed.

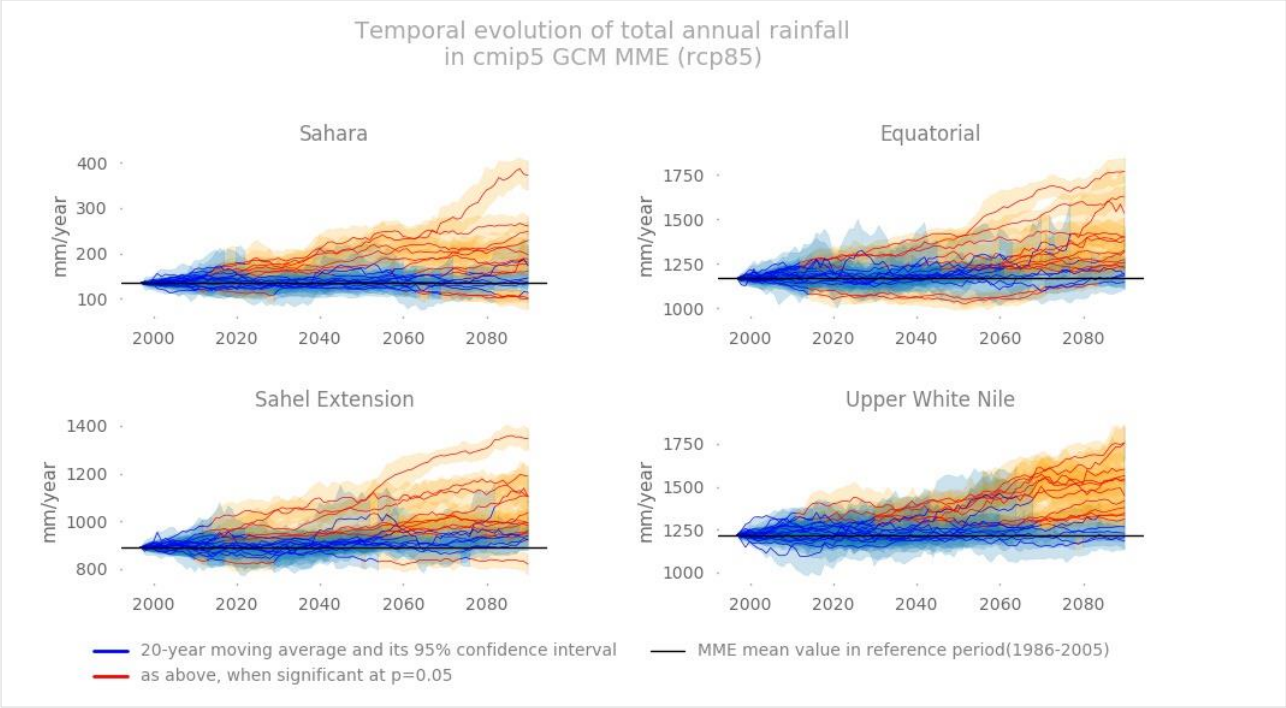

Figure A-5: Projected changes and emergence of changes in total annual rainfall

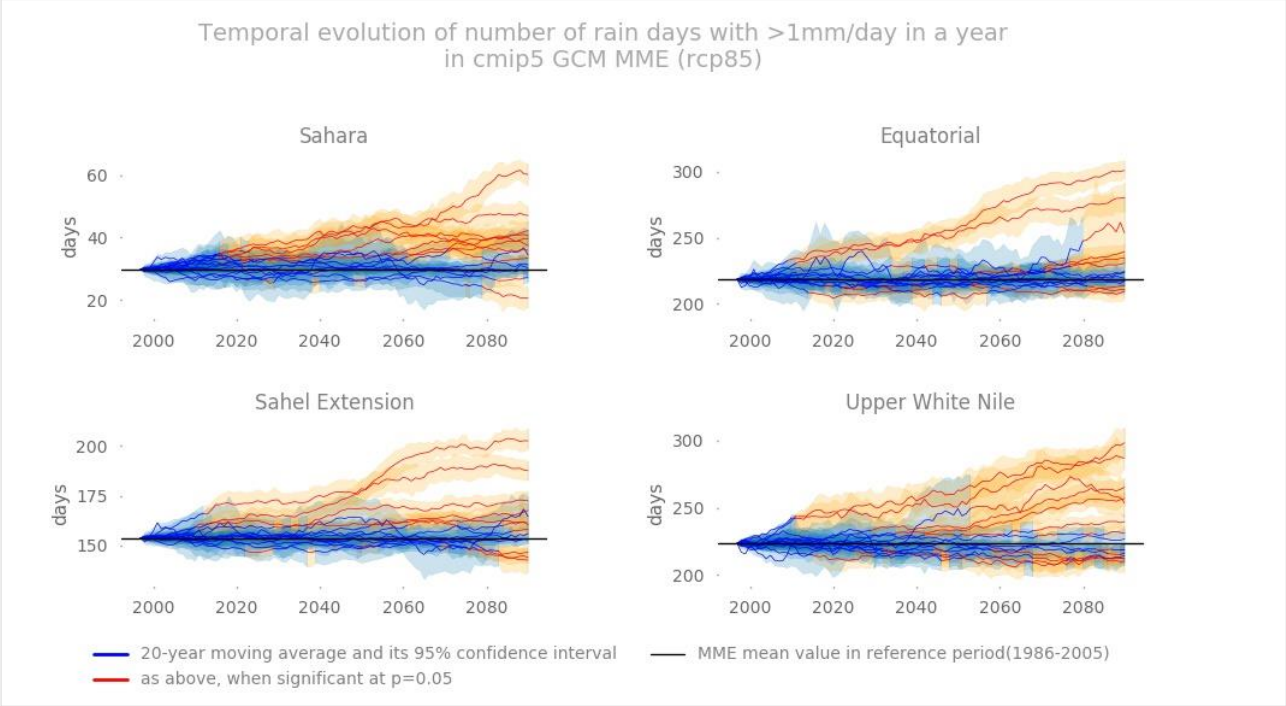

Figure A-6: Projected changes and emergence of changes in number of rain days per year

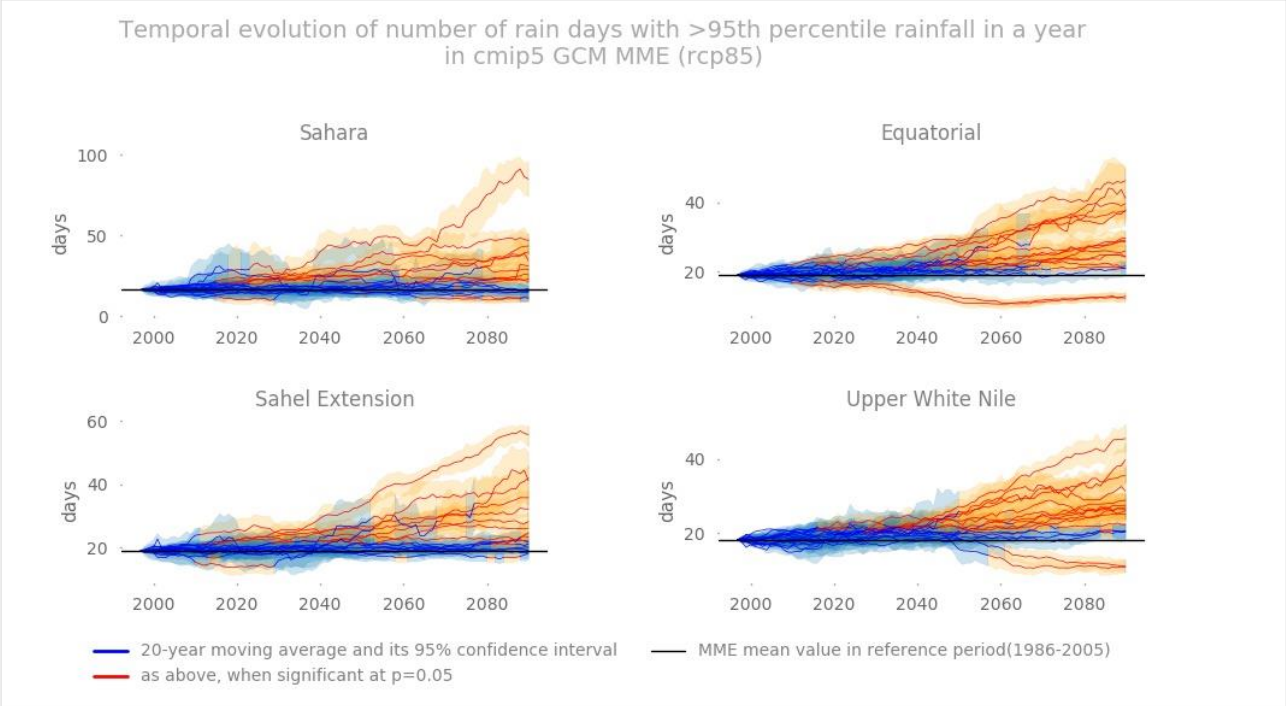

Figure A-7: Projected changes and emergence of changes in number of very heavy rainfall days (greater than 95th percentile) per year

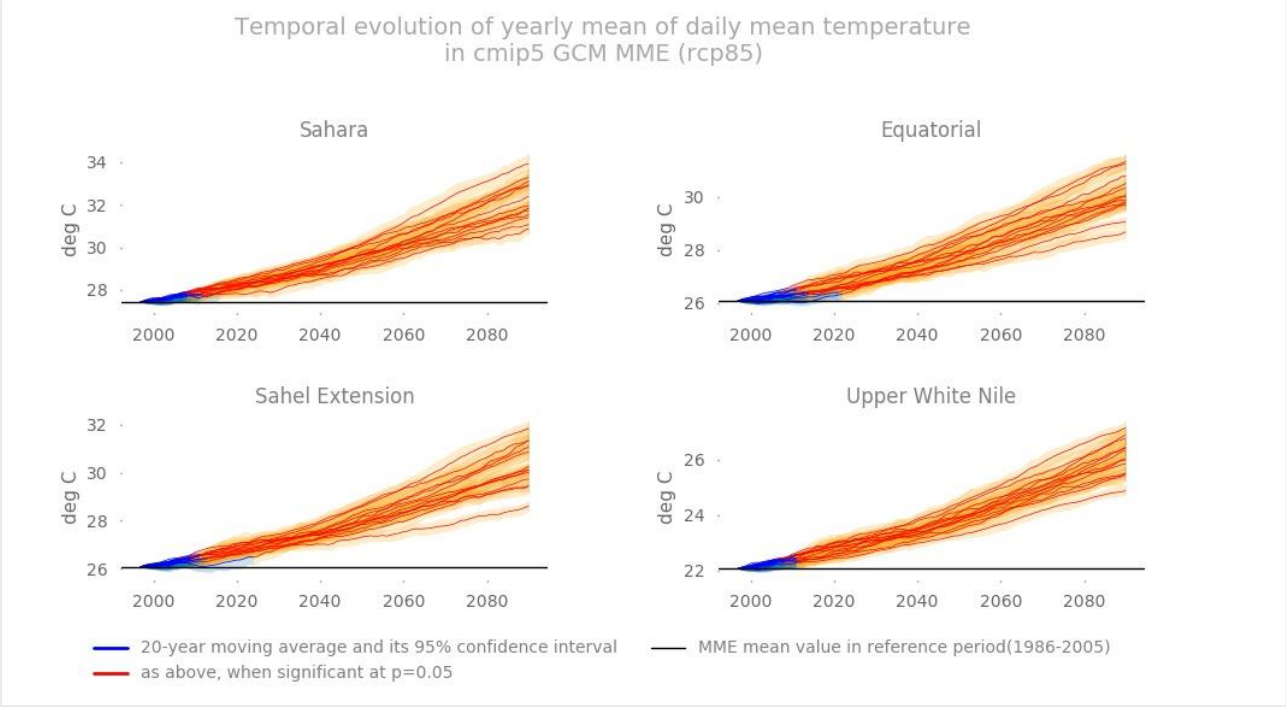

Figure A-8: Projected changes and emergence of changes in annual mean daily mean temperatures

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