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Title:

Climate Change

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الأية

قال تعالى:

(قُلْ أَإِنَّكُمْ لَتَكْفُرُونَ بِالَّذِي خَلَقَ الْأَرْضَ فِي يَوْمَيْنِ وَتَجْعَلُونَ لَهُ أَنْدادًا ذلِكَ رَبُّ الْعالَمِينَ (9) وَجَعَلَ فِيها رَواسِيَ مِنْ فَوْقِها وَبارَكَ فِيها وَقَدَّرَ فِيها أَقْواتَها فِي أَرْبَعَةِ أَيَّامٍ سَواءً لِلسَّائِلِينَ(10)).

صدق الله العظيم

سورة فصلت الآيات (9-10)

Dedication

I dedicate this work to… my dear father …who dedicated his life for the sake of our comfort and keep us happy…

To…Which melted candle to illuminate the way for us…My mother

To my Friends

Acknowledgments

I wish to thank many people who contributed immensely to this work.

A special thanks to my supervisor **Prof. Mohammed Osman Sid Ahmed**

For his helpful discussion in the development of the problem.

Abstract

In this research the cclimate change and its effect on temperature and rainfall. Special consideration is given to the case Sudan.

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CHAPTER ONE

INTRODUCTION

1-1 Introduction

Climate change may refer to a change in average weather conditions, or in the time variation of weather around longer-term average conditions (i.e., more or fewer extreme weather events). Climate change is caused by factors such as biotic processes, variations in solar radiation received by Earth, plate tectonics, and volcanic eruptions. Certain human activities have also been identified as significant causes of recent climate change, often referred to as "global warming".

Scientists actively work to understand past and future climate by using observations and theoretical models. A climate record—extending deep into the Earth's past—has been assembled, and continues to be built up, based on geological evidence from borehole temperature profiles, cores removed from deep accumulations of ice, floral and faunal records, glacial and per glacial processes, stable-isotope and other analyses of sediment layers, and records of past sea levels. More recent data are provided by the instrumental record. General circulation models, based on the physical sciences, are often used in theoretical approaches to match past climate data, make future projections, and link causes and effects in climate change. [1]

1.2 Causes

On the broadest scale, the rate at which energy is received from the Sun and the rate at which it is lost to space determine the equilibrium temperature and climate of Earth. This energy is distributed around the globe by winds, ocean currents, and other mechanisms to affect the climates of different regions.

Factors that can shape climate are called climate forcing or "forcing mechanisms"

These include processes such as variations in solar radiation, variations in the Earth's orbit, variations in the albedo or reflectivity of the continents and oceans, mountain-building and continental drift and changes in greenhouse gas concentrations. There are a variety of climate change feedbacks that can either amplify or diminish the initial forcing. Some parts of the climate system, such as the oceans and ice caps, respond more slowly in reaction to climate forcing, while others respond more quickly. There are also key threshold factors which when exceeded can produce rapid change.

Forcing mechanisms can be either "internal" or "external". Internal forcing mechanisms are natural processes within the climate system itself (e.g., the thermohaline circulation). External forcing mechanisms can be either natural (e.g., changes in solar output) or anthropogenic (e.g., increased emissions of greenhouse gases).

Whether the initial forcing mechanism is internal or external, the response of the climate system might be fast (e.g., a sudden cooling due to airborne volcanic ash reflecting sunlight), slow (e.g. thermal expansion of warming ocean water), or a combination (e.g., sudden loss of albedo in the arctic ocean as sea ice melts, followed by more gradual thermal expansion of the water). Therefore, the climate system can respond abruptly, but the full response to forcing mechanisms might not be fully developed for centuries or even longer. Predominant source of energy input to the Earth. Other sources include geothermal energy from the Earth's core, and heat from the decay of radioactive compounds. Both long- and short-term variations in solar intensity are known to affect global climate.

Three to four billion years ago, the Sun emitted only 70% as much power as it does today. If the atmospheric composition had been the same as today, liquid water should not have existed on Earth. However, there is evidence for the presence of water on the early Earth, in the Hadean and Arcana eons, leading to what is known as the faint young Sun paradox. [1]

Hypothesized solutions to this paradox include a vastly different atmosphere, with much higher concentrations of greenhouse gases than currently exist. Over the following approximately 4 billion years, the energy output of the Sun increased and atmospheric composition changed.

Some changes in climate may result in increased precipitation and warmth, resulting in improved plant growth and the subsequent sequestration of airborne CO_2. A gradual increase in warmth in a region will the size of continents is also important. Because of the stabilizing effect of the oceans on temperature, yearly temperature variations are generally lower in coastal areas than they are inland. A larger supercontinent will therefore have more area in which climate is strongly seasonal than will several smaller continents or island Of most concern in these anthropogenic factors is the increase in CO_2 levels due to emissions from fossil fuel combustion, followed by aerosols (particulate matter in the atmosphere) and the CO_2 released by cement manufacture. Other factors, including land use, ozone depletion, animal agriculture and deforestation, are also of concern in the roles they play – both separately and in conjunction with other factors – in affecting climate, microclimate, and measures of climate variables.

1.3 Vegetation

A change in the type, distribution and coverage of vegetation may occur given a change in the climate lead to earlier flowering and fruiting times, driving a change in the timing of life cycles of dependent organisms. Conversely, cold will cause plant bio-cycles to lag. Larger, faster or more radical changes, however, may result in vegetation stress, rapid plant loss and desertification in certain circumstances. An example of this occurred during the Carboniferous Rainforest Collapse (CRC), an extinction event 300 million years ago. At this time vast rainforests covered the equatorial region of Europe and America. Climate change devastated these tropical rainforests, abruptly fragmenting the habitat into isolated 'islands' and causing the extinction of many plant and animal species. [1]

1.4 Cloud cover and precipitation

Past precipitation can be estimated in the modern era with the global network of precipitation gauges. Surface coverage over oceans and remote areas is relatively sparse, but, reducing reliance on interpolation, satellite clouds and precipitation data has been available since the 1970s. Quantification of climatological variation of precipitation in prior centuries and epochs is less complete but approximated using proxies such as marine sediments, ice cores, cave stalagmites, and tree rings.

Climatological temperatures substantially affect cloud cover and precipitation. For instance, during the Last Glacial Maximum of 18,000 years ago, thermal-driven evaporation from the oceans onto continental landmasses was low, causing large areas of extreme desert, including polar deserts (cold but with low rates of cloud cover and precipitation) In contrast, the world's climate was cloudier and wetter than today near the start of the warm Atlantic Period of 8000 years ago.

Estimated global land precipitation increased by approximately 2% over the course of the 20th century, though the calculated trend varies if different time endpoints are chosen, complicated by El Niño-Southern Oscillation (ENSO) and other oscillations, including greater global land cloud cover precipitation in the 1950s and 1970s than the later 1980s and 1990s despite the positive trend over the century overall. Similar slight overall increase in global river runoff and in average soil moisture has been perceived. [1]

1.5 Ice cores

Analysis of ice in a core drilled from an ice sheet such as the Antarctic ice sheet, can be used to show a link between temperature and global sea level variations. The air trapped in bubbles in the ice can also reveal the CO_2 variations of the atmosphere from the distant past, well before modern environmental influences. The study of these ice cores has been a significant indicator of the changes in CO_2 over many millennia,

And continues to provide valuable information about the differences between ancient and modern atmospheric conditions. [1]

1.6 Sea level change

Global sea level change for much of the last century has generally been estimated using tide gauge measurements collated over long periods of time to give a long-term average. More recently, altimeter measurements — in combination with accurately determined satellite orbits — have provided an improved measurement of global sea level change. To measure sea levels prior to instrumental measurements, scientists have dated coral reefs that grow near the surface of the ocean, coastal sediments marine terraces, zooids in limestone and near shore archaeological remains. The predominant dating methods used are uranium series and radiocarbon, with cosmogony radionuclides being sometimes used to date terraces that have experienced relative sea level fall. In the early Pliocene, global temperatures were 1–2˚C warmer than the present temperature, yet sea level was 15–25 meters higher than today. [1]

CHAPTER TWO

Global Warming

2.1 Paris Agreement

According to Paris 2015 agreement, a goal has been set to limit the global warming to less than 2 degrees Celsius (°C) compared to pre-industrial levels. The agreement calls for zero net anthropogenic greenhouse gas emissions to be reached during the second half of the 21st century. In the adopted version of the Paris Agreement, the parties will also "pursue efforts to" limit the temperature increase to 1.5°C.The 1.5 °C goal will require zero emissions sometime between 2030 and 2050, according to some scientists. Prior to the conference, 146 national climate panels publicly presented draft national climate contributions (called "Intended Nationally Determined Contributions", INDCs). These suggested commitments were estimated to limit global warming to 2.7 degrees Celsius by 2100.For example, the EU suggested a 40 percent reduction in emissions by 2030 compared to 1990. However, no detailed timetable or country-specific goals for emissions were incorporated into the Paris Agreement - as opposed to the previous Kyoto protocol. Observed changes in climate. This contribution has Human-induced warming could lead to large-scale, irreversible, and/or abrupt changes in physical systems. An example of this is the melting of ice sheets, which contributes to sea level rise. The probability of warming having unforeseen consequences increases with the rate, magnitude, and duration of climate change. [1]

2.2 Effects on weather

Observations show that there have been changes in weather. As climate changes, the probabilities of certain types of weather events are affected. Changes have been observed in the amount, intensity, frequency, and type of precipitation. Widespread increases in heavy precipitation have occurred, even in places where total rain amounts have decreased. With medium confidence, Intergovernmental-Panel on Climate Change (IPCC) (2012) concluded that human influences had contributed to an increase in heavy precipitation events at the global scale.

Projections of future changes in precipitation show overall increases in the global average, but with substantial shifts in where and how precipitation falls. Projections suggest a reduction in rainfall in the subtropics, and an increase in precipitation in sub polar latitudes and some equatorial regions. In other words, regions which are dry at present will in general become even drier, while regions that are currently wet will in general become even wetter. This projection does not apply to every locale, and in some cases can be modified by local conditions. [1]

2.3 Extreme weather

Over most land areas since the 1950s, it is very likely that there have been fewer or warmer cold days and nights. Hot days and nights have also very likely become warmer or more frequent. Human activities have very likely contributed to these trends. There may have been changes in other climate extremes (e.g., floods, droughts and tropical cyclones) but these changes are more difficult to identify.[1]

2.4 Global warming

Global surface temperatures have increased about 0.74 °C (plus or minus 0.18 °C) since the late-19th century, and the linear trend for the past 50 years of 0.13 °C (plus or minus 0.03 °C) per decade is nearly twice that for the past 100 years. The warming has not been globally uniform. Some areas have, in fact, cooled slightly over the last century. The recent warmth has been greatest over North America and Eurasia between 40 and 70°N.Lastly, seven of the eight warmest years on record have occurred since 2001 and the 10 warmest years have all occurred since 1995.Increasing temperature is likely to lead to increasing precipitation but the effects on storms are less clear. Extra tropical storms partly depend on the temperature gradient, which is predicted to weaken in the northern hemisphere as the polar region warms more than the rest of the hemisphere. It is possible that the Polar and Ferrell cells in one or both hemispheres will weaken and eventually disappear, which would cause the Hadley cell to cover the whole planet. This would greatly decrease the temperature gradient between the arctic and the tropics, and cause the earth to flip to a hothouse state. Historically (i.e., over the 20th century), subtropical land regions have been mostly semi-arid, while most sub polar, regions have had an excess of precipitation over evaporation. Future global warming is expected to be accompanied by a reduction in rainfall in the subtropics and an increase in precipitation in sub polar latitudes and some equatorial regions. In other words, regions which are dry at present will generally become even drier, while regions that are currently wet will generally become even wetter. This projection does not apply to every locale, and in some cases can be modified by local conditions. Drying is projected to be strongest near the pole ward margins of the subtropics (for example, South Africa, southern Australia, the Mediterranean, and the south-western U.S.), a pattern that can be described as a pole ward expansion of these semi-arid zones. This large-scale pattern of change is a robust feature present in nearly all of the simulations conducted by the world's climate modeling groups for the 4th Assessment of the Intergovernmental Panel on Climate Change (IPCC), and is also evident in observed 20th century precipitation trends. An enhanced greenhouse effect is expected to cause cooling in higher parts of the atmosphere. Cooling of the lower stratosphere about (49,000-79,500ft.) since 1979 is shown by both satellite Microwave sounding unit and Radiosonde data, but is larger in the radiosonde data likely due to uncorrected errors in the radiosonde data. [1]

CHAPTER THREE

CLIMATE CHANGE IN SUDAN

3.1 Total greenhouse gases (GHG) emissions

Table 3-1 presents total GHG emissions and sinks for the year 2000. Total GHG emissions in 2000 were 77,650 GgCO_2-equivalent (CO_2e), which includes57,611Gg from agriculture, 9,392Gg from LUCF, 8,539Gg from energy;2,015Gg from waste, and only 93Gg from industrial processes. Agriculture-related activities accounted for the dominant portion of GHG emissions in 2000. Approximately 74% of all CO_2e emissions are associated with enteric fermentation and manure management. LUCF accounts for about 12% of all GHG emissions, mostly from forest and grassland conversion. The combustion of fossil fuels in the energy sector is small, accounting for only 11% of total emissions. The remaining 3% of total emissions are mostly. [2]

Table3-1: Total GHG emissions in Sudan and South Sudan, 2000 (Gg) [2]

GHG Sources & Sinks	CO_2e	CO_2	CH_4	N_2O	NO_x	CO	NMVOC	SO_2	HFCs
Total National Emissions	**77,650**	**14,201**	**2,153**	**59**	**112**	**2,892**	**188**	**1**	**6**
1 Energy	8,539	6,090	95	1	80	2,020	176	0	0
2 Industrial Processes	93	93	0	0	0	0	12	1	6
3 Solvent & Other Product Use	0	0	0	0	0	0	0	0	0
4 Agriculture	57,611	0	1,923	56	17	353			
5 Land-Use Change & Forestry	9,392	8,018	59	0.4	15	520			
6 Waste	2,015	0	76	1					

3.2 GHG emission trends

Figure 3-1 presents the trend in total GHG emissions for 1995, the year of the initial GHG inventory, and 2000. GHG emissions have increased by about 8%; from 72,014Gg of carbon dioxide-equivalent (CO_2e) in 1995 to 77,650Gg CO_2e in 2000. The major drivers for these changes in GHG emission levels are briefly described below and illustrated in Figure 3-2. [2]

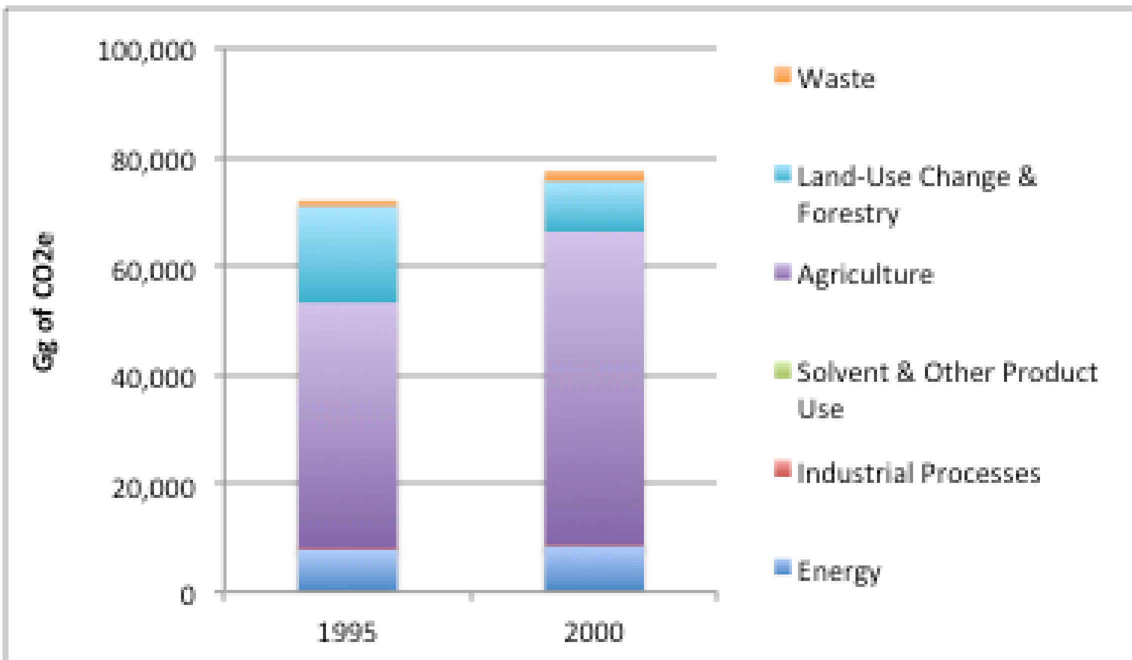

Figure 3-1: Total CO_2e emission trends, 1995&2000 [2]

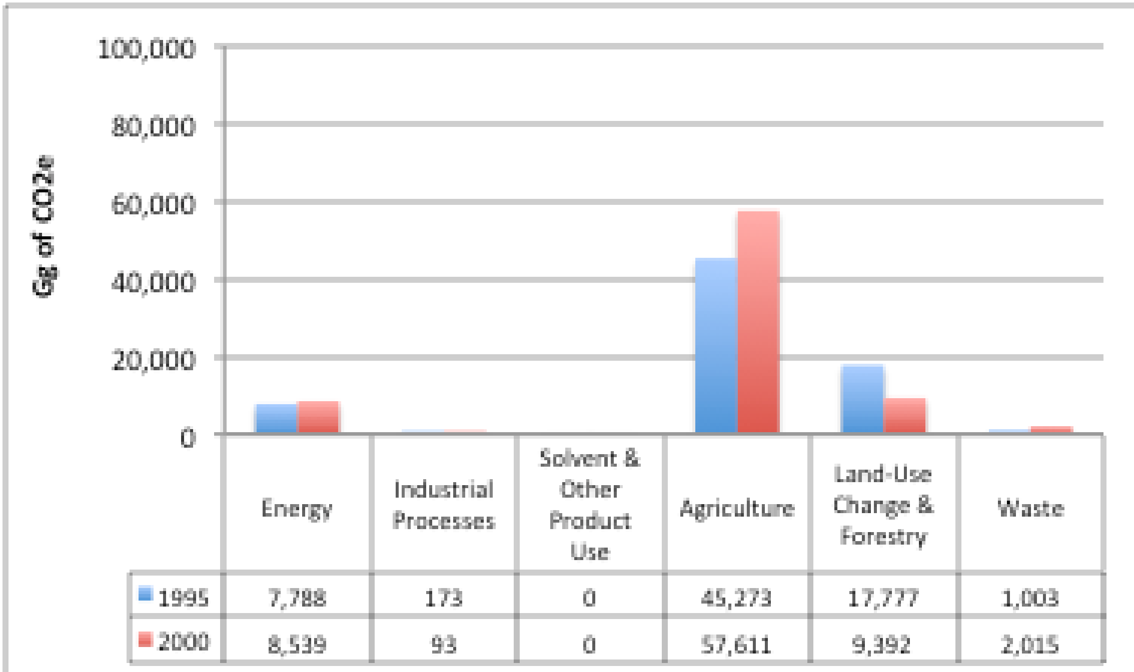

Figure 3-2: Total CO2e emission trends by sector, 1995&2000. [2]

_ Energy: Emissions from energy increased by roughly 10%. Increased fossil fuel consuming activities in electricity production, transport, and manufacturing are the primary reasons. This increase is partially offset by significant switching from biomass/charcoal use in the household sectors (with its corresponding high CH4 emissions) to greater LPG use.

_ Industrial processes: Industrial process emissions decreased by a substantial amount, 46%, although total levels are virtually negligible in both 1995 and 2000 relative to other sectors. The decrease is because one of the main cement factories was not operational during 2000, while another factory underwent renovations in that year.

_ Agriculture: Emissions from agriculture increased by roughly 27%, primarily due to an increase in livestock populations.

_ Land-Use Change and Forestry (LUCF): This sector is responsible for most of the decrease in GHG emissions since 1995. Emissions have reduced by almost 50% compared to 1995 levels, or almost 12% per year. This is a result of reductions in forest and grassland conversion, coupled with the expansion in afforested areas and managed forested land, in addition to improve application of the inventory methodology (forest characterization).

_ Waste: Emissions from waste management more than doubled. The majority of this increase is due to greater amounts of municipal solid waste sent to landfill sites. [2]

3.3 Energy Sector

Significant developments in the energy sector have taken place in Sudan since 1995, the base year for the first inventory. This involves greater crude oil production and increased refinery capacity at the Abu-Jabra, El-Obied and Khartoum facilities. Economic reforms also took place during this period, which helped to stabilize the Sudanese currency and reduce inflation. These changes have led to greater availability and use of petroleum products for electric power production, as well as for commercial, industrial and agricultural activities. [2]

3.3.1 Sectorial overview

Generally, there are only three types of energy that are combusted in Sudan, namely biomass, electricity (i.e., fossil fuels and hydropower), and refined petroleum products, as briefly summarized below and illustrated in Figure 3-3.

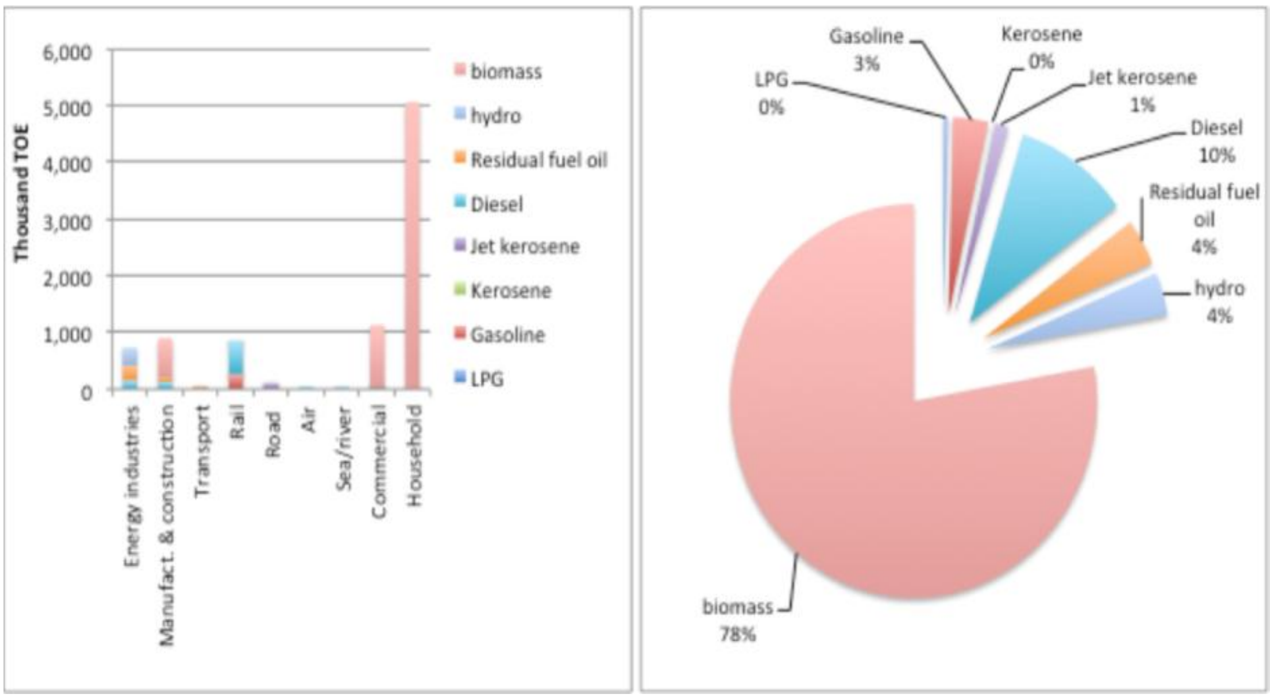

Figure 3-3: Total energy consumption, 2000. [2]

_ Biomass: Combined, fuel wood, charcoal, agricultural residues, and animal dung accounts for about 78% of total energy consumption. Households consume more than 74% of total biomass (mostly in rural areas), followed by 16% in the service/commercial sector, and 10% in the industrial sector.

_ Electricity: Power is produced by a combination of hydro stations and thermal stations that use diesel and residual fuel oil. Together, hydro and fossil fuels account for about 8% of total energy consumption. Since 1980, power generation has been growing at a rate 6% per year, with thermal power generation increasing at roughly six times the rate of hydropower generation

_ Petroleum products: Gasoline, diesel, residual fuel oil, kerosene, and jet kerosene account for about 14% of total energy consumption.

The consumption of petroleum products has significantly increased since 2000 when the Khartoum Refinery began operations. The transport sector is the largest consuming sector of petroleum products, followed by agriculture, services, industry and households. [2]

3.3.2 Data sources

The Sudanese Petroleum Corporation and General Directorate for National Energy Affairs within the Ministry of Energy and Mining (MEM) provided the fossil fuel data used to update the GHG inventory. Biomass data was obtained from the second national energy assessment report published in the year 2003. Hydro data was obtained from the National Electricity Corporation of Sudan (NEC). The reliability of these data is considered high. [2]

3.3.3 Assumptions and key uncertainties

There are two key sources of uncertainty. First, petroleum product consumption data are based on official allocations by the MEM to consuming sectors rather than actual consumption levels. Actual sectorial consumption likely differs from allocated amounts due to fuel swapping between sectors. For example, diesel allocated to the transport sector is frequently consumed in the household and commercial sectors for on-site generation of electricity. Liquid Petroleum Gas (LPG), typically allocated to the household sector in government records, is used in the transport sector (Majid Taxi fleet) as well as some food industries.

Second, no records are available for bunker fuels in the transport sector by fuel type and/or mode of transport. Bunker aviation fuels have been estimated at 60% of the total amount of jet kerosene consumed by Sudan airways. Third, the second National Energy Assessment estimated that 90% of fuel allocated for river/sea transport is used by Sudan Shipping Lines as international bunker fuel. Finally, lubricants have been assumed to represent 3% of the total petroleum product consumption, or about 29 thousand TOE. [2]

3.3.4 Results

Table 2-2 summarizes GHG emissions associated with energy sector in 2000. Relative to overall anthropogenic GHG emissions, the total 8,539Gg CO_2e represents about 11% of total CO2e emissions.

Figure 3-4 illustrates the breakdown in energy-related GHG emissions in 2000 by consuming activity. Transport activities accounted for about 34% of all energy-related CO_2e emissions, followed by the household and commercial sectors, which accounted for 32% of energy-related CO_2e emissions. Power production is based largely on the use of diesel and residual fuels and accounted for about 22% of total CO_2e emissions, plus a considerable amount of CO and Non-methane Manufacturing Volatile Organic Compound (NMVOC) emissions.

Table 3-2: GHG emissions from the energy sector, 2000 (Gg) [2]

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO2e	CO2	CH4	N2O	NOx	CO	NMVOC	SO2
Total Emission from Energy	**8,539**	**6,090**	**95**	**1**	**80**	**2,019**	**175**	**0**
A Fuel Combustion (Sectoral Approach)	8,531	6,090	95	1	80	2,019	175	0
1 Energy Industries	1,873	1,873	0	0	5	0	0	0
2 Manufacturing Industries and Construction	1,029	912	2	0	8	189	3	0
3 Transport	2,867	2,851	0	0	29	123	0	0
4 Other Sectors	2,762	454	93	1	38	1,707	172	0
B Fugitive Emissions from Fuels	8	0	0	0	0	0	0	0
1 Solid Fuels	0		0					
2 Oil and Natural Gas	8		0.4					
Memo Items								
1. International Bunkers	200	198	0	0	1	0	407	0
Aviation	200	198	0	0	1	0	407	0
Marine	0	0	0	0	0	0	0	0
2. CO2 Emissions from Biomass	45,777	45,777						

Activities accounted for only 12% of emissions while fugitive emissions from oil production activities were negligible. The results of the 2000 inventory, does not include an emission estimate for SO2 due to data limitations. [2]

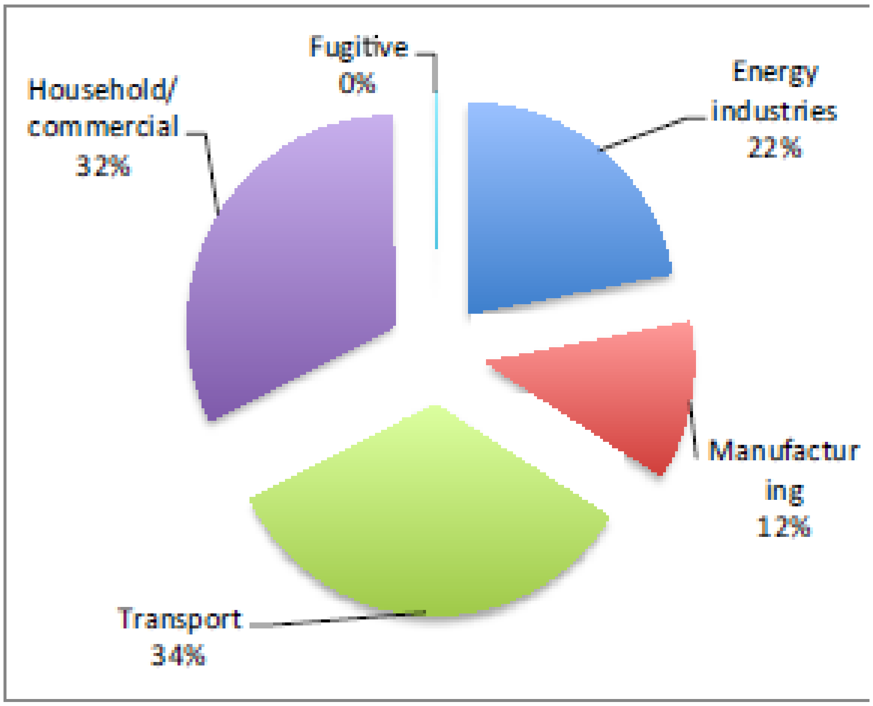

Figure 3-4: Breakdown of CO_2e emissions associated with energy activities, 2000. [2]

3.4 National Automotive Parts Association (NAPA) process design

The NAPA was implemented in five States (Central Equatorial, River Nile, Gadara, South Darfur and North Cordovan States) representing five different ecological zones. The process of preparation involved extensive consultations with stakeholders within the five states on the vulnerable sectors of water resources, food security/agriculture and public health. Initial efforts focused on the characterization of six major current climatic stresses that are typically experienced by communities on a recurring basis, as shown in Table 3-3. Drought was widely recognized as the major climatic shock for which urgent adaptation measures are needed. The process resulted in the identification of 32 potential adaptation projects. Of these, five projects were given the highest priority by stakeholders and were further characterized Relative to their scope, major activities, and costs. [2]

Table3-3 : Extreme weather and climate events in Sudan types, frequency, sectors affected, and impact categories (Source: Government of Sudan, 2007) [2]

Event	*Occurrence*	*Vulnerable areas*	*sectors*	*Impacts*
Drought	Frequent	North & Western Sudan (North Kordofan and Darfur), Kassala State and some parts of the rain-fed areas in central Sudan.	Agriculture, livestock, water resources and health.	Loss of crops and livestock (food shortage), decline in the hydroelectric power, displacement wildfire.
Floods	Frequent	Areas within the River Nile basin and low areas from extreme South to far North. Mountain areas along Red Sea.	Agriculture, livestock, water resources and health.	Loss of life, crops, livestock; insects & plant diseases, epidemic/vector diseases, decline in hydro power; damage to infrastructure & settlement areas
Dust storms	Frequent	Central and northern parts of Sudan	Transport (aviation and land traffic)	Air and land traffic accidents and health.
Thunder - storms	Infrequent	Rain-fed areas throughout all Sudan	Aviation	Loss of lives and properties.
Heat waves	Rare	Northern, central parts of Sudan besides the Red Sea State.	Health, agriculture & livestock.	Loss of live, livestock and crops.
Wind-storms	Rare	Central and north central Sudan	Settlements and service infrastructure	Loss in lives, property; damage to infrastructure (electricity and telephone lines)

The NAPA process represents the first and thus far only national adaptation planning activity undertaken in Sudan. It offers a useful model by which to design future adaptation planning. Each vulnerable sector was systematically characterized, including the institutional, policy, and planning frameworks in need of reform. [2]

3.5 Change in temperature patterns

Figure3-5 shows average monthly temperature for each Google Cloud Messaging (GCM) run relative to the average baseline (1965-2005) period. Two projection years are shown, 2050 and 2090, for the Upper Blue Nile Basin (top chart) and the Equatorial region of the White Nile Basin (bottom chart). The baseline monthly temperature profile is indicated by the black lines. Projections for the 2050 period are shown by gray lines, one for each of the GCMs considered. Projections for 2090 for each GCM are illustrated by the red lines.

As can be seen in the Figure, monthly temperatures are projected to warm considerably throughout the 21st century in the region. 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 roughly 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 roughly between 3.5°C and 4.5°C by 2090.

Hence, there is a clear and consistent tendency for considerably warmer conditions in the future over both the Upper Blue Nile Basin and White Nile Basin. This poses serious concerns regarding increased evapotranspiration over water storage areas that could lead to lower flows in the River Nile. [2]

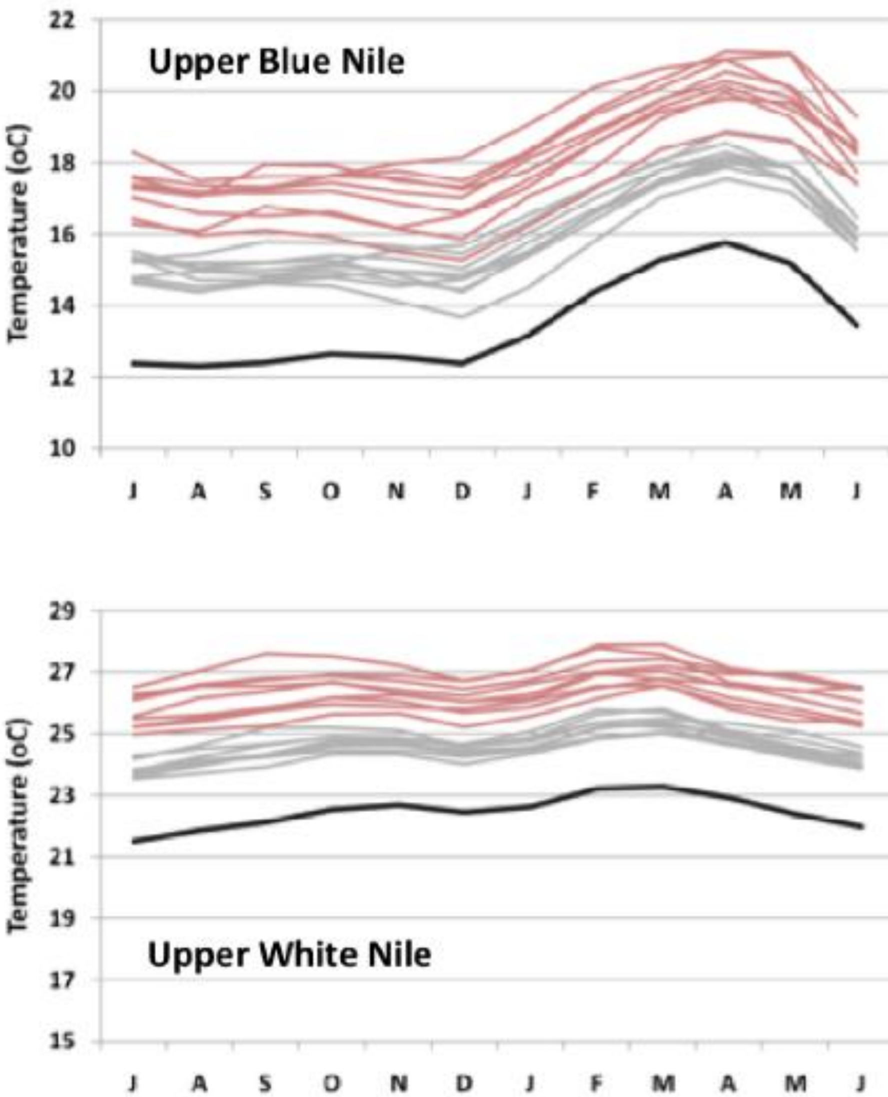

Figure 3-5: Monthly average temperature for the baseline and forecasted periods in Upper Nile regions.

3.6 Change in rainfall patterns

Figures 3-6 shows average annual precipitation for each Google Cloud Messing (GCM) run relative to an annual baseline (1965-2005). Two projection years are indicated, 2050 and 2090, for the Upper Blue Nile Basin (top chart) and the Equatorial region of the White Nile Basin (bottom chart). The baseline annual rainfall profile is indicated by the black lines. Rainfall projections for the 2050 period are shown by gray lines and the projections for 2090 are shown as red lines. As can be seen in the Figure, there is a tendency for drier conditions over the Upper Blue Nile Basin and wetter conditions over the White Nile Basin.

Hence, for the Upper Blue Nile, the combination of higher evapotranspiration rates associated with increased temperature, and lower annual rainfall suggests that water resources in this region will become increasingly vulnerable to climate change. [2]

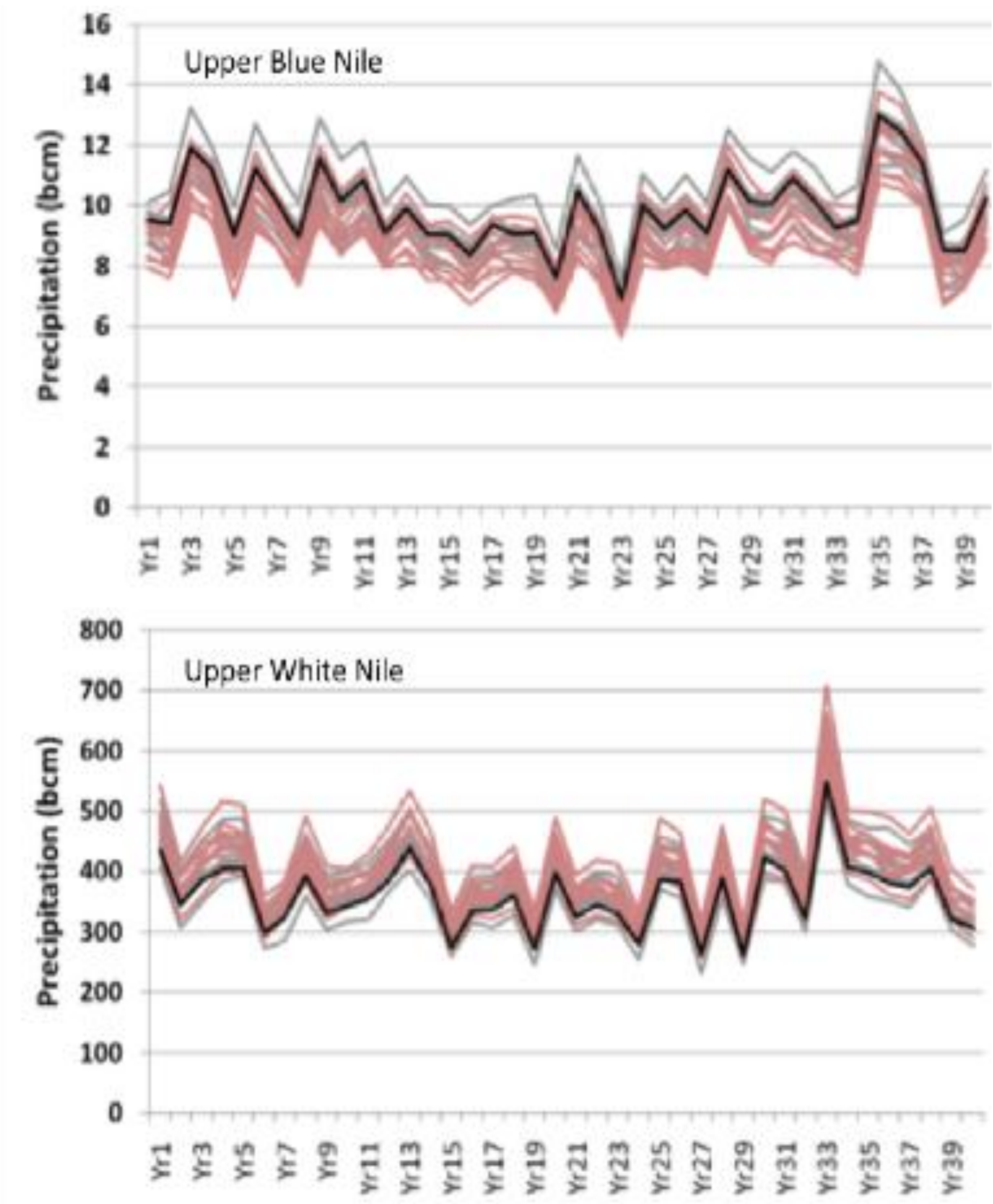

Figure 3-6: Annual rainfall for the baseline and forecasted periods in the Upper Nile regions. [2]

3.7 Impacts on total water demand

Figure 3-7 shows the projection of future water demand for both the projected 2050 and 2090 climate conditions in both the No Growth and 2% Growth scenarios. These figures highlight the fact that the assumptions regarding projections of future socioeconomic growth strongly dominate the results over the assumptions of future climate change. The 2% growth in population and irrigated agriculture lead to water demands that exceed 30 b cm near the end of the 40-year period.

The various downscaled GCM outputs are not individually identified in the figures; rather they are presented as a set of individual ensemble members for both 2050 and 2090. For nearly all scenarios, warming leads to an overall increase in water demand relative to the reference cases. For climate conditions in 2050, some ensemble members lead to less overall demand, as increases in precipitation offset evaporative losses due to warming. On the other hand, with a 2090 climate, warming dominates the climate signal, as increases in precipitation do not overcome the evaporative losses.

Hence, there is a clear and consistent finding that under all socioeconomic and almost all climatic scenarios, 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. This poses serious concerns if it occurs against the backdrop of decreased river flows in the River Nile due to climate change. Since it is unrealistic to assume no future growth in Sudan, only the 2% Growth scenario was explicitly modeled to assess other impacts. [2]

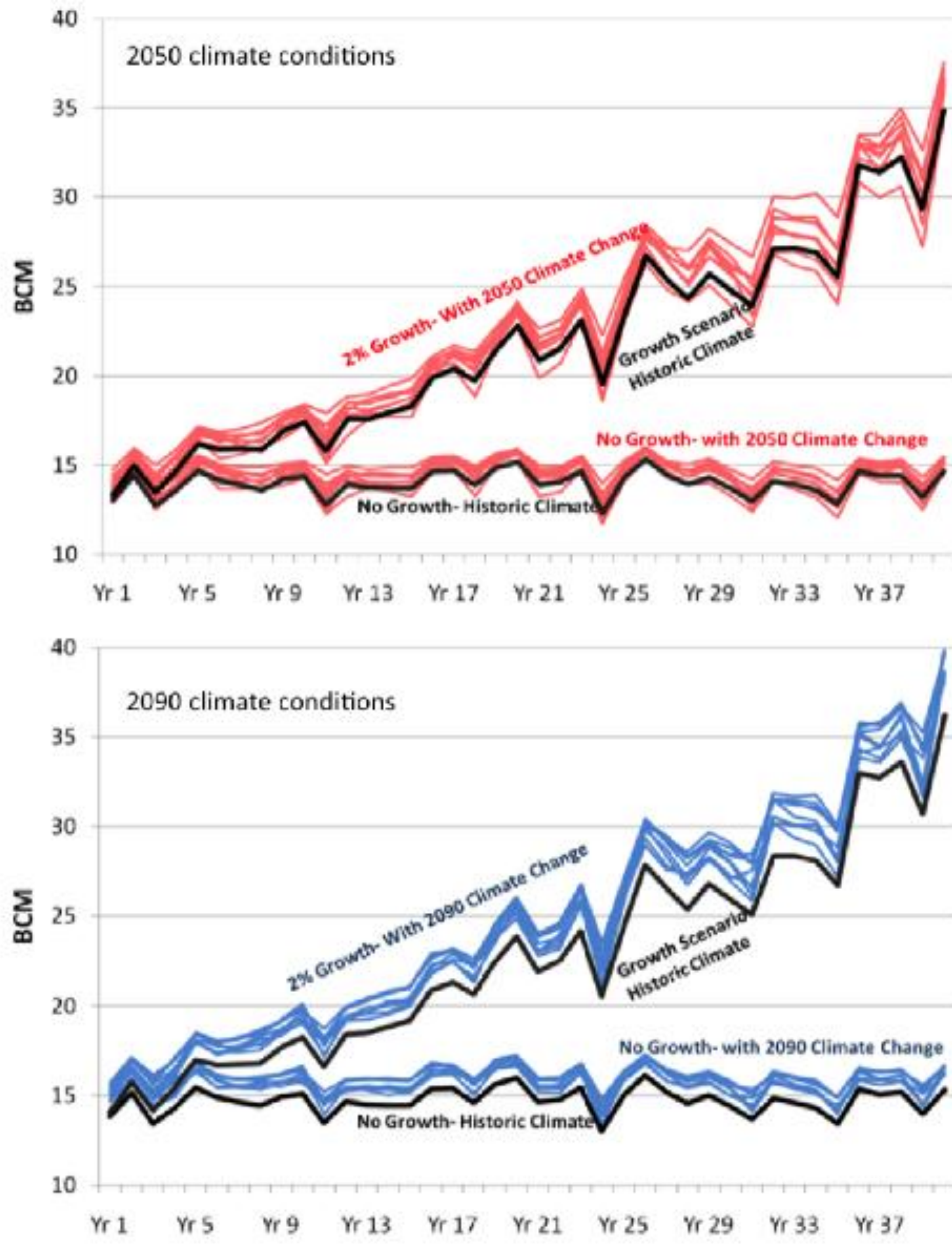

Figure 3-7: Total annual water demands under climate change conditions, 2% Growth and No Growth scenarios. [2]

3.8 Impact on River Nile flow

Figure 3-8 shows flow exceedance curve for two points on the Nile for both the 2050 and 2090 projected climatic conditions. The horizontal axis of the figure shows the frequency with which river flow levels are exceeded; the vertical axis shows projected river flow levels. The top chart corresponds to the main stem of the Nile below the Merowe High Dam Reservoir north of Khartoum; the lower chart corresponds to the Blue Nile at Khartoum. The bold black line corresponds to historic average flow exceedance levels while levels under 2050 climatic conditions are represented by red lines and in 2090 by blue lines.

For the main stem of the Nile below Merowe, there are more scenarios with greater flows under 2050 conditions than 2090 conditions. On average, peak annual flows are about 20% less than historic levels under 2090 climatic conditions. For the Blue Nile at Khartoum, there is greater spread among the change in flow. There are several extreme low flow scenarios on the Blue Nile, where the total annual flow never exceeds 60 bum. On average, peak annual flows are about 30% less than historic levels under 2090 climatic conditions.

Hence, there is a clear finding that under many climatic scenarios, water flow in the Nile River will decrease considerably, between 20% and 30%. This circumstance, combined with the increased water demand discussed previously, suggests that risks of increasing water stress in Sudan over the next 40 years will need to be integrated into water planning and policymaking. [2]

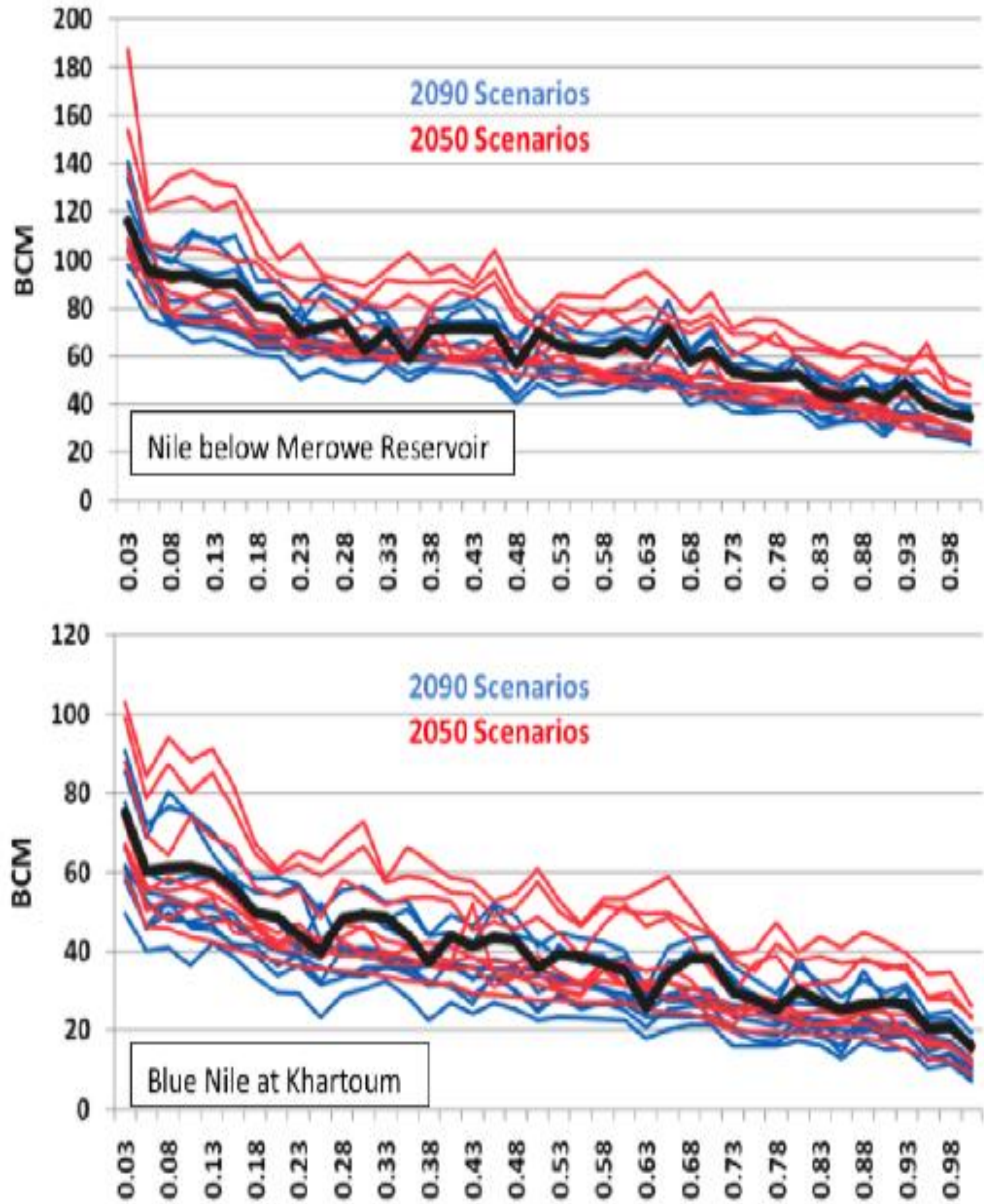

Figure 3-8: Flow exceedance curves for two points along the Nile River under the 2% Growth scenario. [2]

3.9 Impact on water storage

The total combined water storage in the main reservoirs in Sudan, including the Rosaries, Senar, Girba, and Jebel Aulia reservoirs, is shown in Figure 3-6. The bold black line corresponds to the projected baseline levels. By around the middle part of the 40- year evaluation period, storage becomes inadequate to meet the high demands, and the reservoirs are substantially drawn down. The drawdown is primarily driven by increases in water demand, but also due to the much warmer climate and the associated evapotranspiration rates. All but one of the 2050 scenarios shows similar storage to the reference scenario, while the 2090 scenarios show more dramatic drawdown.

Hence, there is a clear finding that under all climatic scenarios, water storage will decrease considerably in Sudan, by about 40% starting around the year 2030. Efforts to increase water storage capacity are likely to face serious challenges due to greater temperatures and associated higher evapotranspiration rates. [2]

3.10 Impact on hydropower generation

Figure 3-9 shows the total hydropower production for the same four reservoirs. The bold black line corresponds to the projected baseline levels of hydropower generation over the evaluation period.

For the 2050 scenarios, hydropower generation is near the baseline scenario, with releases made for downstream water demands. Several of the 2090 scenarios show fairly dramatic reductions in hydropower generation, with about a 35% reduction in total output, as the reservoirs simply do not store adequate water to generate enough electricity. Only a few of the scenarios show hydropower production exceeding the reference scenario, suggesting that the warmer conditions over the Blue Nile Basin in many of the scenarios lead to less overall water in storage.

Hence, there is a clear finding that under all climatic scenarios, 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. [2]

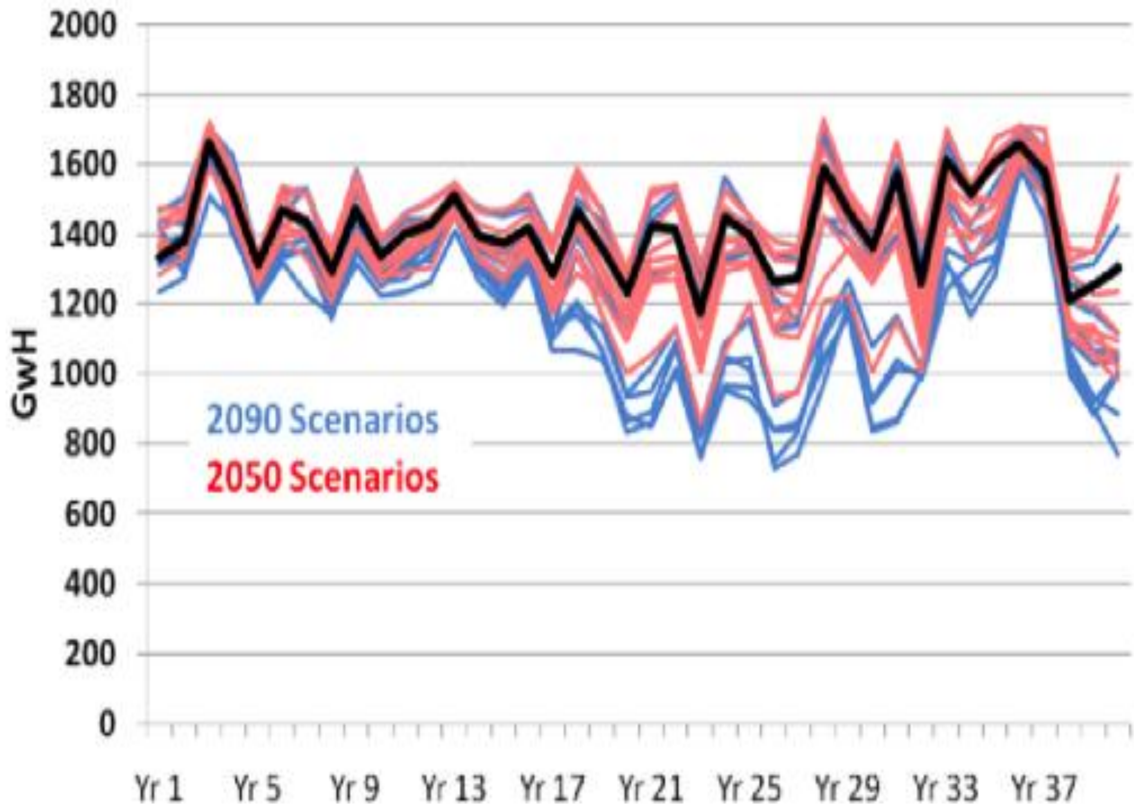

Figure 3-9: Hydropower generation in the Rosaries, Senar, Girba, and Jebel Aulia reservoirs under the 2% Growth scenario. [2]

CHAPTER FOUR

4-1 Conclusion

In this research we have studied the cclimate change and its effect on temperature and rainfall. We noticed that there is continuous decrease in rainfall and increase in temperature**.**

4.2 Recommendation

1-To use renewable energy to reduce the greenhouse gas.

2- A study is needed to develop data for small-scale electricity self-generation in the commercial and household sectors.

3- To develop or find local/better emission and conversion factors that are appropriate to Sudan for both biomass and petroleum products.

4- A study is needed for biomass energy including biomass burnt for purposes other than energy.

5-Planting trees can help much in reducing global warming ,then any other method they not only give oxygen but also take in carbon dioxide, during the process of photosynthesis, which is the main source of global warming.

4-3 References

1- https://www.wikipedia.org.

2-Sudan's Second National Communication under the United Nations Framework Convention on Climate Change.