NIGERIA'S SECOND NATIONAL COMMUNICATION

UNDER THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

FEDERAL REPUBLIC OF NIGERIA

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LIST OF ACRONYMS

AFOLU	Agriculture, Forestry and other Land-Use
AF	Adaptation Fund
AR4	Fourth Assessment Report (by the IPCC)
ASLR	Accelerated Sea Level Rise
BAP	Bali Action Plan
CBD	Convention on Biological Diversity

CDM	Clean Development Mechanism
CER	Certified Emission Reduction
CFC	Chloroflourocarbon
CGE	Consultative Group of Expert on National Communications from Non-Annex I Parties
CNG	Compressed Natural Gas
CO_2	Carbon dioxide
COP	Conference of the Parties (to the UNFCCC)
CRF	Common reporting Format
DI	Drip Irrigation
ECN	Energy Commission of Nigeria
EF	Emission factor
EGP	Escravos Gas Project
EPA	Environmental Protection Agency (of the USA)
FAO	Food and agricultural Organization
FEPA	Federal Environmental Protection Agency
FMEnv	Federal Ministry of Environment
FRN	Federal Republic of Nigeria
GCM	General Circulation Model
GDP	Gross Domestic product
GEF	Global Environment Facility
GHG	Greenhouse Gas
GIS	Geographic Information System
GPG	Good Practice Guidance
GPG	IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories
GPP	Gross Primary Production
GPS	Global Positioning System
GWP	Global Warming Potential
ICC	Inter-ministerial Committee on Climate Change
IPCC	Intergovernmental Panel on Climate Change
IPR	Intellectual Property Rights
JI	Joint Implementation (under the Kyoto Protocol)
LULUCF	Land use, land use change and forestry

MA	Marrakesh Accords
MOP	Meeting of the Parties
MOU	Memorandum of Understanding (between the COP and the GEF)
NAIP	Non-Annex I Parties
NAPEP	National Poverty Eradication Programme
NBS	National Bureau of Statistics
NCAS	National Carbon Accounting System
NGO	Non-governmental organization
NI	National Inventory
NIMET	Nigerian Meteorological Agency
NIWRI	National Institute for Water Resources
NMVOC	Non-methane Volatile Organic Compound
NNPC	Nigeria national Petroleum Corporation
PoA	Programme of Activities
POP	Persistent organic pollutant
QA	Quality Assurance
QC	Quality Control
R&D	Research and Development
SF_6	Sulphur hexafluoride
SRES	Special Report on Emission Scenario
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNCED	United Nations Conference on Environment and Development
UNFCCC	United Nations Framework Convention on Climate Change
URF	Uniform Reporting Format
WMO	World Meteorological Organization

FOREWORD

Nigeria has a population of about 160 million spread over a land area of 924,000 square kilometers, the country spans a wide variety of ecological zones ranging from the fringes of the Sahara Desert in the far North, through the savannah region in the middle part, the rain forests in the southern part and ending in the swampy Delta region with 850 kilometers stretch of coastline. The coastal zone of the country covering about 153,000 square kilometers is a fragile ecological area which is very rich in biological diversity

Nigeria was among the first group of developing countries (Non-Annex I Parties to the convention) that signed the UNFCCC and became a party as soon as the convention came into force. As a Party to the convention, we are mandated to periodically prepare and submit national communication. . It is a document that contains a summary of national greenhouse gas (GHG) emissions by sources and removals by sinks from various sectors of Economy.

Nigeria has prepared and submitted its First National Communication (FNC) in November 2003. Since then, expert work have been undertaken in-session, to ensure broad participation among various stakeholders with a view to produce an update based on the best information available.

This Second National Communication (SNC) was prepared following the methodologies in the revised 1996 IPCCC guidelines; the Good practice guidance and uncertainty management in the national greenhouse gas inventory as well as the GPG for land use, land use change and forestry.

Nigeria is glad to join other Non-Annex I Parties to the UNFCCC in presenting its Second National Communication to the global community as part of its obligation in the joint efforts to combat climate change phenomenon and its adverse effects.

Arc. Darius I. Dickson
Hon. (Supervising) Minister of Environment

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Periodic review meetings, trainings and capacity development workshops organized by the Inter-ministerial Committee on Climate change as the national coordinating committee on Climate Change has really helped in improving the quality of the document. For this, the Federal Government of Nigeria acknowledges tireless effort of the members of the ICCC team on the course of the exercise.

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Federal Ministry of Environment, Abuja

EXECUTIVE SUMMARY

1. NATIONAL CIRCUMSTANCES

Introduction

Accelerated climatic changes are expected with large impacts across Africa. The scale of the change will increase with greater greenhouse gases (GHG) emissions, and global temperature. For Nigeria, there could be significant sea level rise from the 1990 levels to 0.3 m by 2020 and 1m by 2050. There could also be rise in temperature of up to 3.2°C by 2050 under a high climate change scenario (DFID 2009). All of these have serious environmental and economic implications and call for urgent and targeted actions to minimize the impacts of the change.

Since the inception of the Rio Conventions of 1992, Nigeria has been active in many fronts in climate change response. It has for instance submitted the First National Communication (FNC) and prepared other documents like National Adaptation Strategy and Plan of Action to aid its response to climate change. This *Second National Communication* (SNC) captures the progress in climate change actions in the country since the FNC. It also includes a summary of future actions towards climate-proofing Nigeria's environment.

Nigeria's climate is dominated by the influence of three major air masses - the tropical maritime (mT), the tropical continental (cT) and the equatorial easterlies (Ojo, 1977). The mT and cT meet along a slanting surface called the Inter-Tropical Discontinuity (ITD). The equatorial easterlies are cool air masses, which come from the east and flow in the upper atmosphere along the ITD. Land and sea breezes are important in the coastal areas. Annual rainfall generally decreases from the coast inland from an annual average of about 3000 mm in Warri to less than 500 mm in Nguru in the northeast. The rainfall is mostly seasonal.

The distribution of vegetation dovetails that of rainfall and to some extent, the physiographic units in the country. The vegetation types can be broadly grouped into the tropical forests in the south and savanna in the north. The major physiographic elements affecting vegetation distributions are elevation, slope and aspect (Adejuwon, 1979; Adesina 2001). Vegetation associated with altitude is described as montane vegetation. Soils are linked in several ways to vegetation and four main soil groups occur in a zonal pattern from the coast inland: hydromorphic and organic, ferralitic, ferruginous and the arid and semi-arid soils (Faniran, and Areola, 1974).

The country has considerable challenges with its land resources including loss of prime arable lands, opening up of the remaining new land, vegetation degradation and increasing desertification. The proportion of people living in rural areas is rapidly declining, while urban areas are rapidly expanding, taking up more and more of the adjoining rural lands all of which will influence climate change.

The Nigeria's coastal and marine environment stretches for about 853 km, about 15km in Lagos area, 150km in the Niger Delta and about 25km east of the delta. It has about 25% of the country's population and a wide variety of economic opportunities and resources. Oil is got from the region and this brings about 90% of the country's foreign exchange earnings.

In 2006 Nigeria's population stood at 140.43 million with a national growth rate of 3.2% per annum. At that growth rate, the population by projection would double in size in just 24 years. This huge population puts tremendous pressure on the environment and makes Nigeria a high potential contributor to global warming. A majority of Nigeria's more than 140 million as at 2006 live below the poverty line and have limited or no access to basic amenities.

Nigeria has a developing economy. Its strength is derived from its oil and gas reserves, which make up 90% of export revenues, 78% of Government revenues, and 38.8% of the Gross Domestic Product (GDP).The country's agriculture is dominated by small holdings with limited mechanization. These give low productivity and make the country to depend on import to meet its food demand.

Nigeria is making progress in the achievement of the health related MDGs. Nonetheless; indicators show the need for more concerted efforts in this sector. For instance, life expectancy at birth is 43.8 years, infant mortality, 800 per 100,000 live births and maternal mortality,100 in 100,000 (The World Bank Report, 2008).

Air, rail, pipelines, road and water transportation facilities are available in the country but the most important is the road, many of which are in various states of disrepair or incapable of effectively handling the ever increasing traffic volume. The country has less than a million landlines but more than 100 million mobile cellular subscribers. The advent of mobile communication in the late 1990s has revolutionized the sector and impacted positively on the socio-economic development of the country.

The manufacturing sector has not performed as much as expected for a long time. It has low capacity utilization, minimal economic contribution to GDP and low employment share in comparison to other sectors. It contributed only 4% of the country's GDP in 2008.

Nigeria is endowed with energy resources like crude oil, natural gas, coal, tar sand, and biomass. However, production is inefficient and inadequate. Nigeria's is one of the least energy-efficient economies in the world with per capita consumption of 138 kg of oil equivalent. Gas flaring and inefficient energy use play significant roles in Nigeria's GHG emissions. Private production of electricity with diesel- and petrol operated generators is significant but comes at a higher cost per unit. Limited access to reasonably priced electricity is a key factor of low standard of living in the country.

Fuel wood is the main source of domestic energy in the country (Eleri, 2006) and is increasing despite the fact that wood extraction has known damaging effect on plant cover. Nigeria has the highest rate of deforestation in Africa (FAO, 2005), which is increasing due to factors like settlement expansion and logging. The remaining forests could disappear by 2020. The country must thus invest in forestry, encourage use of alternatives to wood and continue to protect the remaining forests.

Floods are becoming more frequent environmental challenge due to heavier and higher intensity rainfall. Other factors like poor watershed management, rapid urbanization, and blockages of drainage channels are worsening the incidences and impacts. Environmental pollution is also an environmental challenge and is linked to a reasonable extent to poor waste management particularly in the urban areas.

All these characteristics of the national environment can accentuate the local impacts of climate change. If well managed however, they could reduce vulnerability to climate change impact and make effective coping and adaptation possible.

2. **Greenhouse Gas Emissions Inventory**

Since the submission of the FNC, Nigeria has updated its national GHG inventory. The procedure used the default methodology of the "Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories" and the "Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories".

The activity data were obtained mostly from national data sources, while most of the emission factors data were IPCC default emission values. The remaining figures were obtained from national measurements and from literature review. Activity data for the national GHG inventory were compiled from published data by the Nigerian National Petroleum Corporation (NNPC), National Bureau of Statistics (NBS) and Central Bank of Nigeria (CBN). Other sources included the IPCC reports, EPA AP-42 and OECD/IEA reports, as well as journal articles. The majority of emission factors used were default IPCC values. The national emissions were obtained by using the software of the IPCC WGI. GHG emissions due to energy consumption used in the various sectors including industry were calculated in the energy sector. All calculations used the recommended Global Warming Potential (GWP) of GHGs.

Estimates were made for the base year 2000 with sectors, as sources of GHG emissions, categorized according to their percentage contributions to the national GHG inventory. The bottom-up approach was used to estimate the emissions and removals from (i) energy; (ii) industrial processes; (iii) agriculture; (iv) land use, land-use change and forestry (LULUCF); (v) waste; and (iv) solvent and other product use sectors. The GHGs whose emissions were estimated in this national inventory are (a) Carbon dioxide (CO_2); (b) Methane (CH_4); and (c) Nitrous oxide (N_2O). Although emissions of Oxides of nitrogen (NOx), Carbon monoxide (CO), Non-methane volatile organic compounds (NMVOC) and Sulphur dioxide (SO_2), as indirect GHGs, were also made and reported in the national inventory, they are not included within the country's aggregate emissions.

The estimates show that, in 2000, Nigeria contributed about 214.21 million tonnes (Mt) of CO_2 equivalent (CO_2e) of GHG to the atmosphere. The corresponding figures for CH_4 and N_2O were 96.76 and 7.10 million tonnes respectively. The energy sector contributed the largest proportion (70%). This is followed by agriculture (27%), with very minimal contributions from waste and industrial processes. The total GHG emissions in Nigeria increased in 2000 to 135% of that in 1990, indicating significant increases in the socio-economic activities. Energy-related activities have the dominant share of emissions. The total emissions from the energy sector were 155.34 $MtCO_2e$, representing 70.4% of the country's total emission in 2000. CO_2 was the largest contributor (114.72 $MtCO_2e$) i.e.74% of the total energy sector emissions. On a per gas basis, the energy sector contributed 53.6 % of the total CO_2 emissions of the country, 39.2% of the CH_4 emissions, 37.5% of the N_2O emissions, 99.3% of the NMVOCs emissions, 65.2% of NOx emissions, 82% of CO emissions and 92.6% of the total emissions of SO_2 in 2000. On a per sub-sector basis, the largest contributor to emissions in the energy sector is gas flaring, which accounted for 40.3% of the energy emissions, followed by the transport sector, which accounted for 18.4%. Following in order of importance are the CRAFF and manufacturing and construction sub-sectors, which accounted for 13.6% and 12.6% of the energy emissions respectively. The energy industries accounted for only 8.5% of the total energy emissions, a reflection of Nigeria's poor performance in the sub-sector.

In the year 2000, emissions from industrial processes sector were a mere 2131 Gg CO_2, which is just 0.8% of total GHG emissions. These CO_2 emissions came mainly from cement production (1375 Gg CO_2). This sector generated insignificant emissions of NOx, CO, NMVOC

and SO_2. In the year 2000, there were no significant emissions from the use of solvents and other products containing volatile compounds.

The GHG emissions of the agriculture activities were also relatively small (6841 Gg CO_2) and accounted only for 2.8% of the country's total GHG emissions in the year 2000. These emissions are composed mainly of CH_4, CO and NOx. Enteric fermentation and rice cultivation constitute the critical sources for CH_4, while all the NOx and CO emissions came from the burning of savannah and agricultural residues.

The land use change and forestry sector was a high net source of CO_2. The emissions were estimated to be 97,384 Gg of CO_2 at 40% of the country's total GHG emissions in 2000. The net CO_2 emissions for the LULUCF sector were derived mostly (97%) from changes in forest and other woody biomass stock, an indication of high rate of deforestation in the country. Waste contributed an insignificant proportion of GHG emissions in 2000. Only 39 Gg of CH_4 and 5 Gg of N_2O (all from wastewater handling) were emitted.

The CO_2 equivalent emissions for the period 1988 – 2000 indicate gross CO_2 emissions per annum ranging from 200 Tg-CO_2-e in 1988 to 318 Tg-CO_2-e in the year 2000. Out of these, CO_2 contribution is highest and in the range 147 – 214 Tg-CO_2-e while N_2O contribution is least, and in the range 6.1 – 7.1 Gg-CO_2-e. The relative contribution of the three GHGs to gross CO_2 equivalent emissions show that CO_2 contributed more than 80% of the gross CO_2-e during the period, followed by CH_4 (25%) and N_2O (less than 5%).

3. Measures to Mitigate Climate Change

The climate change mitigation assessment in this report addresses the main sectors for which emission estimates were made in Chapter 2. However, the ranking and economic implications of the mitigation options are not provided because of the limited analyses conducted in this aspect. These are expected to be captured in future updates. The Nigeria's mitigation efforts as documented in this report include the following sectors: energy; forestry and land use; agriculture; mitigating in the savannas and rangelands and service. Some other issues discussed in the climate change mitigation efforts in Nigeria include: financing climate change mitigation; national policies on climate change mitigation; natural gas flare out policy; mainstreaming climate change into sustainable development; relevant national development plan to climate change; and uncertainties.

The Clean Development Mechanism (CDM) has provided ample opportunities for emission reduction from the energy sector in the country. One of these is in the conversion of the natural gas that was once flared in the process of petroleum exploitation into cooking gas. This is running in Kwale oil gas processing plant with an annual emission of reduction of 1,496,934 tCO_2 and the Gas utilization project responsible for 2,626,735 tCO_2. The third project on efficient wood stove is capable of reducing emission by 31,309 tCO_2. Apart from these, there are other possible CDM projects that can be developed. These include: Expansion of solar energy utilization in units such as residences, educational institutions and hospitals; Using the notoriously spreading invasive species such as water *Eichornia crassipes* for biofuels and producing biodiesel from *Jatropha curcas;* Popularizing the use of energy saving devices such as CFL, LED, automated power switch-offs in homes, offices and hotels, energy efficient cars; Use of efficient charcoal cook stoves to reduce emission from biomass burning, Improving charcoal production methods to reduce wood wastages typical of traditional methods in the carbonization process; Utilization of Compressed Natural Gas (CNG) as a Transport Fuel; and Expansion of Bus Rapid Transit System which is already well tested in Lagos State. The potential for this sector is huge in the country and it could bring about the reduction of GHGs of about 100 million tonnes of CO_2 equivalent annually.

Land use change and forestry sector contributes significantly to the net emissions of GHGs, particularly CO_2, to the atmosphere. One reason is that Nigeria is an agrarian country, which means that a lot of interferences with vegetation and to soil carbon dynamics go on from time to time. But perhaps more importantly is that Land use is changing very rapidly in the country reflecting in extensive deforestation, de-vegetation and expansion of cultural features particularly houses. One area in which the government is addressing emissions in this sector is in its forestry programmes both to meet growing demand for wood and enhancing the vegetation cover with all the attendant benefits. Three forestry practices are commonly pursued by forestry agencies in the country. These are afforestation, agro forestry and forest protection.

The agricultural sector is a significant contributor of anthropogenic GHGs. Among others, the sector plays an important role in the oxidation of biomass and organic matter and the combustion of fossil fuels in the automation of agricultural activities. Soils contain high levels of soil organic matter (soil carbon) and agricultural practices release CO_2 from the breakdown of the soil organic matter. Thus, with suitable agricultural management practices such as zero- or minimum-tillage, improved fallows, crop rotation and retention of residues on the soil surface, soils can be enhanced to replenish their lost organic matter. Two appropriate agricultural management practices reported here are mitigation options for rice cultivation and to control emissions from livestock. Some of the practices that are being encouraged in rice cultivation include: improvement in nutrient management including the retention of rice residues; improved water management in irrigation projects; Use of organic fertilizers to boost soil fertility; and improved cultivation practices while maintaining the productivity of rice fields. In Nigeria, the population of livestock has increased tremendously. For instance poultry production especially around the urban areas has become important sources of income to many. Some of the proven options for reducing methane emissions from livestock are: Increasing animal production efficiency through proper veterinary care, sanitation, ventilation, nutrition and animal comfort; provision of modern abattoirs to keep slaughtering processes clean and hygienic; encouragement of production of moths and other insects to reduce consumption and demand for livestock products; improved production of mushrooms as substitute for meat; focus on small stocks like snails and fish which give animal protein but produce lower emissions compared with big livestock.

The management of the savanna and rangelands is an important part of mitigation efforts in Nigeria. The greatest challenge is dry season bush fire, which is used by herdsmen to provide fresh fodder for their animals. It is also used to prepare farmland for new round of cultivation as well as chase games out for hunting. Mitigation options in this sector include: Massive sensitization on the dangers of bush burning; Awareness creation on methods to avert bush fires; Designation of grazing zones where the herdsmen can manipulate fodder production without interference with farmlands; enriching rangelands and reduce degradation by afforesting the rangelands; rehabilitation of degraded areas, reduction in livestock numbers, changing the mix of animals, and effective watershed management.

The potentials for climate change mitigation in the service sector of Nigeria are also enormous. When energy efficient and low carbon technologies/procedures are adopted in the various service sectors, it will serve as an impetus for the growth of green economy and cleaner environment.

Mitigating climate change impacts in the country requires a huge financial commitment. Unfortunately, the economic situation of the country Nigeria makes it challenging for the government to allocate sufficient funds for climate change programmes. At present, the

Federal Government is devoting part of its national budget to addressing issues in climate change sensitive sectors of the economy. At the regional level, Nigeria is actively involved in the climate change activities of ECOWAS and AU, in part, to source additional and complimentary flow of financial resources to tackle climate change. At the international level, funding is being sourced through UNFCCC and other global sources of finance for the environment.

The development and implementation of environmental and other policies in Nigeria to support mitigation measures are yet to be fully realized. Most of the existing policies are very broad and are not specifically focused on responding to climate change concerns of the country. While climate change is mentioned in some key government policies, there is yet to be specific policies or strategies for climate change mitigation in the country. Nigeria is just in the process of putting in place a climate change policy or a response strategy that could address the issues of mitigation (and adaptation) measures and financial requirements and mobilization. The draft policy document has been approved by the federal executive council and currently with the legislators for passage into law. At the Convention domestication and policy development level, the Federal Ministry of Environment of Nigeria (FME) set up a Special Climate Change Unit, which has now been upgraded, to the Department of Climate Change. The National Environmental Policy (1989), which was revised in 1999 to make room for new and emerging environmental concerns, has also been a key policy drive to stem greenhouse gas emissions. There is also Natural Gas Flare out Policy, as contained in the National Energy Policy, which is primarily targeted at cessation of gas flares in Nigeria. Other policies that are relevant to national climate change mitigation response efforts include: National Policy on Drought and Desertification; Drought Preparedness Plan; National Policy on Erosion, Flood Control and Coastal Zone Management; National Forest Policy; and National Biodiversity Strategy and Action Plan; The National Forestry Development Programme; The National Capacity Self-Assessment (NCSA); and The Presidential Afforestation Initiative. The country has also put in place many laws and regulatory measures that have implications on climate change response efforts. These include: National Park Service Act (for conservation and protection of natural resources in national parks; and Endangered Species (Control of International Trade and Traffic) Act (conservation of wild life and protection of threatened and endangered species).

Given the potential impacts of climate change on Nigerian economy, climate change is no longer just an environmental issues but a core development issue. It has become a major threat to the sustainable development of Nigeria, like many other developing countries. The challenge now is to keep climate change from reversing all the development gains achieved over the years. The National Environmental Policy (1999) is developed in part, to strengthen developmental initiatives in the country. The goal of the policy is to achieve sustainable development in Nigeria.

There are expectedly a lot of uncertainties in the discussion of mitigation response arising primarily from the fact that the options have not been analyzed using objective quantitative matters. Because of this gap, the determination of which option should be of priority remains at best guesswork. Also, the quantitative assessment of the economic impacts of potential mitigation actions has not been reported. In future reports, detail analyses of the mitigation options would be provided to further sharpen the country's focus at mitigating climate change.

4. Climate, Climatic Trends and Climate Change Scenarios

The climate of Nigeria, its trends, anomalies, variability and change in the last couple of decades were examined. The climatic data were also projected to the end of the 21st Century using statistical and global models (Atmosphere/Ocean General Circulation Models, AOGCMs) and regional models (statistical and dynamical downscaling). The study focuses on two main aspects, which relate to (a) the characteristics of present climate, climatic variabilities, especially as related to rainfall and temperature and (b) the characteristics of the changes expected in the climate of the country over the next 50 - 100 years. In considering these two areas of concern, emphasis was placed on rainfall and temperature, although issues relating to other climatic parameters are implied.

The observed climate indicates that temperatures in Nigeria have been on the increase in the last five decades and have been very significant since 1980s. After the last major drought in 1983, temperature had been above normal except in 1989 and 1992. The linear warming for the period under study for 30-year averages on a decadal slice, further reveal changes in temperature by an average of 0.2^{o}C. Temperature anomalies patterns over the country also show that except for 1973 when the country experienced its first significant drought in recent times, temperatures were below normal between 1951 and 1978. From the 1980s till date, except in 1989 and 1992, temperatures have been above normal by as much as 2^{o}C in 1998, which is considered as the hottest year in instrumental records. In line with the surface air temperature, there has been a steady increase in the trend of maximum temperature in the country with values ranging from 31 – 33^{o}C. Further regional investigations show that in the north, maximum temperature values lie between 32 – 35^{o}C while in the south, values lie between 30 – 33^{o}C. Although the minimum temperatures also show increasing trend, the increase is much stronger in the south than the north of the country, indicating much colder nights in the north.

The inter-annual fluctuations observed in the annual rainfall over the country are high and are responsible for the extreme climate events such as drought and flood. The fluctuations during the first relatively wet period, which occurred between 1951 and 1968, had high values of rainfall in 1954, 1955, 1957 and 1963. The lowest value of rainfall during this period was in 1958. The period 1970 – 1990 was dry except between 1978 – 1980 and coincided with the Sahelian droughts of early 1970s and 1980s. From 1990s to present, rainfall has been generally above normal. However, rainfall was much better in the 1990s than the present. The general trend indicates a decline in rainfall over the country although some locations may experience better rainfall than what has been expressed over the country. There are three periods, which may be noted, in the cyclic pattern of rainfall over the country. These include (a) a relatively wet period, which occurred between 1951 and 1968; (b) a relatively dry period, which occurred between 1969 and 1992; and (c) another relatively wet period that shows a period of recovery between 1993 and present day. Between approximately 1968 and 1992, there were relatively low rainfall values with the lowest rainfall below average in 1973 and 1983 with a slight recovery in 1978 and 1979. It is informative that the period of lowest rainfall in 1973 and 1983 coincided with the severe droughts in West Africa. In spite of the general recovery in rainfall, since 1993, the general trends show slight decrease in rainfall especially since 2001. The climatic cycles in the northern and southern Nigeria have similar temporal pattern with that over the country but the amplitudes are much higher in the northern than in southern Nigeria.

The statistical analyses suggest that the present observed mean temperature over the country is about 27.2 ^{o}C. When compared with the baseline period (1961 – 1990), an approximate 2% increase has taken place and a further 3.7% increase is expected from the

present day value and a likely 5.6% increase from the baseline period. Even though, temperatures are higher in the north and the region is therefore warmer, the temperature changes are higher in the south than in the north. Temperature change in the north is about 0.5^{o}C from the baseline period while in the south; it is about 0.6^{o}C, a difference of 0.1^{o}C between the north and the south. However, the present day rainfall increased by 7% from the baseline period but it is expected to fall by about 5% by 2020s from the present climate condition and about 1% increases from the baseline period. However, these statistical projections do not depend on changes in the concentration of the greenhouse gases, population, energy consumption, land use, etc.

In the previous paragraphs, the mean state, variability and trends including statistical projection in the near future climate were discussed in order to provide the required benchmark for future climate scenarios using B1 and A2 scenarios. The future period considered are 2046 – 2065 and 2081 – 2100 and these time slices will provide useful information at the middle and end of the 21st Century. The data from synoptic stations over the country have been subjected to statistical analyses to determine the current climate. The climate scenarios downscaled from GCMs is reliable and therefore the climate change scenarios can be computed by taking a difference between the current climate and future climate scenarios for B1 and A2. This provides discussions on projected annual and seasonal maximum and minimum temperatures changes, rainfall changes and extreme temperature and rainfall events. The pattern and trends in extreme events are vital to determining vulnerabilities of regions of the country and potential impacts of climate change.

The time series of projected minimum and maximum temperature changes during the periods of 2046-2065 and 2081-2100 using the B1 and A2 scenarios show an increasing temperature and therefore a warmer climate. However, it is relatively warmer in A2 scenario than in B1 scenario. The B1 scenario indicates an increase of +0.20^{o}C per decade from 2000 to the end of 2100 and A2 shows +0.40^{o}C per decade from 2000 up to the middle of the century (2046-2065). Thereafter, an increase of +0.80^{o}C per decade is projected till the end of the century (2080-2100). It is worthy of note that by the middle of the century, the projected annual surface temperature changes in Nigeria are +1.5^{o}C and +0.2^{o}C for B1 and A2 scenarios, respectively.

The spatial distribution of the changes in rainfall patterns show wetter climate over the entire country in B1 scenario than in A2 scenario. In B1 scenario, the highest increase (mm/day) is in the coastal region and the lowest (mm/day) value in the northeast region. Although, the rainfall pattern does not change significantly between the middle and end of the century, it is slightly wetter at the end than at the middle of the century over the coastal region. With A2 scenario, the models suggest a wetter climate over most regions in the country, except in the northeast, where they predict a drier climate. They also show the possibility that the Jos Plateau may have a drier climate by the end of the century. Again, similar to the pattern in B1 scenario, the coastal region is slightly wetter at the end than at the middle of the century.

Extreme climate events have constituted serious threat to global economic growth over the past years, especially to the socio-economy of developing nations. In Nigeria, severe floods, drought, windstorms, heat waves, ocean surges and several other climate extremes have impacted negatively on the socio-economic activities of the country. Therefore, examining the extreme climatic characteristics in the projections provide useful information for

possible guidance in the socio-economic development of the country. The models project an increase in future occurrences of extreme temperature and rainfall events over all four of the agro-climatic zones (Mangrove, Rainfall forest, Tall Grass Savanna and Short Grass Savanna) in both B1 and A2. The findings in the scenarios are that by the middle of the century, the number of days with temperatures greater than 38^{o}C would increase. The number of days with extreme rainfall (50 mm/day) increases by 1-2 days over all the agro-climatic zones for both scenarios, except over the Savanna zones by the end of the century when a decrease of one day is projected. The projected increase in extreme rainfall events is consistent with what is expected, especially in the coastal regions. Furthermore, both scenarios show an increase of 1-2 weeks in the length of the rainfall season over the zones by the middle and end of the century, except over the Short Grass Savanna, where both scenarios project a decrease of less than one week.

There are strong indications that Nigeria is highly vulnerable to climate change resulting from both its location and the level of human resources and institutional capacity for adaptation. Therefore, mitigation options need to be adopted and adaptation strategies developed. However, some areas of the country may experience higher levels of seasonal change than others. The present extreme weather and climate events such as floods, droughts, desertification, coastal erosion and salt water intrusion from sea level rise may become severe if the future projections in the 21st Century are taken into consideration.

In the final analysis, it is important to note that the values obtained for future climate scenarios for Nigeria are not exact but provides guidance to aid socio-economic planners and decision makers. It is important to emphasise that the climate of Nigeria varies on timescales of years and decades due to natural interactions between atmosphere, ocean and land, and this natural variability is expected to continue into the future. For any given period in the future (e.g. 2046-2065) natural variability could act to either add to or subtract from changes (for example in local rainfall) due to human activity. This uncertainty and indeed other uncertainties inherent with projections need to be understood in the use of figures under climate scenario developments.

5. **Evaluating Vulnerability to and Impact of Climate Change**

Here, the strategies adopted in evaluating Nigeria's vulnerability to and impacts of climate change in the country are described. The vulnerability assessment was based on the framework for socio-economic analyses and planning as suggested in the IPCC report of 2000. Data analyses and characterization were considered at the geopolitical zonal level to make for assessment of relative vulnerabilities. Climatic data were analysed at the geopolitical zonal level and integrated into the vulnerability assessment. For rainfall- and temperature-based scenarios, data were obtained from second-order polynomial analyses of climatic data from 1961 to 2007 for temperature and from 1961 to 2008 for rainfall. With respect to other parameters including sea level, average yield of millet and sorghum, cereal yields, rice yield, cropping season, agricultural losses, lengths of growing period in agricultural areas within the livestock-only systems, lengths of growing period in rain-fed mixed crop/livestock systems, yields from rain fed agriculture, sensitivity of African mammals, settlements, and global total of those earning below US$1/day, various sources including the NBS and other published consistent data sets were consulted.

The analytical approach used in assessing vulnerability is the econometric method, which uses the household-level socio-economic data to assess the level of vulnerability of different

social groups to climate change. It does this by constructing a measure of welfare loss that can be attributed to shocks, in this case, climate change. For this assessment, the indicators were weighed using expert judgments and reviews of literature. The scores for the various indicators were aggregated and overall estimations considered using panel judgment in each case to control the errors that may come up with averaging the data. The assessments were also benchmarked as climate change is expected to impact various locations differently. To assess coastal environment, the matrix developed by Gornitz in 1991 was used. The matrix contains five levels of vulnerability in relation to coastal parameters such as relief, rock type, landforms, sea level rise, shoreline displacement, tidal range and annual maximum wave heights in meters.

Vulnerability is considered a function of *adaptive capacity*, *sensitivity* and *exposure*. For *exposure,* three parameters, using water demand for agriculture and domestic purposes as proxies, were considered. These parameters are actual and potential irrigation opportunities, rainfall trend and access to safe water. For rainfall, the beta coefficient of the linear regression of total annual rainfall with time from 1983 to 2008 was used. The key input variables for *sensitivity* analyses were quality of dwelling units, fertilizer usage, home ownership, crop diversity and population density. A large number of socio-economic and physical features are put in the model for the assessment of the *adaptive capacity.* For instance, level of education and access to health facilities were considered as measures of adaptive capability.

There are a number of uncertainties in estimating vulnerabilities. These include government policies, which can affect the characteristics of key indicators such as home ownership, health care delivery, fertilizer utilization, sanitation, water supply and maintenance of facilities. It is also unknown whether the quality of the irrigation infrastructures can sustain cropping into the future. Although the trends in temperature and rainfall distributions are known from the observed data analysis presented, their future behaviours are uncertain.

6. Vulnerability to and Impact of Climate

The vulnerability to, and impact of, climate change on Nigeria is presented here. The assessments are all tied to agricultural productivity because of its significance in the socio-economy of the country. They also involve extracting data from various sources and projections for each geopolitical zone on vulnerability indices. Data for coastal vulnerability were assembled from documentary sources including topographic maps of the region. The TOPEX/POSEIDON altimetry data were also accessed to define rates of sea level rise per annum.

The sea level rise in the coastal areas ranged from 2 mm around Lagos in the west, 3 mm in Warri to about 5 mm in Calabar. Landform characteristics were quantified and ranked based on Gonitz (1991). The dominant landforms are beaches/lagoons, barrier, bay beaches and delta. The three locations used as sampling sites i.e. Lagos, Warri and Calabar have similar values based on relief, rock types and erosion/deposition and erosion indices, the Strand Coast of The Niger delta is the more severe with the highest overall vulnerability. Up to 600 km^2 of land could be impacted with a metre rise in sea level in the region. This land area would include substantial parts of Lagos, Warri, Port Harcourt and other coastal cluster of communities in The Niger delta. It will also affect the coastal clusters of communities in the Niger delta. The analyses of vulnerability are first considered at three levels: *adaptive capacity*, *sensitivity* and *impact*. A summary of vulnerability pattern in the country's geographic space is then computed. The Northeast zone has the least adaptive capacity followed by the Northwest. It is highest in the Southwest, followed by the Southeast. The pattern is consistent with the geography of the country. For example the vastness of the land area in the Northeast tends to 'thin' out what

could be described as adaptive capacity in the zone, whilst compactness and historical development trends in the Southeast and Southwest put the two of them ahead of other zones. The implication of these analyses is that climate change response should continue to be implemented in such a way that they are flexible and sensitive to spatial variations over the country's space.

Of the six zones, the North-central has the lowest sensitivity and the South-south the highest. The lower sensitivity in the North-central is probably associated with the large distribution of lakes in the zone. These lakes make all year round irrigation in the sub-region possible and help to compensate for rainfall that could be below expectation. The high sensitivity of the Southeast zone is due to the porosity of its soils and a short dry period normally has severe effects on soil moisture. The least exposed is the Southwest while the most is the Northeast. However, the Southeast is almost as exposed as the Northeast. Two issues are important here: exposure to climate change is not a regional phenomenon in terms of north/south dichotomy; rather, it is a national phenomenon; exposure factors must be addressed in every part of the country. For instance, rainfall decline, which would affect water supply in rain fed agriculture, is an exposure issue that is of priority in the north while water loss due to high soil porosity is a major concern in the Southeast. The Southwest is relatively the least vulnerable with the three zones in the north having higher vulnerabilities. The South-south is the most vulnerable of the three zones in the south. This is most probably linked with the challenges of coastal flooding and erosion as well as problems associated with petroleum exploration in that part of the country.

7. Actions to adapt to Impacts of Climate Change

There is a wide range of adaptation options that could be applied in Nigeria and are presented here sector by sector. The main issues about the vulnerabilities of each sector necessitating the measures are first discussed.

Nigeria has a huge fresh water resource capable of yielding more than 214 km^3 of fresh water with about 53 km^3 additional from groundwater and rainfall. However water supply remains a big challenge. Only about 52% of the urban and 39% of rural dwellers have access to potable water. Irrigation agriculture is also limited by access to water. Specific vulnerability factors include lengthening dry seasons, limited infrastructures for rural water distribution, and among others widespread occurrence of water weeds like *Eichornia crassipes*, and *Typha latifolia* in drainage channels and lakes. Relevant adaptation options many of which are already being used at varying levels of details include: enhancement of research in water resources management and development; reducing water loss from dams; controlling evaporation with biodegradable suppressants; using efficient irrigation systems; enhancing storage of water in reservoirs; protecting water bodies from further pollution; adopting hardier and early maturing fish species; clearing of water weeds; regular fish culling; recycling of waste water; strengthening the Fadama project; inter- and intra-basin water transfer; and effective **c**ontrol of commercial production of water in sachets and bottles.

Most of the key challenges in the agricultural sector arising from climate change are connected with water resources. However, certain features make it compelling to treat agriculture as a separate entity. These include increasing crop failure/loss of yields and widespread malnutrition resulting from food shortages. Some of the adaptation strategies for the sector include: expanding and optimizing irrigation infrastructures; adopting drought-tolerant and early maturing varieties of crops; diversifying livelihoods to improve income; increasing and upgrading storage facilities for harvests; provision of efficient weather forecasting; effective pest control; use of cover crops to protect soils; stabilizing

gullies and erosion sites; improving M&E of agricultural Programmes; providing agricultural insurance; enhancing agricultural extension services; providing artificial flooding downstream of large dams; adoption of short-lived hardy crop varieties; recharging wetlands and providing more irrigation water; improving rural-urban transportation; improving livestock production and promoting alternatives to animal products; adopting semi-intensive livestock keeping and mixed farming; intensification of livestock; rangelands enrichment; designating larger grazing zones; and building mutual trust between farmers and herdsmen.

The coastal region is critical to the country's development process. Nine of the thirty-six states in the federation share the coastal environment and virtually all the oil and gas resources of the country are from there. The region is highly vulnerable especially to increasing sea level rise and coastal erosion exacerbated by increasing ship abandonment/wreck. Specific adaptation strategies that should be adopted within the integrated coastal management framework can be classified into three: abatement designs, ecological enhancement and withdrawal from areas dangerously threatened.

The forestry sector is also threatened by climate change. Most of the native forests are already lost and climate change is creating more challenges like difficulty in tree planting, retardation of regeneration process, death of trees, and decline in species diversity. There is also desertification in the arid and semi-arid areas where population pressure, over-grazing and over-exploitation of marginal lands are aggravating environmental degradation. Some of the effective adaptation strategies for dealing with forest loss and desertification include afforesting with fast growing species; protecting the remaining forests; re-vegetating threatened sites, protection of trees in marginal areas as well as social re-engineering.

In the energy sector some of the critical issues include crude oil and natural gas production, electricity supply and fuel wood utilization. The exploitations of these resources are sources of environmental concerns in the country. For instance, growing environmental challenges associated with oil exploitation in the Niger delta has continued to increase the vulnerability of the people of the region. Most households depend on fuel wood for domestic cooking and other renewable energy sources such as solar are little exploited. Relevant adaptation strategies in crude oil and gas sector include: control of oil spillage; awareness creation to prevent vandalisation of oil infrastructures; enforcement of legislation in oil exploration and exploitation; and promotion for the use of gas for domestic purposes. The relevant adaptation options in electricity supply include: deployment of efficient HEP turbines; encouragement of private production of electricity; development of alternative sources of electricity; replacement of aging infrastructures; and use of more efficient devices. For fuel wood exploitation, suitable adaptation options include development of alternative sources of energy; use of efficient cook stoves; encouraging energy farm and woodlots for active production of fuel wood; and integrating wood production into local farming system.

Climate change also has impacts on human health and vulnerability of individuals and households is increasing. For instance, incidences of vector-borne diseases and the prevalence of malnutrition are increasing. As health issues are multi-dimensional, possible adaptation can be adopted to address vulnerability in the sector are numerous. These can be classified as preventive and curative and include strengthening weather forecasting; adapting architectural designs to suit new weather regimes; awareness creation about preventive options; increase access to health services; promoting climate-health education

in schools; building capacity of health workers; and engaging private sector in climate and health issues.

Settlements all over the country are expanding rapidly due to population growth and are contributing to GHG emissions. One of the challenges of the expanding settlements is that they are largely unplanned. Also most houses are poorly built and incidences of collapsed buildings are increasing. Rapid expansion of settlement is also a threat to the sustenance of adjoining rural. Adaptation strategies that can be adopted are implementation of Town and Country Planning regulations; enforcement of building standards; minimising concrete surfaces around buildings; setting green belts in urban areas; and controlling of settlement growth on floodplains.

Tourism is an expanding area of interest in Nigeria. Most of the tourist sites are nature-based. Such sites depend significantly on local biodiversity. A change in climate, which affects vegetation, will reduce the value of such sites. Relevant adaptation strategies in the sector include: protecting tourism estates from encroachment; enriching biodiversity in tourist sites; developing water storage capacities for the tourist sites.

The transport sector is especially vulnerable to climate change as infrastructures are poorly developed. The road, which is the dominant mode, is not completely in good shape. Road arteries are constrained both by their sizes and the growing number of vehicles on them. Rainfalls with high intensities, which now flood roads more frequently, increase the rates at which the roads require repairs. Air travels and safety are also affected by weather and climate variability. The impact is more challenging at both the take-off and landing phases of flights due to poor infrastructure. Possible Adaptation strategies include: re-investing in other transport modes apart from road; expanding the roads; improving lighting at airports; and setting standards for vehicles on the roads; re-organizing the public transport system.

Industries are in many ways affected by factors associated with climate change. For instance, industrial processes require heavy input of energy, which is presently largely inadequate in supply and also implicated in the production of GHGs. Also industries whose raw materials are dependent on climate-related features such as agriculture and water resources would be adversely affected by climate change. Some of the relevant adaptation options in this sector are: deploying economic instruments such as suitable tax regimes to strengthen industrial activities; putting effective control on imports either to make them cheap or otherwise, in order to protect local industries; developing inventory of local raw materials that can support new industries or strengthen the older ones; and empowering the private sectors to tap opportunities in climate change businesses including in the aspects of green initiatives.

CHAPTER ONE

NATIONAL CIRCUMSTANCES

1. 1 Introduction

Accelerated climatic changes are expected to lead to potentially large impacts across Africa,

including Nigeria, in the future. The scale of climate change will increase with high anthropogenic emissions, greenhouse gas (GHG) concentration, and average global temperature. Climate models suggest that Africa's climate will generally become more variable, with high levels of uncertainty regarding climate projections in the Africa Sahel zone. Evidences indicate that the world has already warmed by 0.8^{o}C since the pre-industrial era. Temperatures in West Africa, and particularly the Sahel, have increased more sharply than the global trend, and the average predicted rise in temperature between 1980/99 and 2080/99 is between 3°C and 4°C, which is more than 1.5 times the average global trend (IPCC 2007).

For Nigeria, it has been shown that a possible sea level rise from 1990 levels to 0.3 m by 2020 and 1m by 2050, and rise in temperature of up to 3.2°C by 2050 under a high climate change scenario has been predicted (DFID 2009). The low estimate predictions are for sea level rise of 0.1 m and 0.2 m by 2020 and 2050 respectively, and a temperature increase of 0.4 to 1°C over the same time periods. Sea level rise of 1m could result in loss of about three-quarters of the land area of Niger Delta.

All of these have serious environmental and economic implications and call for urgent and well-targeted actions to minimize the potential disasters that could attend a full-scale climate change.

Since the inception of joint global actions on climate change arising from the Rio Conventions of 1992, Nigeria has been active in many fronts. In 2003, it submitted the First National Communication (FNC) in response to one of the requirements of the United Nations Framework Convention on Climate Change (UNFCCC), to which it is a signatory. It had prepared other major documents including the National Adaptation Strategy and Plan of Action (NASPA) to guide its adaptation efforts. A National Climate Change Policy and Response Strategy have been submitted to the National Assembly for passing into law. There had also been efforts to strengthen the institutional arrangement for climate change response in the country. One major aspect of this is the upgrading of the Special Climate Change Unit (SCCU) to a Department of Climate Change in the Ministry of Environment. This *Second National Communication* (SNC) in furthering the fulfilment of requirements of the UNFCCC captures the progress in climate change action in the country since the first NC. It also includes a summary of policies and initiatives aimed at responding to the challenges of Climate Change activities as a Non-Annex 1 Country Party to the UNFCCC.

.1.2. Location, Extent and Governance Structure

Nigeria lies roughly between latitudes 4^{o} and 14^{o}N and longitudes 3^{o} and 15^{o}E covering a land mass of approximately 923,768 km^{2}which is about 14% of the land area of West Africa (Federal Ministry of Environment (FME), 2009)). The country is bordered by Benin Republic to the West, the Niger Republic to the north, the sub-equatorial Cameroun to the east and the Atlantic Ocean to the south (Iloeje, 1981). In 2006, the country's population stood at about 140 million (NPC, 2006). The country runs a Federal system of government with a strong centre and 36 States together with a Federal Capital Territory (FCT). The States and FCT are further sub-divided into 774 Local Government Areas/Area Councils for grassroots administration. The 36 States are grouped into six geopolitical zones for political and development purposes. These are shown in Figure 1.1. The Constitution of the country affirms that it is one indivisible and indissoluble sovereign state, whose constituent units are bound together by a Federal arrangement. It provides for a presidential system of government in which there is an Executive, a Legislature and a Judiciary, with each arm acting as a check and balance on the powers of the other two arms. The legislative structure

is bicameral with upper and lower chamber at the Federal level while State governments and Local Councils operate single legislative chambers. A judicial structure erected in all three tiers of government completes the operational framework for checks and balances and separation of powers in governance as enshrined in the Constitution. The Constitution further provides for the operation of three tiers of government, at the Federal, State and Local levels.

1.3 Physical situation

1.3.1 Climate

The climate of Nigeria is dominated by the influence of three major air masses - the tropical maritime (mT), the tropical continental (cT) and the equatorial easterlies (Ojo, 1977; Iloeje, 1981). The mT originates from the southern high-pressure belt off the coast of Namibia, picks up moisture over the Atlantic Ocean, crosses the Equator, and enters Nigeria from the south-western direction. On the other hand, the cT originates from the high-pressure belt north of the Tropic of Cancer. Entering Nigeria from north-eastern direction, it picks up only little moisture en-route and is thus dry. The two air masses meet along a slanting surface called the Inter-Tropical Discontinuity (ITD). The equatorial easterlies are rather erratic cool air masses, which come from the east and flow in the upper atmosphere along the ITD. Occasionally however, the air mass dives, undercuts the mT or cT air mass and gives rise to line squalls or dust devils (Iloeje, 1981). Land and sea breezes are important in the coastal areas of the south-west Nigeria and because they are limited and confined largely to this zone, they are of relatively minor role in the climate of the country.

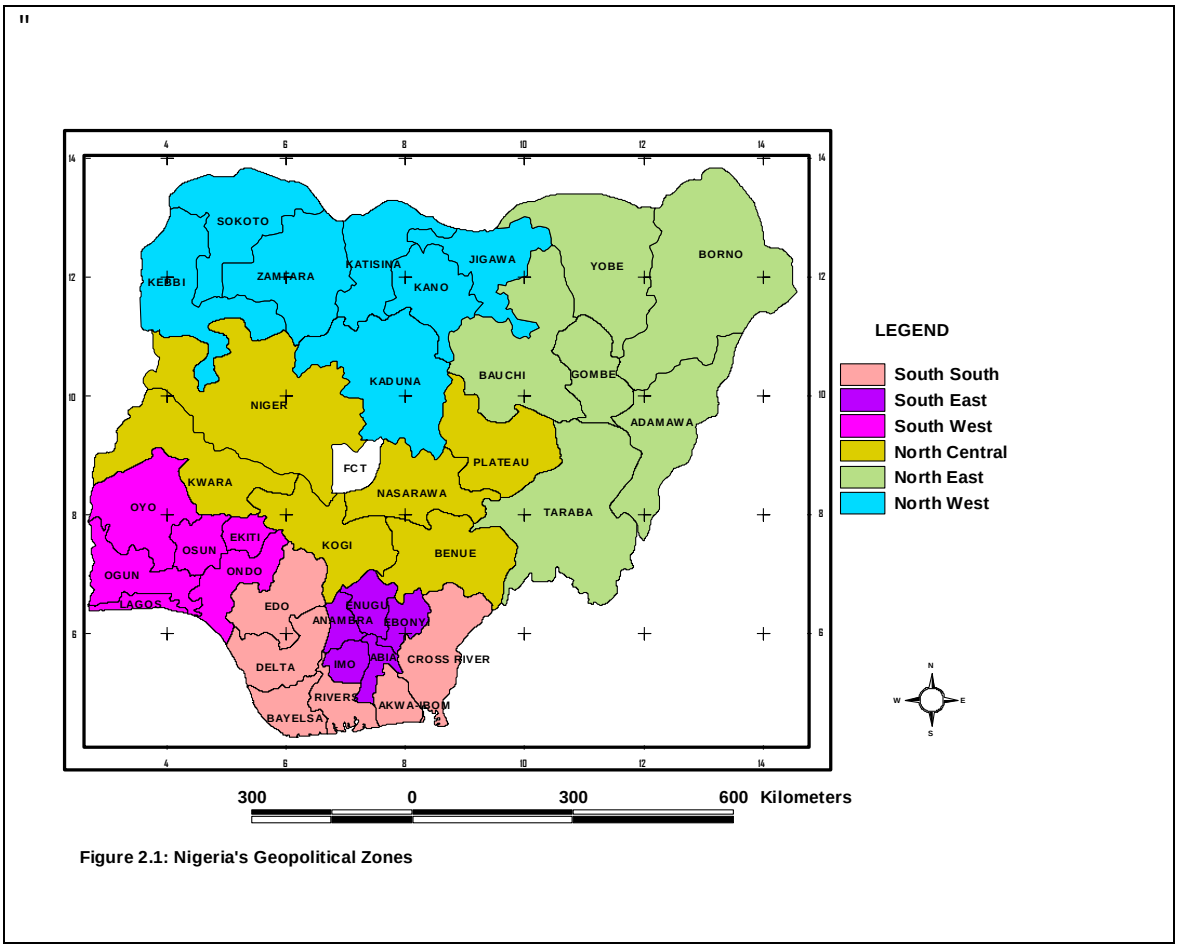


Figure 2.1: Nigeria's Geopolitical Zones

Figure 1.1: Nigeria's Geopolitical Zones

The latitudinal position of the ITD is a function of the season although there are also considerable short period fluctuations. Generally however, it is situated well to the north in July and August thereby allowing the country to be totally under the influence of mT winds during this period. It is located along the coastal part during January, with the effect that most of the country is covered by the dry cT during this period. As a result, the country is subject to marked wet and dry seasons associated with the moist and dry air currents, respectively. The northward latitudinal distance of the surface location of the ITD from the equator has had significant upward trends during the months of May, June, July, August and September since 1983, suggesting general increase in the length of rainy season in many of parts of the country (e.g. Odekunle *et al*., 2008).

The ITD's influence on rainfall is modulated by the pressure systems of Azores, Libyan and St. Helena anticyclones (Hastenrath, 1985) and the SST of the Gulf of Guinea (GOG) (Adedokun, 1978; Odekunle et al., 2005;) and to some extent; complex feedback mechanisms due to deforestation and land cover change (Christensen et al., 2007; IPCC, 2007). The SST of the GOG has undergone some warming over time. At the same time, an area of relatively cool SST near the Guinea Coast may have expanded.

Annual rainfall generally decreases from the coast inland from an average of about 3000 mm in Warri on the coast to less than 500 mm in Nguru in the Sahel of the north-east. However, rainfall is mostly seasonal- in the south, the wet season extends from March to October, while it is May to September in the north (Ojo, 1977; Iloeje, 1981). The southern two-thirds of the country is characterised by double maxima rainfall regime. The period of the maximum in the north may have shifted from August to July and the primary rainfall peak in the south from July to September. Also, the high intra-annual variability of Nigeria's rainfall is becoming more prominent (Odekunle and Adejuwon 2007). This comes with long dry spells during the growing seasons causing crop failures, and excessive wet spells leading to floods. Temperatures are more or less moderate throughout the year except in one or two months when the dry cold north-easterly wind dominates the wind system. The mean temperature is 27^{o}C (FME, 2009). In addition, temperate-like weather is experienced in the high ranges such as Obudu, Mambilla and Jos Plateaux.

1.3.2 Relief and Drainage

Nigeria has two main relief regions: the high plateaux ranging between 300 and more than 900 metres above the sea level, and the Lowlands, which are generally less than 300 metres (Figures 1.2a &1.2b) (Iloeje, 1981; Jeje and Adesina 1995). The high plateaux include the north central plateau, the eastern and north eastern highlands and the western uplands. The Lowlands comprise the Sokoto plains, the Niger-Benue trough, the Chad Basin, the interior coastal lowlands of western Nigeria, the lowlands and scarplands of south eastern Nigeria and Coastlands.

Most of the country's rivers take their sources from four main hydrological centres: the North Central plateau (Sokoto-Rima, Hadejia, Gongola, and Kaduna rivers etc.), the Western Uplands (Moshi, Awun, Ogun, Osun, Osse rivers etc.), the Eastern Highlands (Katsina-Ala, Donga rivers, etc.) and the Uri Plateau (Anambra, Imo and Cross rivers etc.). These drainage and relief features of the country have impacts on water resources and land use potentials of the country particularly for agriculture. According to the 2008 State of the Environment Report (Federal Ministry of Environment, 2008), the total surface water resources potential for Nigeria is estimated at 267.3 billion m^3 while the groundwater potential is put at 51.9 billion m^3, giving a total of 319.2 billion m^3. In addition, the number of relatively large dams completed or under construction is about 160 with a total active storage of 30.7 billion m^3.

1.3.3 Vegetation

The distribution of vegetation in Nigeria follows largely that of the rainfall and to some extent, the physiographic units. This is because in the tropical environment like Nigeria, temperatures are fairly uniform and what distinguishes one region from the other is mainly the amount of rainfall received. Nigeria's vegetation can be broadly grouped into two belts: Tropical rainforest and Savannah. The Forest subtypes include Salt-water swamps (Mangrove), Fresh-water swamps and High forest. The Savannah subtypes are Guinea, Sudan and Sahel. The major physiographic elements affecting vegetation distributions are elevation, slope and aspect (Adejuwon 1979; Adesina 2001). Vegetation associated with altitude is described as montane vegetation.

The mangrove vegetation is found along the coastal strip where brackish water inundates the land diurnally. Sometimes the land here is waterlogged. The vegetation is dominated by mangrove species particularly *Rihzophora mangle R. harrisonii and R. racemosa, Avicennia Africana* among others (White 1983; Onwugbuta-Enyi*et al.* 2008). This vegetation has been heavily degraded and now contains large presence of invasive species such as *Nypa fruticans*. The Fresh-water swamp vegetation is found further inland where the land is free from the salt water intrusion. Although the belt is also waterlogged, the mangrove vegetation is replaced by fresh-water plant species such as *Raffia* spp., *Elaies guineensis* and *Milicia exclsa* among others, which typically develop stilt-roots to adapt to the water-logged conditions. Most of the tree species found here invariably also occur in the dry tropical forests.

The high forest vegetation belt is relatively more extensive than the two previously described, stretching from the western boundary of the country south-eastwards through Ibadan and Benin, across the Niger to the Oban Hills. The natural vegetation is made up of trees arranged in three distinct storeys-ground, middle and top storeys. The lower storey comprises of herbs, shrubs and some grasses 3 to 6 metres high. Depending on how dense the middle and the crown layers are, the ground layer may carry only little plant growth. The middle storey consists of heavily branched trees ranging between 18 to 24 metres in height (Richards 1989). In most cases these natural forests have been modified and are now replaced by secondary forests, oil palm bushes, derived savannah or other anthropic features.

The Guinea savannah is the largest vegetation belt in the country. The belt covers about half the total land area of the country (Iloeje, 1981), mainly in the middle belt. The unique feature of the savannah is the presence of a ground layer of grasses. Most common trees here are the *Parkia biglobosa*, *Butryospermum parkii*, *Pentaclethra macrophylla* and *Isoberlina doka*. The Sudan savanna is north of the guinea savannah with such trees such as the *Adansonia digitata*. The Sahel savanna is mainly to the north eastern part where the mean annual rainfall is less than 450mm. The vegetation is made up of short and tussocky grasses (about 0.5 to 1 metre high) and tree plants such as acacia and date palms. Most of the species found originally in the Savanna (NBSAP, 2009) have disappeared or are at the verge of extinction. Deforestation rates in the country are some of the highest in the world with a high likelihood that all of the remaining forests may disappear in the 2020s.

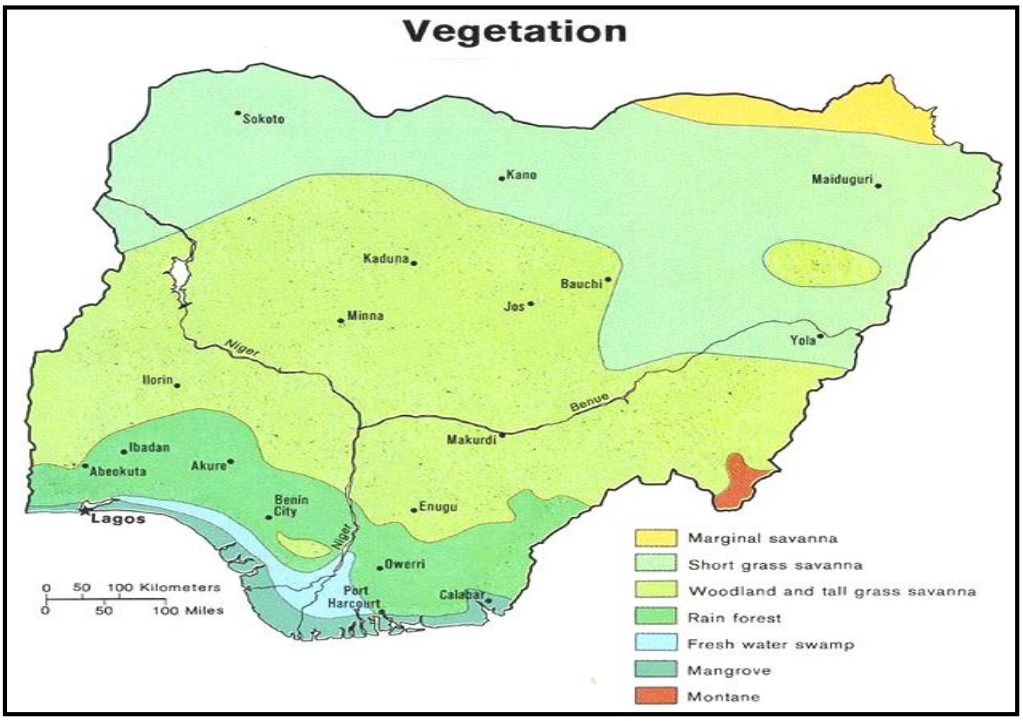


Fig 1.2a: Vegetation Map of Nigeria

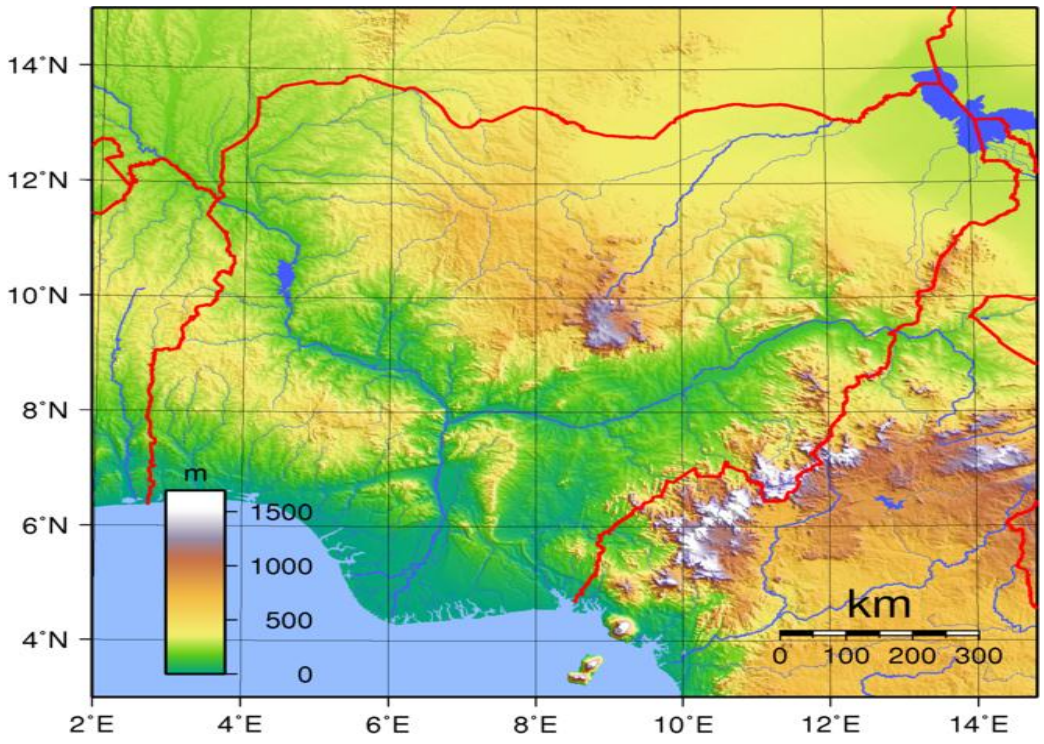


Fig 1.2b: Relief Map of Nigeria

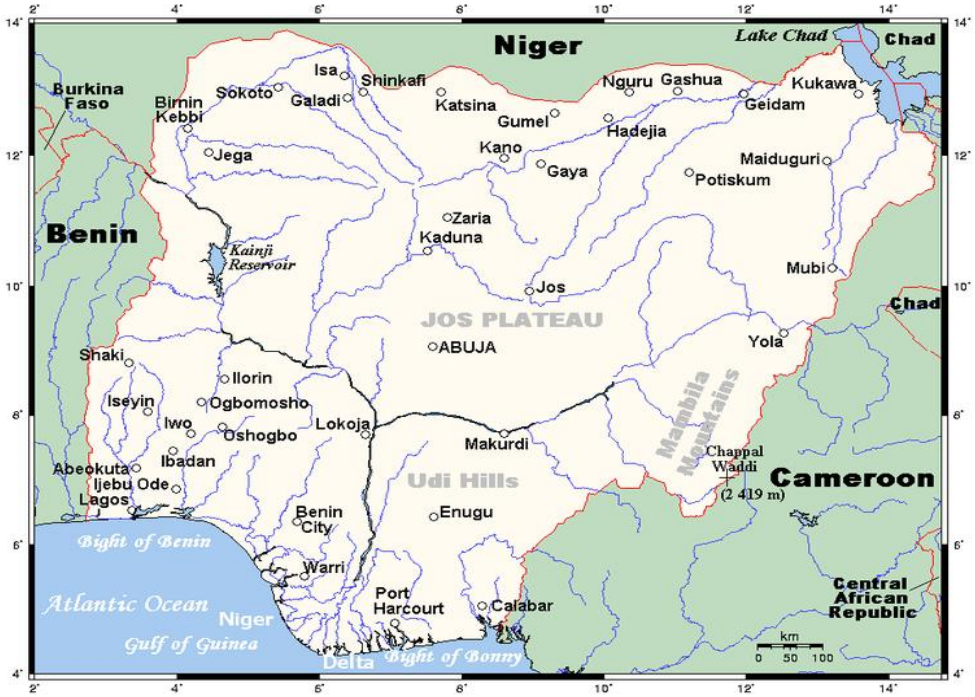


Fig 1.2c: Drainage characteristics and key settlements in the Country

1. 3.4 The Soil

Four main soil groups occur in a zonal pattern from the coast inland. These are often the hydromorphic, ferralitic, ferruginous and the arid and semi-arid tropical soils. The hydromorphic are found in the coastal zones and along the major rivers. The ferralitic soils occur in the rainforest environment mainly on sedimentary rocks. They are mainly clayey in texture with largely undifferentiated horizons. Ferruginous soils are found at the drier margins of the forest zone and more extensively in the Savannah. The soils are red or reddish in colour, rich in iron and are often low in organic matter. The arid and semi-arid soils are found in the northernmost regions with low rainfall (FME, 2006). The most predominant of the soil types in the country are the *Utisols*, extending over 46% of the country (NBSAP, 2009). Although, this type of soil is of moderate to low productivity, it does very well under good management practices. Only a small fraction (6%) of the country is covered by high productive soil. This type of soil is known as *Entisol* (NBSAP, 2009).

1.4 Natural Resources

The utilization of Nigeria's natural resources particularly land, water and coastal and marine, will have significant impact both in terms of damages of and ability to respond to the phenomena of Climate Change. A brief presentation of these resources apart from water resources that have been discussed above is made in this section.

1.4.1 Land Resources and Uses

Land is a most important resource serving as a platform or basis on which virtually all-human activities take place. Land cover is central to environmental processes, including climate change, through its influence on biodiversity, water, energy, trace gas emissions, carbon cycling, and a wide range of socio-economic and ecological processes that, affect

livelihoods. Nigeria with a total land area of about 923,768km^2 was once richly endowed with abundant and diverse renewable and non-renewable resources. Human use and misuse has however led to significant decline in the quality of land resources in the country.

In general, there is loss of prime arable lands, which in turn leads to the opening up of new land towards the southern part of the country. In the northern and central parts of the country, the Sudan savannah ecology is transiting to Sahel, an indication that desertification is intensifying. Desertification is affecting nearly 40 million Nigerians living in about 35 percent of Nigeria's land-mass. In a similar manner, the Guinea savannah in the south is giving way to Sudan savannah grassland. More importantly, the proportion of people living in rural area is rapidly declining, while urban areas are rapidly expanding, taking up more and more of the adjoining rural lands all of which will influence climate change.

1.4.2 Coastal and Marine Environment

The Nigeria's coastal and marine environment stretches for about 853 km, extending inland by about 15km in Lagos area, 150km in the Niger Delta and about 25km east of the delta. It consists of barrier bar/lagoon system, the Mahin mud coast, the Niger Delta, Strand coast and a moderately wide continental shelf. It is home to about 25 per cent of the country's population and harbours a wide variety of opportunities and resources. Oil production in the region makes Nigeria one of the largest oil producers in Africa, the eleventh largest producer of crude oil in the world. The sector provides the country about 90 percent of its foreign exchange earnings. A major feature of Nigeria's coastal and marine environment is the Niger Delta, which covers an area of about 70,000 km^{2}which makes it one of the largest wetlands in the world (FAO, 2006).

The coastal and marine environment also have non-fuel minerals like sand and heavy minerals, coastal agricultural land, and recreational and scenic resources including beaches, coastal lagoons and estuaries, coal, tin, columbite, palm oil, peanuts, cotton, rubber, wood, hides and skins. Almost half of Nigeria's industries are located within the coastal zone mainly due to accessibility to ports, raw materials and energy (HBF, 2008).

1.5 Demography

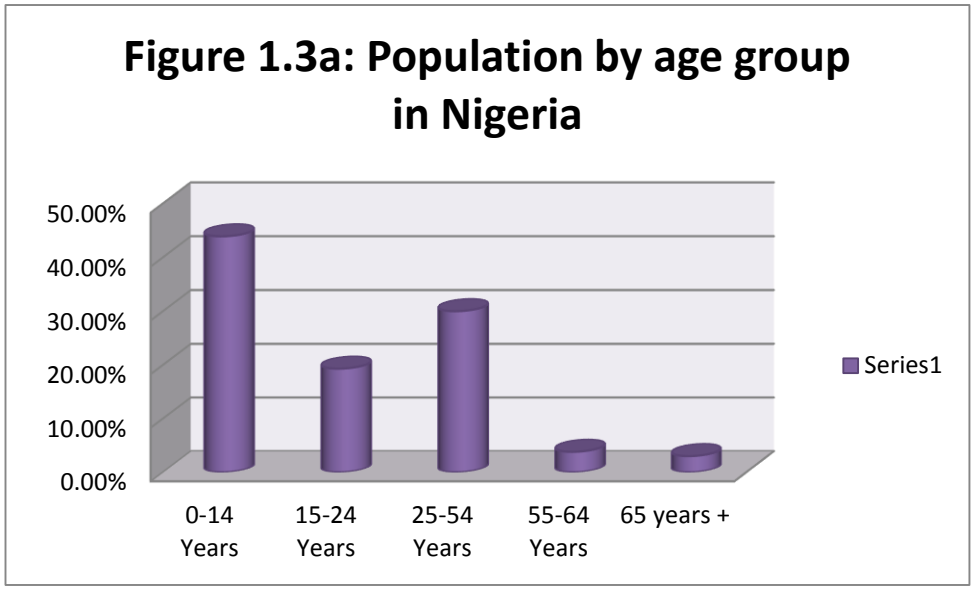
The 2006 Population and Housing Census puts Nigeria's population at 140.43 million with a national growth rate estimated at 3.2 percent per annum. At a growth rate of 3.2 per cent per annum, the population will double in size in just 24 years.

The large number and high rate of population growth has placed tremendous pressure on the environment and makes Nigeria a high potential contributor to global warming and, consequently, climate change. For example, in parts of the eastern Nigeria, the population density exceeds 1,000 people per km^2 and is probably the most densely populated part of Africa Sahara.

Figure 1.3a shows the distribution by age. It shows that the population consists largely of youths with high potentials for exponential growth as suggested by NPC (2006). Some of the impacts of population growth include decrease in rangeland as livestock populations grow, expansion of farmlands due to growth in framing population, and greater demand for water among others. All of these have implications in various ways for climate change. About 39 per cent of the population lives in urban areas, a figure that is projected to increase considerably by more than 50 per cent by 2020. The provision of basic infrastructure is no where growing close to meeting the new levels of demand. The improvement of these facilities is crucial to sustaining the country's socio-economic development.

Education is constrained by under-funding, inadequate and poor infrastructural facilities, and loss of professional staff. A growing significant number of Nigerians do not have access to good quality education and this is affecting the quality of life including productivity (Nigeria Vision 20:2020). There is also a decrease in primary school enrolment between 2001 and 2005 with a marked gender disparity (see Fig.1.3b).

A majority of Nigeria's more 140 million as at 2006 live below the poverty line and have limited or no access to basic amenities, such as potable water, good housing, reliable transportation system, affordable healthcare facilities, basic education, sound infrastructure, security and sustainable sources of livelihood.



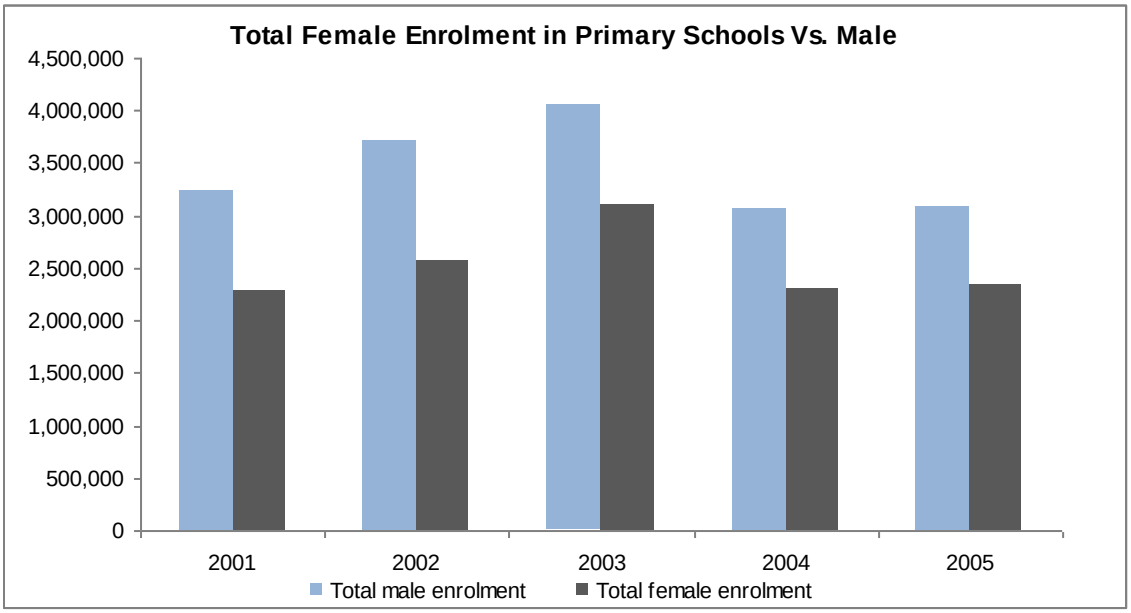


Fig. 1.3b: Gender differentials in Primary School Enrolment (2001-2005)

Source: National Bureau of Statistics

1.6 The Economic profile

According to the World Bank classification of 2010 (World Bank 2010), Nigerian economy is typical of a developing country in the lower-middle income category. Despite various reforms, the productive base of the Nigerian economy remains weak, narrow and externally-oriented with primary production activities of agriculture and mining and quarrying (including crude oil and gas) accounting for about 65 percent of the real gross output and over 80 percent of government revenues (NPC, 2009). In addition, primary production activities account for over 90 percent of foreign exchange earnings and 75 percent of employment. In contrast, secondary activities comprising manufacturing and building and construction, which traditionally have greater potential for broadening the productive base of the economy and generating sustainable foreign exchange earnings and government revenues account for a mere 4 percent of gross output. Services or tertiary activities, which depend on wealth generated by the productive sectors for their operations, comprise about 30 percent of gross output. Significantly, service activities have been expanding their influence in the economy over the last decade accounting for over 35 percent of the growth of the real gross domestic product (GDP).

The country's economic strength is largely derived from oil and gas reserves, which make up 90% of export revenues, 78% of Government revenues, and 38.8% of the Gross Domestic Product (GDP) (2006). A sectoral analysis of the real GDP performance in 2007 indicated that agricultural subsector contributed the largest share of 42.2 per cent, compared with 41.7 per cent in 2006. This was followed by Industry whose share fell from 26.1 per cent in 2006 to 23.7 per cent in 2007 (Figure 1.4). The contribution of crude oil in the GDP in 2007 was 19.7 percent from 21,9 percent in 2006. The contributions of mining and quarrying and manufacturing components of industry remained insignificant. Services as a group contributed 6.1 per cent to the GDP while finance and insurance; utilities and transport accounted for 3.8, 3.5 and 2.7 percent respectively (Figure 1.7).

Figure 1.4a: Contributions of different sectors of the Nigeria's economy to the GDP (CBN, 2008)

Figure 1.4b shows the growth of the GDP from 2003 to 2007 (CBN, 2008). A growth rate of 6.2 per cent was recorded in 2007 compared with 6.0 per cent in 2006. Agriculture the main non-oil sector of the economy increased partly due to the agricultural policy and institutional support government gave to the sector recently. Some of these supports

include: Presidential initiatives on rice and cassava production, provision improved maize seeds and agro-chemicals and the provision of Millennium development goal loans to farmers.

Before the advent of civilian administration in 1999, Nigeria had large public sector comprising over 550 public enterprises in most sectors of the economy. The public enterprise sector accounted for about 50 per cent of the GDP, 57 per cent of the investments, and 33 per cent of formal sector employment (CBN, 2002). The recent civilian administrations have put in place a number of policies to liberalize, deregulate and privatize some key sectors of the economy such as the national electric power authority, telecommunication, downstream petroleum and steel sectors. It is believed that these policy reforms combined with investment in human capital and physical infrastructure and good governance are essential to achieving self sustaining long term economic growth.

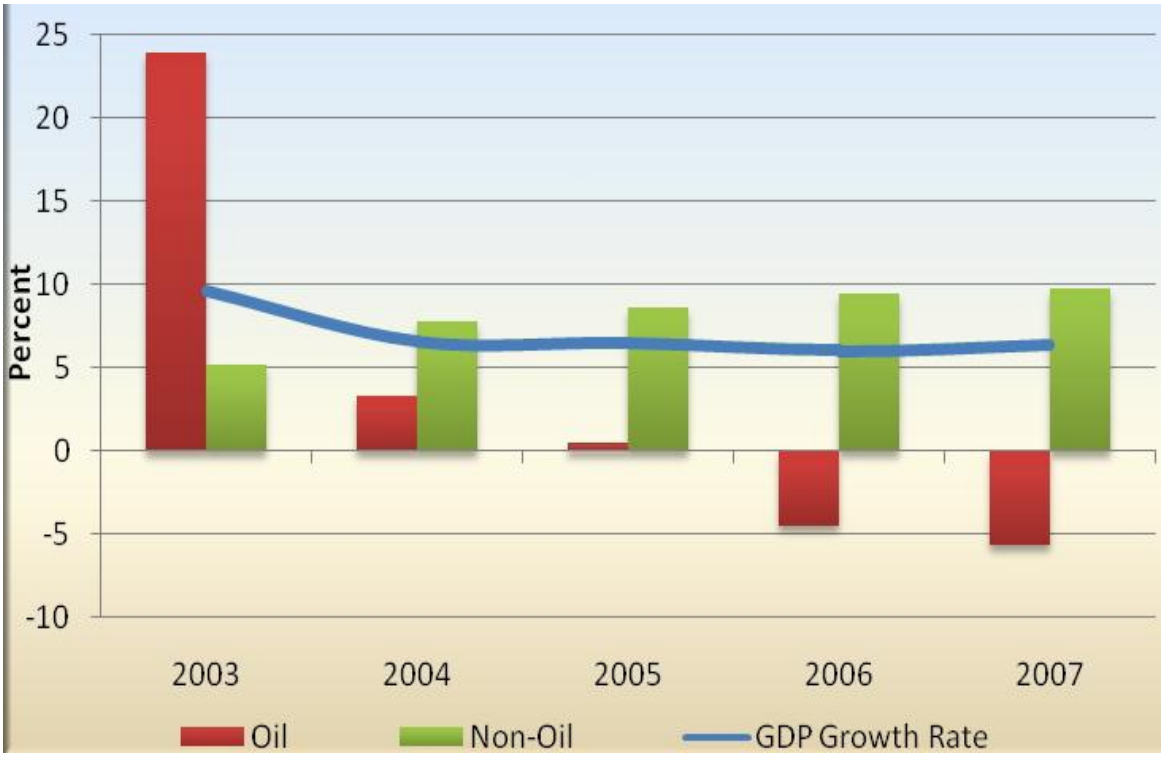


Figure 1.4b: Oil and Non-Oil Revenue as percentage of GDP (CBN, 2008)

1.7 Profile of the key sectors

1.7.1 Agriculture

Nigeria's agriculture is dominated by small-holdings and characterized by limited mechanization. These together with the nature of soil, climate, land tenure and inefficient land management practices are responsible for low productivity despite various interventions since the turn of the 21st Century. This low productivity has in part, resulted in the country's heavy dependency on import to meet its food demand. Some of the most significant food imports include wheat, fish, rice and sugar. On rice alone, Nigeria spent more than ₦200billion annually making it the second largest importer of rice in the world. Over the years, increasing effort is being directed at reducing food imports. These include programmes to attract the youth to agriculture; improvement of local rice production through value chain enhancement, and cassava production initiatives, which have

contributed to making Nigeria a leading producer of cassava in the world. So much still needs to be done to improve Nigeria's food supply as the population rapidly grows.

1.7.2 Human Health

Nigeria is making some progress in the achievement of the health related MDGs. Nonetheless, development indicators show the need for more concerted efforts in this sector. Live expectancy at birth is 43.8 years, infant mortality, 800 per 100,000 live births and maternal mortality, 100 in 100,000 (The World Bank Report, 2008). Also, the prevalence of infectious and parasitic diseases like malaria (141 in 100,000), tuberculosis (282 in 100,000), HIV/AIDS (3.9% of the population) and Schistosomiasis among others, remains very high. Furthermore, illnesses such as diabetics and cardio-vascular diseases that are often associated with increasing socio-economic wellbeing are becoming significant health problems in the country (Babatimehin, 2003). Only 48% of the population has "sustainable" access to clean water and a lower proportion – 44% has good sanitation (World Bank, 2008). Nigeria is a major health-professional-exporting country in Africa and this is increasing. For example, 432 nurses legally emigrated to work in Britain between April 2001-March 2002, compared with 347 between April 2000-March 2001 (Uneke et al., 2008). National statistics show that there were a total of 30,885 registered Doctors for all the people of the country (NBS, 2005). This gives a rather low ratio of 1 Doctor to 3,755 people. Access to government health facilities varies considerably from one part of the country to the other. The South-South zone has a ratio of 7,284 persons to one PHC facility. This is the highest in the country, and is followed by the North-West (7,067 persons per PHC), South-East (6,509 persons per PHC), and the North-East (6,348 persons per PHC) respectively. These four geo-political zones had values that are higher than the national average, which are 5,719 persons per PHC facility. Higher ratios are obtained in the North-Central (3,430 persons per PHC facility) and South-West (5,436 persons per PHC facility) zones. The two zones have ratios lower than the national value. The average ratio of population to tertiary healthcare facility is 1,932,884 persons to one facility (NBS 2005).

1. 7.3. Transportation

Air, rail, pipelines, road and water transportation facilities are available in the country but the most important in terms of functionality and number of patronage is the road. The total length of Federal Government highway roads is about 34,340.90 km. States also make complementary investments on high grade road development. The total rail length is about 4000km while both water and air travels are the least developed. The country has close to 9,000 km water ways the longest being on Rivers Niger and Benue system. Governments at both the state and federal levels are investing on airports to increase access to air travels. In general, every facet of transportation is inadequate or inefficient. Roads are often in a state of disrepair or incapable of handling the ever increasing traffic volume. This has impacted negatively on the socio-economic development of the country.

1. 7.4 Telecommunication

Nigeria has less than a million landlines but certainly more than 100 million mobile cellular subscribers. The advent of mobile communication in the late 1990s has revolutionized the sector and impacted positively on the socio-economic development of the country. Incentives are being provided to enhance the development of information and communications technology (ICT) and its enabling infrastructure (for every part of the country including the rural areas).

While encouraging investment in ICT, appropriate legal and regulatory frameworks are being put in place to safeguard the investments. Suitable Public Private Partnership

frameworks and arrangements are also being developed for the Build, Operate and Transfer (BOT) of public sector ICT infrastructure. Government is targeting a teledensity of up to 100% by year 2020 (Vision 20:20 20).

1.7.5 Manufacturing

The manufacturing sector has the potential to boost economic growth and stimulate employment generation, wealth creation and poverty eradication. However the sector has not performed as much as expected for a long time. It has low capacity utilization, minimal economic contribution to GDP and low employment share in comparison to other sectors. It contributed only 4 percent of the country's GDP in 2008, due mainly to low capacity utilization (see Figures 1.5 and 1.6).

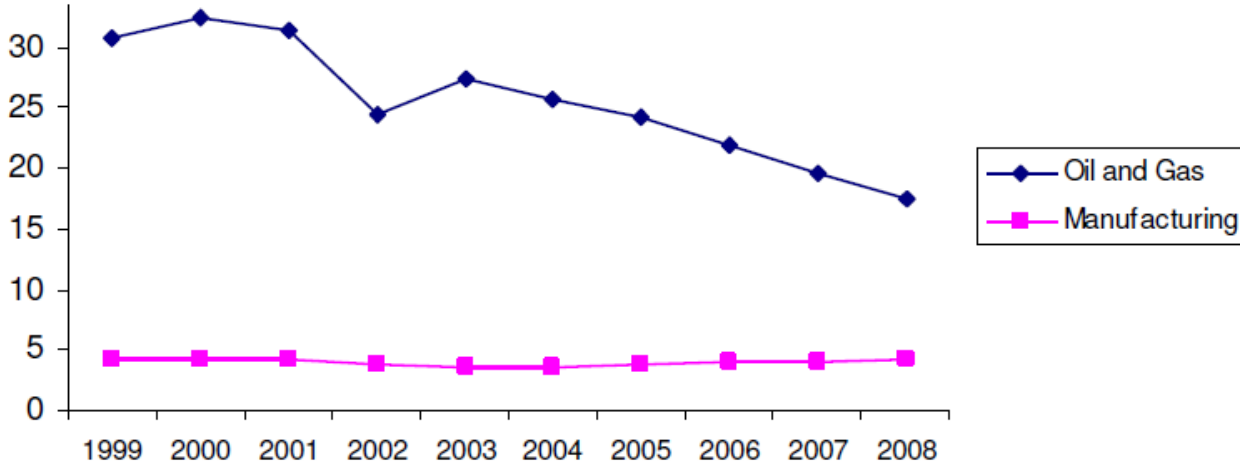


Figure 1.5: Manufacturing versus Oil and Gas – Contribution to GDP (%)

Source: National Bureau of Statistics (2008)

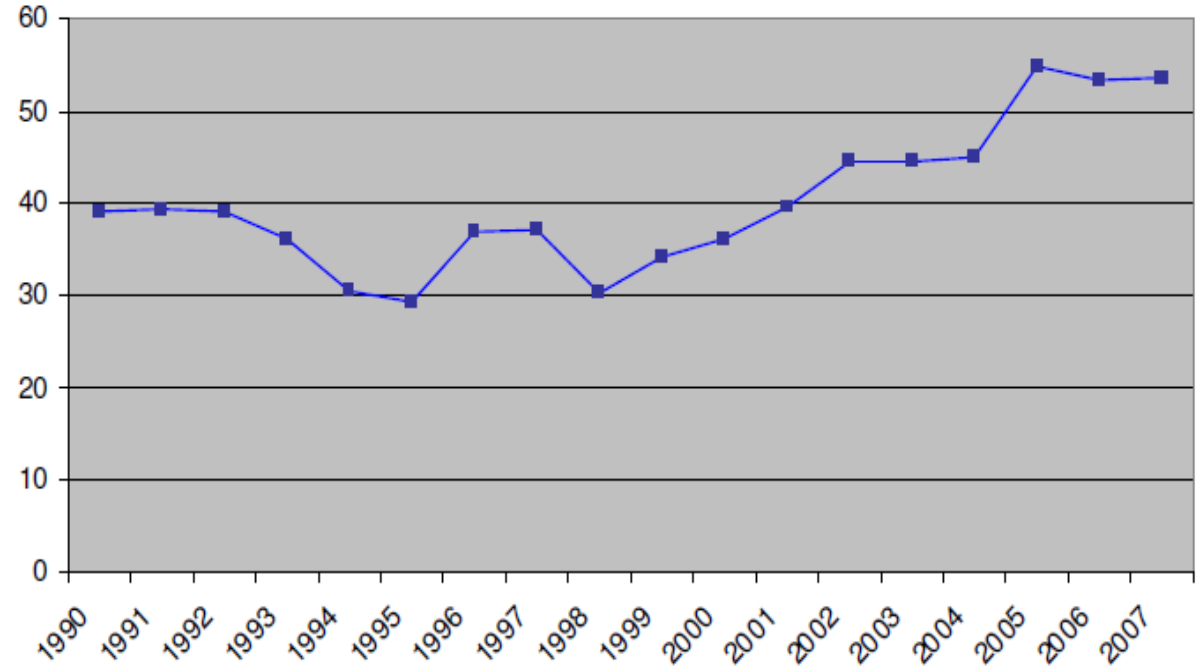


Figure 1.6: Manufacturing Sector Capacity Utilization (%) (*Vision 2020 Technical Report 2009)*

The country's vision for the manufacturing sector is *'a technologically driven and globally competitive manufacturing sector, with a high level of local content and contributing a high proportion of the National GDP'* with a focus of increasing annual growth in manufacturing sector from 8% in 2005 to a minimum of 35.9% on the average annually (Vision 2020 Technical Report on Manufacturing). This will have serious implications for energy use and climate change in the very near future.

1. 7.6 The Energy Sector

1.7.6.1 Energy

Nigeria is endowed with a rich variety of energy resources, the major ones being crude oil, natural gas, coal, tar sand, and biomass (Table 1.1). Nigeria has recorded about 40 years of successful oil exploration and the country consumes a very considerable amount of liquefied petroleum gases, motor spirits, kerosene, diesel oil, fuel oil and gas oil, all of which significantly contribute to climate change problems in particular and environmental problems in general. The bulk (99%) of the natural gas produced is flared while only 1% is consumed in Nigeria.

Table 1.1: Nigeria's Energy Reserves/Capacity as at December 2005

Energy Source	Reserves
Crude Oil	36.5billion barrels
Natural Gas	187.44TCF
Tar Sands	30 billion barrels of oil equivalent
Coal & Lignite	Over 4 billion tones
Large Hydropower	11,235 MW
Small Hydropower	3,500MW
Fuel wood	13,071,464 Hectares
Animal Waste	61 million tones/yr.
Crop Residue	83 million tones/yr.
Solar Radiation	3.5 – 7.0 KWh/m2 – day
Wind	2-4m/s at 10m height

Source: Draft National Energy Master plan, Energy Commission of Nigeria, June 2007

In general, the exploitation of petroleum resources in the last four decades has resulted in massive injection of hydrocarbons into the atmosphere as well as considerable environmental problems. This makes the sector an important one in the discussion of GHG-induced climate change, its consequences, and the need for mitigation and adaptation measures in the sector. The country's proven crude oil reserves are more than 20 billion barrels and may reach 40 billion barrels with additional offshore potentials. Gas reserves are about 2.7 billion m^3. The abundance of oil and gas supplies in the country has to a large extent accounted for Nigeria's heavy reliance on energy. In particular, Nigeria consumed about 19 million metric tonnes of oil equivalent of commercial energy in 1990, and the level of consumption has been increasing since this period.

Nigeria has a lot of potential for renewable energy. It has huge potentials for hydroelectric power (HEP) generation, which for many decades dominated the sector. HEP is now responsible for less than a tenth of what is consumed. The annual radiation level in northern Nigeria is about 190 kcal while the level in the south is about 110 kcal. The nation also has potentials for other energy sources. At present, only little of these varieties of energy are tapped and there is a strong dependence on biomass energy, which is contributing significantly to deforestation. Within the framework of discussions on climate change, its impacts and mitigation these renewable resources are very important and would need to be encouraged for effective national development.

The production of energy in Nigeria is characterized by inefficiency and inadequacy. Nigeria possesses one of the least energy-efficient economies in the world with energy consumption per capita at 138 kg of oil equivalent with an energy intensity of 0.476 in 1990. Gas flaring and inefficient energy use play significant roles in Nigeria's GHG emissions. Growing population and expanding economic challenges are making the sector less and less adequate. Far less of what is required is being produced. More energy comes from thermal plants fired by gas. Private production of electricity with diesel- and petrol operated generators has become a common practice to augment, sometimes to substitute the supply from the national grid. This is usually at a substantially higher cost per unit. The poor access to reasonably priced electricity is a key factor of low standard of living in the country.

Despite the large reserves of energy resources available in the country, the levels of energy consumption have been very low relative to other countries with comparable energy resources and population figures. In 2004, about 776.9 kgoe of energy per capita (population of 140million) were consumed as against about 2596.9kgoe of energy per capita consumed by South Africa (population of 44million). This low energy consumption is caused by the recurrent scarcity of petroleum products and the persistent electricity black outs, which have resulted in a high reliance on self, generated electricity. Figure 1.10 shows Nigeria's energy per capita in comparison with some select developing countries. Nigeria is currently ranked 62 out of 75 countries on the IEA's Energy Development Index (EDI). EDI is a simple composite measure of a country's progress in its transition to modern fuels and of the degree of maturity of its energy end-use. Nigeria's EDI ranking highlights the country's low per capita commercial energy consumption and the low percentage of the population with access to electricity (Vision 2020 Technical Report on Energy, 2009).

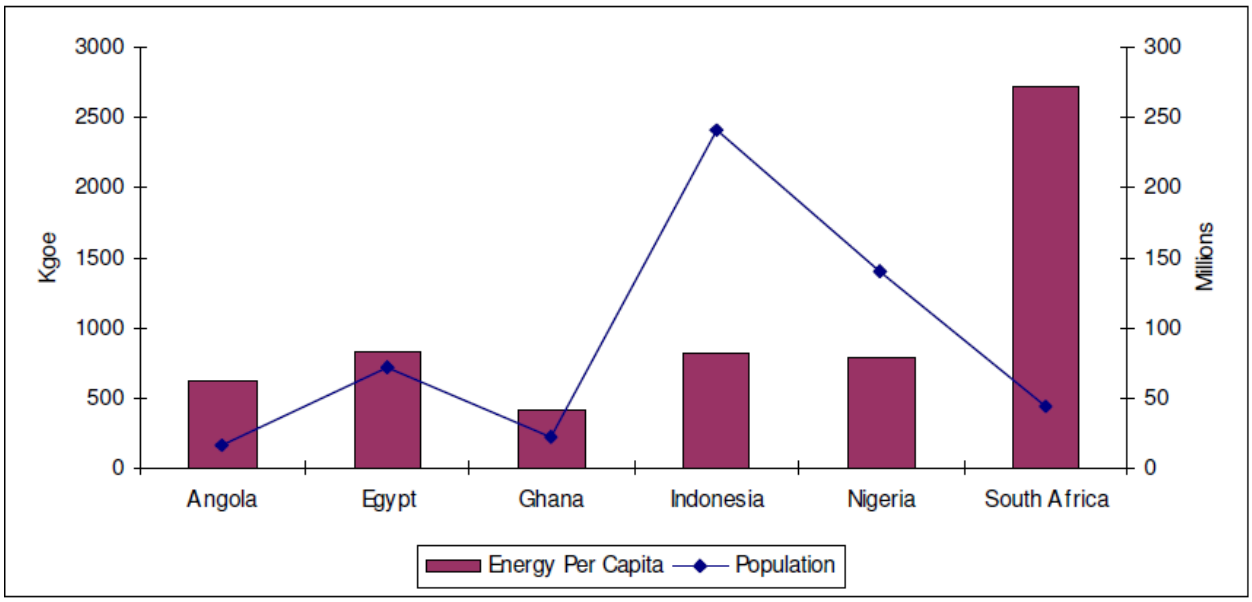


Figure 1.7: Comparison of Energy per Capita for Select Countries, 2004 (Vision 2020 Technical Report on Energy)

1.7.6.1.1 Energy Demand and Supply

By 2005, Nigeria's energy consumption mix was dominated by oil (53%), followed by natural gas (39%) and hydroelectricity (7%) as shown in Figure 1.11. Coal, nuclear and other renewables are currently not part of Nigeria's energy consumption mix, with the exception of biomass often used to meet rural heating and cooking needs.

As at 2005, it was estimated that households accounted for about 50% of the energy demand in Nigeria while the industrial and transportation sectors accounted for 30% and15% respectively (see Table 1.2). As the economy of the country grows, and the country gets more industrialized, it is expected that the industrial sector will account for a larger percentage of the energy demand (Vision 2020 Technical Report on Energy, 2009).

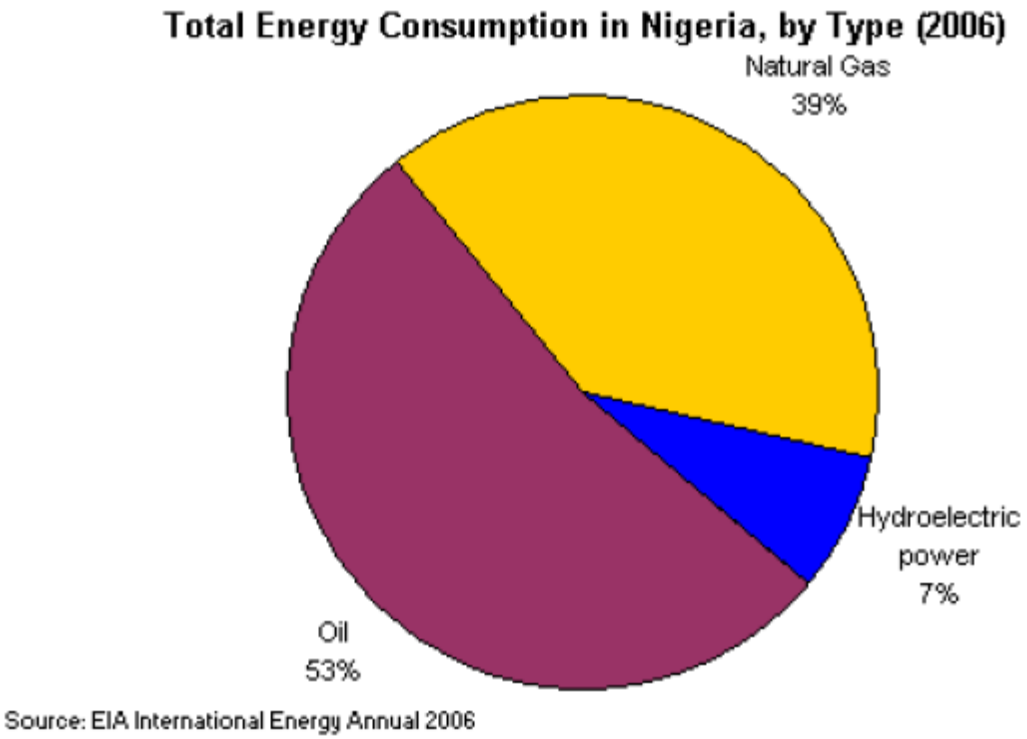


Figure 1.8: Total Energy Consumption in Nigeria, by type (2006) – Vision 20:2020 Technical Report on Energy

Table 1.2: Energy Demand in Economic Sectors in Nigeria (Vision 2020 Report on Energy)

	Sector Energy Consumption (PJ)							
Years	Agric.	Industry	Transport	Commercial	Residential	Total	% Annual Growth	% Renewable(1)
1990	7.13	240.48	287.34	6.99	735.70	1,277.64		64.19
1991	7.18	248.67	260.07	6.48	717.30	1,239.70	-3.0	68.23
1992	7.56	247.30	354.41	6.40	770.19	1,385.86	11.8	62.96
1993	7.60	258.96	342.35	6.96	790.92	1,406.79	1.5	63.99
1994	5.54	259.98	246.32	4.63	817.55	1,334.02	-5.2	69.60
1995	5.38	261.75	278.76	7.00	810.18	1,363.07	2.2	70.24
1996	5.71	277.79	241.36	8.01	849.98	1,382.85	1.5	71.42
1997	7.17	311.97	272.58	7.74	918.19	1,517.65	9.7	70.69
1998	6.09	355.75	272.34	8.16	1,002.01	1,644.35	8.3	70.87
1999	6.57	494.64	260.98	7.97	1,074.93	1,845.09	12.2	68.61
2000	8.65	466.94	357.21	7.19	1,163.10	2,003.18	8.6	68.64
2001	7.58	609.64	404.55	8.91	1,274.81	2,305.49	15.1	64.78
2002	8.04	683.79	414.95	8.54	1,373.13	2,488.44	7.9	65.20
2003	6.34	702.88	402.67	9.87	1,462.67	2,584.43	3.9	68.19
2004	3.28	771.88	350.39	9.70	1,571.23	2,706.49	4.7	70.73
2005	5.05	868.16	486.34	10.35	1,758.40	3,128.30	15.1	66.47

1. 7.6. 2 Fuel wood

Fuel wood i.e. charcoal and firewood is the dominant source of domestic energy both in the rural and urban areas of the country (Eleri, 2006). The main factor remains its cheapness compared with other sources. However, fuel wood extraction has seriously damaging effect on the plant cover of the country. It is the main cause of deforestation particularly in the middle belt of the country (Adesina, 2001). Nigeria has the highest rate of deforestation in Africa and loss of primary forest in the world (FAO, 2005). Over 25,000 ha of the gazetted forest are being lost to de-reservation annually (Oyebo, 2006). Furthermore, smoke from traditional biomass stoves causes close to 100,000 deaths in the country annually (WHO 2010). Other sources of energy have to be expanded to make them affordable costs if the dangerous damages to health, and vegetation resources of the country would be put under control.

1.7.7 Wetlands

Wetlands are "areas of marsh, fen, peat land or water, … with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres" (Ramsar Convention 1975). They support rural livelihoods as bases for crop production, grazing animals, fishing, and harvesting of medicinal plants among others. The *fadama* projects have hung on their potentials. Wetlands are also important for biodiversity promotion. Nigeria presently has 11 sites designated as Wetlands of international importance, with a surface area of 1,076,728 hectares. These are shown in Table 1.3.

Table 1.3: Wet lands declared as Ramsar Sites in Nigeria

S/N	SITE	DATE OF DECLARATION	LOCATION	SIZE
1	Apoi Creek Forests	30/04/08	Bayelsa	NA
2	Baturiya Wetland	30/04/08	Kano	NA
3	Dagona Sanctuary Lake	30/04/08	Yobe	344 ha
4	Foge Islands	30/04/08	Kebbi	NA
5	Lake Chad Wetlands	30/04/08	Borno	NA
6	Lower Kaduna-Middle Niger Floodplain	30/04/08	Kwara	NA
7	Maladumba Lake	30/04/08	Bauchi	1,860 ha
8	Nguru Lake (and Marma Channel)	02/10/00	Jigawa	NA
9	Oguta Lake	30/04/08	Imo	572 ha
10	Pandam and Wase Lakes	30/04/08	Nasarawa	19.742 ha
11	Upper Orashi Forests	30/04/08	Rivers State	25,165 ha

1. 8 Environmental Challenges

The main environmental challenges in Nigeria are land degradation, environmental pollution, floods and erosion. Land degradation is resulting from many factors including

pressure on the land resources, which lead to deforestation or de-vegetation and badland. Environmental pollution is a serious challenge especially around the major urban areas.

1.8.1 Climate Change

Accelerated climatic changes are expected to lead to potentially large impacts across Africa, including Nigeria, in the future. The scale of climate change will increase with high anthropogenic emissions, greenhouse gas (GHG) concentration, and average global temperature. Climate models suggest that Africa's climate will generally become more variable, with high levels of uncertainty regarding climate projections in the Africa Sahel zone. Temperatures in West Africa, and particularly the Sahel, have increased more sharply than the global trend, and the average predicted rise in temperature between 1980/99 and 2080/99 is between 3°C and 4°C, which is more than 1.5 times the average global trend. For Nigeria, sea level rise of 1m could result in loss of 75% of the Niger Delta.

1.8.2 Deforestation

Deforestation is a significant environmental issue in Nigeria. The factors of deforestation are growing demand for land for various purposes including settlement development, logging, fuel wood extraction, transport facility development and mining. Virtually all of the forests in the country may have now disappeared due in part to the mismanagement of the country's natural areas. In the 1980s, about 400 hectares of forest and woodland out of every 1000 hectares suffered from deforestation while only 26 hectares were reforested on an annual basis (UNDP Nigeria, 1996). According to Food and Agricultural Organization (FAO), the remaining forest areas in Nigeria will likely disappear by 2020 if the current rate of forest depletion continues unabated. To protect natural areas for ecological purposes, efforts need to be made to intensify forest reserve efforts, encourage the use of alternatives to wood and continue to sensitize the communities on the need to protect the forests.

Desertification is also a key environmental challenge in the northern parts of the country. The problem of drought and desertification is so acute that between 1976/78 and 1993/95 desert conditions may have moved southwards from 12º30' to 10º30' (Hewawasam *et al*, 2003). The main impacts of drought and desertification are loss of biodiversity, loss of land cover and depletion of water resources. Drought and desertification thus affect the socio-economic development of the affected areas. Persistent droughts, in particular, may result in failure of crops and death of livestock, and bring about famine. Drought and desertification-induced changes in population dynamics may include increased migration from rural areas into the urban centres. This leads to greater pressure on the existing urban infrastructure. In reducing the spread and depth of desertification, sustainable use of land has to be put in place. The programmes on shelter belt development should be sustained to improve vegetation cover in the desert-prone areas.

1.8.3 Floods

Floods in the last couple of decades have become more frequent in every part of the country. Generally, floods result from heavy and high intensity rainfall. However, poor watershed management, unplanned rapid urbanization, blockage of river/drainage channels through careless waste disposal and poor land use practices, land clearing for agricultural

purposes, poor dam construction and deforestation among other factor also influence the occurrence and severity of flooding. The most flood-prone areas in the country include:

- Low-lying coastal areas of southern Nigeria such as Calabar, Warri, Port-Harcourt and Lagos where annual rainfall is quite heavy. The adverse impacts of flooding are felt more when stormy weather coincides with high tides.
- The floodplains of the major rivers such as the Niger, Benue, Gongola, Sokoto, Hadejia, Katsina-Ala, Donga, Kaduna, Gurara, Ogun and Anambra.
- The flat, low-lying areas around and to the South of Lake Chad which may be flooded during and even a few weeks after the rains.

1.8.4 Environmental Pollution

Environmental pollution is increasing due to large human population concentrations, industrial activities, agricultural change, use of new technologies, increase in recycling of items particularly metal and consumer products, and, poor institutional, logistic and policy framework for managing pollutants. Air pollution is influenced by many factors particularly industrial activities and use of spent automobile engines. Water pollution occurs from many sources including the deposition of household and industrial effluents as well as petroleum products through oil spills into water bodies and streams. Some spills are caused by vandalization of oil pipes, which has escalated with the heightening of crisis in the Niger Delta. The use of fertilizers and other farm inputs are also factors of soil and water pollution in many parts of the country.

1.8.5 Wastes

The burden of waste management is growing everywhere particularly in the urban areas. The total amount of domestic waste per annum in Nigeria is about 63million tonnes (0.45kg/capital/annum), which must be increasing (Osibanjo, 2008). The volume of solid wastes has been overwhelming particularly around the major cities. The problem is largely with collection and disposal. Waste is indiscriminately disposed in many areas, and solid waste dumps dot the urban landscape in many parts of the country. Usually only about 30-50% of waste in Nigeria is collected (Osibanjo, 2008), leaving so much unattended to. There are generally inadequate frameworks for refuse collection and management in many parts of the country.

1.9 Economic challenges

The Nigerian economy continues to be dominated by the oil sector which fetches more than 90% of the foreign exchange for the country. The impact of the sector is however little felt by the vast majority of the people. The agricultural sector which once occupied a dominant position has been forced to a poor second position and Nigeria now imports a substantial proportion of its food. For instance, more than 50% of rice consumed is imported from Thailand (Ezedinma 2004). Most people are consequently poor. Linkages between various sectors of the economy are weak and unemployment and underemployment are high. For example the poor development of the nations' energy sector is keeping large industrial establishments in the Lagos, Kaduna and Kano axis out of business. The critical economic issues concern the need to foster sustainable rapid economic growth that will cater for the needs of over 140 million people and the imperative for proper integration of its domestic economy with the world economy.

1.10. Socio-Political challenges

Viable and stable democracies have never evolved overnight; it takes considerable number of decades to mature. Also, democracies never thrive in a situation where it is periodically truncated or terminated on the pretext that political actors are not getting things right or performing to expectation. Thus, the main political challenge in the country is to advance democracy in a way that is dynamic, peaceful and sustainable, leaving behind the challenges of the old.

1. 11. Conclusion

Although the Nigeria's environment is richly endowed, it is passing through a series of changes that need to be properly managed for sustainability. More than any other thing, there is a need to put firm checks on the use of resources particularly land to prevent imminent land crisis especially for agriculture. The population is growing at very fast with concomitant demand for resources in the environment. These have implications on the physical environment. It is important that the country addresses all of these to assist it in the fulfilment of its commitment under the United Nations Framework Convention on Climate Change (UNFCCC).

CHAPTER TWO

NATIONAL GREENHOUSE GAS INVENTORY

2.1 Introduction

Since the submission of the First National Communication in 2003, Nigeria has updated its national GHG inventory. The procedure involved the use of the default methodology of the "Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories" (IPCC, 1996) and the "Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories" (IPCC, 2000). In this approach, the emission (E) of greenhouse gases from any activity (A) was represented by the relation:

$$E_i = \sum_j \sum_k A_k * F_{kj} \qquad \text{Equation 2.1}$$

where F is the emission factor or emissions per unit of activity (A), j - summation over identified economic sectors contributing to the emission of each GHG or its precursor i; k - the summation over specific processes or technology types within each major economic sector. In this regard, the total GHG or precursor gas was obtained by summing each GHG or precursor across sectors and processes.

In order to obtain solutions to Equation 2.1, all processes leading to the emission of a GHG or its precursor gas were identified. The activity data (A) were obtained mostly from national data sources, while most of the emission factors (F) data were extracted from the

IPCC (1996) default emission factor database. The remaining figures were obtained from national measurements and from literature review. The national emissions were obtained by using the accompanying software of the IPCC WGI guidelines for national GHG. GHG emissions in the industry sector were only emissions due to industrial processes. All calculations used the recommended Global Warming Potential (GWP) of GHGs.

The inventory covers all of the major sectors presented by IPCC (1996) with the exception of Solvents and Other Products Use, which was not available electronically from the downloaded software. Emissions of GHG in the energy, industrial processes, agriculture, land use change and forestry, and wastes have been estimated and the production and consumption of energy under different sectors evaluated with data from national and international sources. Based on these and emission factors mainly drawn from default IPCC emission factors database supported with some national estimates where available, the estimates of gross national emissions from the different energy production and consumption activities were derived.

Activity data for the national GHG inventory was compiled from published data by the Nigerian National Petroleum Corporation (NNPC), National Bureau of Statistics (NBS) and Central Bank of Nigeria (CBN). Other sources of data included the IPCC reports, EPA AP-42 and OECD/IEA (1991, 1994) reports, as well as journal articles (Obioh et al., 2004). The majority of emission factors used is default values taken from the Revised 1996 IPCC Guidelines.

Estimates have been made for the base year 2000 with sectors, as sources of GHG emissions, categorized according to their percentage contributions to the national GHG inventory. Sectoral (bottom-up) approach has been used to estimate the GHG emissions and removals from (i) energy; (ii) industrial processes; (iii) agriculture; (iv) land use, land-use change and forestry (LULUCF); (v) waste; and (vi) solvent and other product use sectors.

Furthermore, GHG emissions from bunker fuels are estimated and reported as a memo item (these emissions are not included in the national total). In addition to the sectoral approach, the reference approach has also been used for the estimation of CO_2 emissions from the overall fuel consumption figures for the time series of 1988-2000.

The direct GHGs whose emissions have been estimated in this national inventory are (a) Carbon dioxide (CO_2); (b) Methane (CH_4); and (c) Nitrous oxide (N_2O). Although emissions of Oxides of nitrogen (NOx), Carbon monoxide (CO), Non-methane volatile organic compounds (NMVOC) and Sulphur dioxide (SO_2), as indirect GHGs, have also been made and reported in the national inventory, they are not included within the country's aggregate emissions because they have not been allocated global warming potentials.

2.2 Elements of the national GHG emission inventory for year 2000

Figure 2.1 presents Nigeria's direct GHG emissions by gas type for the year 2000, while Table 2.2 present the country's total direct GHG emissions by sector for the same year. In the year 2000, Nigeria contributed about 214.21 million tonnes (Mt) of CO_2 equivalent (CO_2e) of GHG to the atmosphere. The corresponding figures for CH_4 and N_2O were 96.76 and 7.10 million tonnes respectively (Fig. 2.1). As expected, the energy sector (fuel combustion and fugitive emissions) contributed the largest proportion (70%) to direct GHG emissions in Nigeria in

year 2000. This is followed by agriculture (27%), with very minimal contributions from waste and industrial processes[1] (Table 2.2).

Figure 2.1 present Nigeria's total GHG emissions by gas type (e.g. CO_2, CH_4 and N_2O);.' and sector respectively for the year 2000.

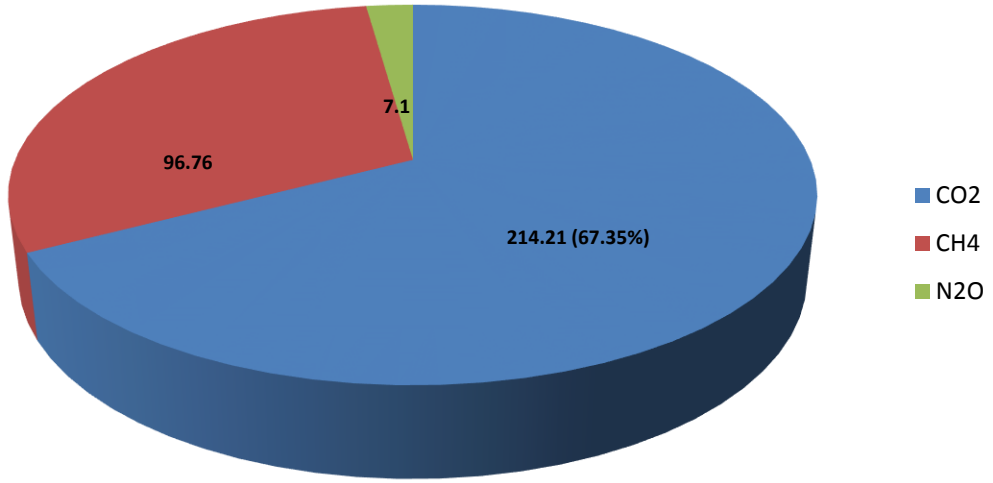


Fig. 2.1a: Nigeria's GHG emissions by gas type for the year 2000

Table 2.1 Nigeria's GHG emissions by sector for the year 2000

Sector	**Emissions ($MtCO_2e$)**	**Emissions (%)**
Energy:		
• Fuel Combustion	133.01	60.32
• Fugitive Fuel Emissions	22.33	10.13
Agriculture	60.69	27.52
Industrial Processes	2.10	0.95
Waste	2.38	1.08
TOTAL	**220.51**	**100**

The summary of Nigeria's direct (CO_2, CH_4 and N_2O) and indirect (NOx, CO, NMVOC and SO_2) GHG emissions for all sectors in year 2000 are presented in Table 2.3.

Table 2.2: Nigeria's GHG Emissions Summary (by sectors) for the Year 2000 (Gg)

Country: Nigeria							
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 Emissions	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Total National Emissions and	**214,210**	**4,207**	**24**	**1,009**	**22,435**	**1,847**	**190**

[1] A further indication of the weak industrial capacity utilization that was earlier discussed.

Removals								
Energy	Reference Approach[1]	**123,257**						
	Sectoral Approach[1]	**114,724**	**1,650**	**9**	**658**	**18,387**	**1,834**	**176**
A Fuel Combustion		114,724	679	9	620	13,635	1,753	
B Fugitive Emissions from Fuels		0	971		37	4,752	81	7
Industrial Processes		**2,101**	**0**	**0**	**0**	**2**	**14**	**14**
Solvent and Other Product Use		**0**		**0**			**0**	
Agriculture			**2,510**	**10**	**348**	**3,975**		
Land-Use Change & Forestry	**(2)**	**97,385**	**8**	**0**	**3**	**70**		
Waste			**39**	**5**				
Other (please specify)		**0**	**0**	**0**	**0**	**0**	**0**	**0**
Memo Items:								
International Bunkers		**801**	**0**	**0**	**24**	**8**	**3**	**0**
Aviation		189	0	0	12	8	3	0
Marine		612	0	0	12	0	0	0
CO_2 Emissions from Biomass		**74,265**						

Table 2.4 shows the change of sectors' contribution to Nigeria's total inventory. It is clear that the total GHG emissions of Nigeria increased in year 2000 to be 135% of that in 1990, a clear indication of significant increases in the socio-economic activities in the country.

Table 2.3 Changes in contributions to the GHG inventory of different sectors

Sector	**Emissions ($MtCO_2e$) for 1990 and 2000**				**% of 2000 emissions relative to those of 1990**
	1990		**2000**		
	$MtCO_2e$	**% of Total**	**$MtCO_2e$**	**% of Total**	
Energy (Fuel Combustion and Fugitive emissions	119.83	73.11	155.34	70.45	130
Industrial Processes	2.17	1.32	2.10	0.95	97
Agriculture	39.26	23.95	60.69	27.52	155
Waste	2.65	1.62	2.38	1.08	90
TOTAL	**163.91**	**100**	**220.51**	**100**	**135**

2.3 Greenhouse Gas Emissions by Sector

2.3.1 Energy

Energy-related activities have the dominant share of GHG emissions in Nigeria. Emissions from this sector are classified into two main categories: (i) emissions from fuel combustion, and (ii) non-combustion (fugitive) emissions.

As indicated in Table 2.3, the total emissions from the energy sector were 155.34 $MtCO_2e$, representing 70.4% of the country's total GHG emission in the year 2000. Carbon dioxide was the largest contributor (114.72 $MtCO_2e$) at a percentage of 74% of the total energy sector emissions (Table 2.3).

The energy sector contributed 53.6% of the total CO_2 emissions of the country, 39.2% of the CH_4 emissions, 37.5% of the N_2O emissions, 99.3% of the NMVOCs emissions, 65.2% of NOx emissions, 82.0% of CO emissions 92.6% of the total emissions of SO_2 in the year 2000.

The largest contributor to emissions in the energy sector is the gas flaring sub-sector, which accounted for 40.3% of the energy emissions, followed by the transport sector, which accounted for 18.4% of the energy emissions. Following in order of importance are the CRAFF and manufacturing and construction sub-sectors, which accounted for 13.6% and 12.6% of the energy emissions respectively. Ironically, the energy industries accounted for only 8.5% of the total energy emissions, a reflection of Nigeria's poor investment in the sub-sector. Table 2.5 depicts the emissions of the energy sub-sectors and their shares to the total energy emissions and the total national GHG emissions.

Table 2.4 GHG emissions of the energy subsector for the year 2000

Energy sub-sector	**GHG emission (Gg CO_2 eq.)**	**Percentage of total energy emissions**	**Percentage of total national emissions**
Energy industries	11,970	8.5	5.5
Manufacturing and construction	17,579	12.6	8.2
Transport	25,752	18.4	12.1
Commercial, residential, agriculture, forestry and fishing (CRAFF) activities	19,120	13.6	2.6
Gas flaring	56,570	40.3	24.0
Petroleum refining	2,962	2.1	1.3
Fugitive process	6,162	4.4	0.1

2.3.2 Industrial Processes

This sector comprises emissions from industrial processes where GHGs are by-products of those processes. They account for emissions generated from non-energy related activities. In general, this sector generates negligible emissions of GHG in the country. In fact, only the mineral production that include mainly cement production and limestone show evidence of any measurable contribution.

In the year 2000, emissions from industrial processes sector was 2131 Gg CO_2e, which is just 0.8 percent of Nigeria's total GHG emissions. These CO_2 emissions came mainly from

cement production (1375 Gg CO_2). This sector generated significant emissions of NOx, CO, NMVOC and SO_2.

2.3.3 Solvents and Other Products Use

In the year 2000, paucity of data limited our estimation of emissions from the use of solvents and other products containing volatile compounds.

2.3.4 Agriculture

Emissions from all anthropogenic activities within the agriculture sector were estimated from (i) enteric fermentation, (ii) manure management, (iii) rice cultivation, (iv) agricultural soils, (v) savannah burning, (vi) burning of agricultural residues; and (vii) other, using the 1996 Revised IPCC Guidelines.

The GHG emissions of the agriculture activities were 6843 Gg CO_2 in the year 2000. These emissions are composed mainly of CH_4, CO and NOx. Enteric fermentation and rice cultivation constitute the critical sources for CH_4, while all the NOx and CO emissions came from the burning of savannah and agricultural residues.

2.3.5 Land Use Change and Forestry (LUCF)

The GHG emission/removals for the year 2000 were calculated for the Land Use Change and Forestry sector (LUCF), using (i) changes in forest and other woody biomass stock, (ii) forest and grassland conversion, (iii) abandonment of managed lands, (iv) carbon dioxide emissions and removals from soil, and (v) other as subsectors.

The land-use change and forestry sector was a high net source of CO_2. This is contrary to what is expected. The emissions were estimated to be 97,384 Gg of CO_2 at 40% of the country's total GHG emissions in the year 2000 (Table 2.3). The net CO_2 emissions for the LUCF sector were derived mostly (97%) from changes in forest and other woody biomass stock, an indication of high rate of deforestation in the country.

2.3.6 Waste

The sub-sectors of solid waste disposal on land, wastewater handling and waste incineration sub-sectors were used to estimate GHG emissions from the waste sector. The result indicated that waste contributed an insignificant proportion of GHG emissions in Nigeria in 2000. Only 39 Gg of CH_4 and 5 Gg of N_2O (all from wastewater handling) were emitted.

2.5 Trends in GHG Emissions in Nigeria (1988 – 2000)

Table S- 1: SUMMARY OF ANNUAL GHG AND PRECURSOR GASES EMISSION TRENDS: 1988 - 2000

Year	*GHG AND PRECURSOR GASES EMISSIONS (Gg)*						
	CO_2	*CH_4*	*N_2O*	*NO_x*	*CO*	*NMVOC*	*SO_2*
1988	147039	2070	20.6	705	18150	1213	154.1
1989	154878	2201	21.0	720	18537	1257	157.8
1990	154772	2959	21.0	701	18967	1362	158.7
1991	155473	1987	21.3	730	19002	1394	164.5

1992	167407	2249	21.4	780	19769	1467	170.0
1993	170143	2829	21.6	786	19868	1419	171.2
1994	182686	2939	21.9	906	20736	1591	169.1
1995	174568	3031	22.2	791	20053	1383	162.0
1996	190761	3006	22.6	919	20965	1581	175.0
1997	191694	3062	22.9	900	21435	1661	183.7
1998	187306	3115	23.1	883	21158	1648	168.9
1999	197388	3283	23.4	902	21552	1682	181.5
2000	214210	4207	24.0	1009	22435	1847	190.3

Table 2.6. Trend of GHG Emissions in Nigeria (1988-2000)

Table S- 2: Trends in Percentage Annual Growth Rate in Emissions with Respect to Previous Year's Emissions

		ANNUAL EMISSIONS GROWTH RATE (%)					
Year	*CO_2*	*CH_4*	*N_2O*	*NO_x*	*CO*	*NMVOC*	*SO_2*
1988	-	-	-	-	-	-	-
1989	5.3	6.3	1.8	2.1	2.1	3.6	2.4
1990	-0.1	34.4	0.0	-2.6	2.3	8.4	0.6
1991	0.5	-32.9	1.5	4.1	0.2	2.3	3.7
1992	7.7	13.2	0.4	6.8	4.0	5.3	3.3
1993	1.6	25.8	1.1	0.7	0.5	-3.3	0.7
1994	7.4	3.9	1.5	15.3	4.4	12.1	-1.2
1995	-4.4	3.1	1.4	-12.7	-3.3	-13.1	-4.2
1996	9.3	-0.8	1.8	16.1	4.5	14.3	8.1
1997	0.5	1.9	1.0	-2.1	2.2	5.1	4.9
1998	-2.3	1.7	1.2	-1.8	-1.3	-0.8	-8.0
1999	5.4	5.4	1.3	2.1	1.9	2.0	7.4
2000	8.5	28.1	2.6	11.8	4.1	9.9	4.8
MEAN	3.3	7.5	1.3	3.3	1.8	3.8	1.9

Using the IPCC (2001) data on global warming potentials over a 100 averaging period, the CO_2 equivalent emissions for the period 1988 – 2000 were computed as shown in Table 2. 6.

The gross CO_2 equivalent emissions per annum ranged from 200 (1988) to 318 (2000) $TgCo_2$-e. The most prominent GHG is CO_2 whose contributions ranged from 147 (1988) to 214 (2000) $TgCo_2$-e while N_2O contributions were the least prominent (6.7 to 7.1 $TgCo_2$-e).

The percentage contribution of the three GHGs to gross CO_2 equivalent emissions is presented in Figure 2.7. The contribution of CO_2 was about 71% of the gross CO_2-e during the period under review, while the contribution of CH_4 accounted for 26% and N_2O contributed less than 3%.

Table 2. 6: Trends in CO2 Equivalent Emissions

	Global Warming Potential (IPCC, 2001)			
YEAR	CO_2	CH_4	N_2O	
	1	23	296	
	CO_2 Equivalent Emissions ($GgCO_2$-e)			
	CO_2	CH_4	N_2O	TOTAL
1988	147,039	47,610	6,097	200,747
1989	154,878	50,623	6,216	211,717
1990	154,772	68,057	6,216	229,045
1991	155,473	45,701	6,304.	207,479
1992	167,407	51,727	6,334	225,468
1993	170,143	65,067	6,394	241,604
1994	182,686	67,597	6,482	256,765
1995	174,568	69,713	6,571	250,852
1996	190,761	69,138	6,690	266,589
1997	191,694	70,426	6,778	268,898
1998	187,306	71,645	6,838	265,788
1999	197,388	75,509	6,926	279,823
2000	214,210	96,761	7,104	318,075
Total	2,288,325	849,574	84,952	3,222,851

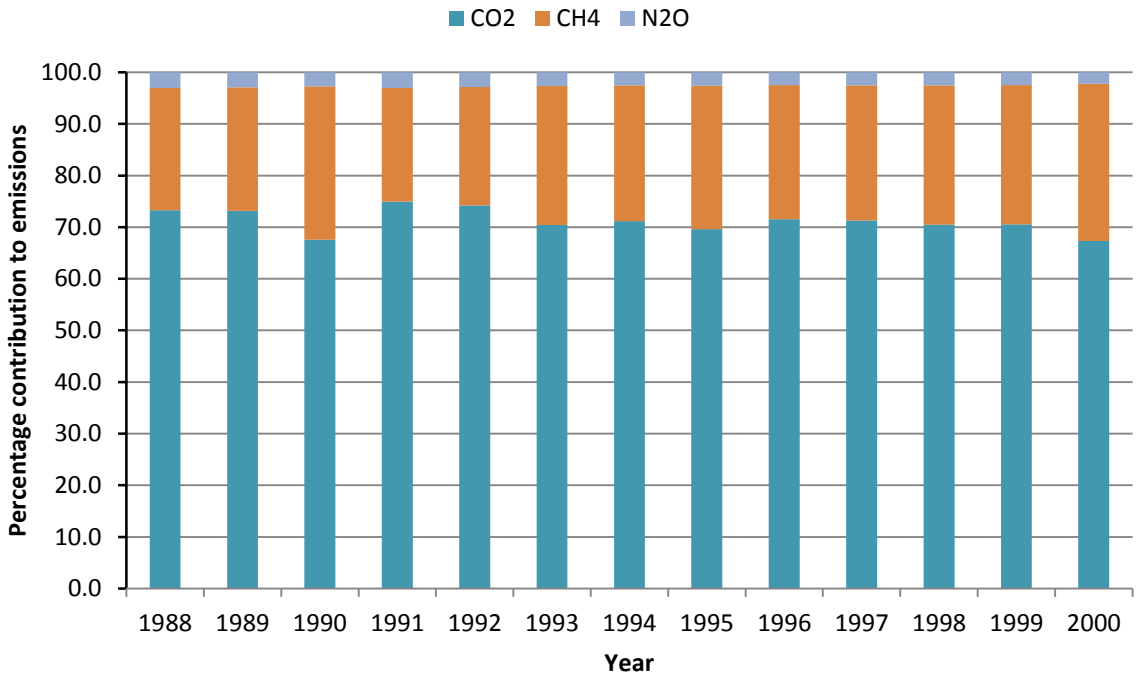


Figure 2.1b: Relative Contributions of each GHG to CO_2 Equivalent Emissions for the Period 1988 to 2000

2.3.7 CONCLUSIONS

Data of the CO_2 and non-CO_2 GHG as well as precursor gases (Table 2.6) indicated that Nigeria's annual emissions were in the range of 147 to 215 $TgCO_2$-e, CH_4 accounted for 48 to 97 $TgCO_2$-e and N_2O ranged from 6 to 7 $TgCO_2$-e f during the period under review. These revealed an annual growth rates of about 1.3% in all GHGs and precursor gases considered. With these results, it therefore becomes imperative that at a minimum, Nigeria may double its current annual emissions in time frames of 30 years if the population growth rates as well as the consumption patterns increased.

The national emissions spread sheet still has substantial uncertainties in emission factor and activities data. It is likely that segmented sub-sector emissions could be obtained if all current data gaps are filled by improved coverage of all activities. This implies that current result may represent lower minima for national emissions.

In conclusion, the energy and land use change sectors contributed highest CO_2-e emissions, while CO_2 contributes more than 70% to gross CO_2 equivalent emissions. Thus, the energy and land use change sector, and the reduction in national emissions for CO_2 should be the first step towards sustainable management of future GHG emissions in Nigeria.

CHAPTER THREE

MEASURES TO MITIAGATE CLIMATE CHANGE

3.1 Introduction

Under the UNFCCC and the Kyoto Protocol (KP), only the Annex 1 Parties whose emissions have continued to increase tremendously over the decades due to their rapid economic growth are required to take measureable actions to reduce their emission of GHGs. The Annex 1 Parties are expected to cut their GHGs emissions by 5% compared to 1990 levels between 2008 and 2012. Countries not included in that group have no quantified emission limitation or reduction commitments for their emissions. However, in recent times there has been a push for developing countries to demonstrate voluntary commitments to cut down their emissions for example as contained in the Bali Action Plan (BAP) of 2007.

Mitigation component of the National Communication provides information about options and action to reduce future GHG emissions in a country without compromising

opportunities for sustainable development. The component is expected to cover major sectors of the economy such as energy, forestry and land use change, industrial activities and waste management.

3.2 Methodology

The methodology employed here is basically to track what Nigeria has put in place or capable of doing to mitigate climate change as required under the Convention. The assessment addresses the main sectors for which emission estimates were made in Chapter 2. The ranking and economic implications of the mitigation options are not provided because of the limited analyses conducted in this aspect. These are expected to be captured in future updates.

3.3 Nigeria's Mitigation efforts

3.3.1 Energy Sector

The Clean Development Mechanism (CDM) under KP to which Nigeria is a signatory has provided ample opportunities for emission reduction from the energy sector in the country. One of these is in the conversion of the natural gas that was once flared in the process of petroleum exploitation into cooking gas. This is running in Kwale oil gas processing plant with an annual emission of reduction of 1,496,934 tCO_2 and the Gas utilization project responsible for 2,626,735 tCO_2. The third project on efficient wood stove is capable of reducing emission by 31,309 tCO_2. These projects are important for a country like Nigeria that is making huge efforts to generate adequate energy for its industrial and domestic purposes. The various CDM projects with their Certified Emission Reductions (CERs) in the country are shown in Table 3.1

Table 3.1: CDM Project With CERs as at October 2009

Name of CDM Project Activity	Type of Project	UN Reg. Date	Annual Emission Reduction (tCO_2/y)
Recovery of associated gas project that would otherwise be flared at Kwale oil gas processing plant	Waste gas/heat utilization	November 9th, 2006	1,496,934
Gas utilization project	Waste gas/heat utilization	Feb 10th 2009	2,626,735
Efficient Fuel Wood Stoves for	Energy efficiency	Oct 12th,	31,309

Nigeria		2009	

A number of CDM projects are at various stages of consideration and are shown in Table 3.2

Table 3.2: Proposed CDM projects

Name of CDM Project Activity	Type of Project	Annual Emission Reduction Potentials (tCO2/y)
Improved cooking stoves for Nigeria programme of activities (PoA)	Energy efficiency	8,912
Distribution of fuel-efficient improved cooking stoves in Nigeria (PoA)	Energy efficiency	46,717
African improved cooking stoves (PoA)	Energy efficiency	15,477
Municipal Solid Waste Composting Project in Ikorodu, Lagos State	Methane recovery & utilization	281,781
Landfill gas (LFG project in Nigeria)	Methane recovery & utilization	129,932
Multi country small scale CDM program of activity for reduction of emission from non-renewable fuel from cooking at household level	Renewable energy	51,385
Lafarge WAPCO partial substitution of alternative fuels in cement facilities project in Nigeria	Cement	166,557
Recovery & Marketing of Gas that would otherwise be flared at the Asuokpa/ Umutu Marginal Field, Nigeria	Waste gas/heat utilization	256,793

Apart from the list, there are other possible projects that can be developed. These include:

- Expansion of solar energy utilization in units such as residences, educational institutions and hospitals. Solar energy can be used for lamps, radio, mobile phones and laptops, as well as cooking including drying of agricultural products such as tomatoes, pepper and corn;
- Using the notoriously spreading invasive species such as water hyacinths (*Eichornia crassipes)* for biofuels; and producing biodiesel from *Jatropha curcas*;

- Popularising the use of energy saving devices such as CFL, LED, automated power switch-offs in homes, offices and hotels, energy efficient cars;
- Use of efficient charcoal cook stoves to reduce emission from biomass burning;
- Improving charcoal production methods to reduce wood wastages typical of traditional methods in the carbonisation process;
- Utilization of Compressed Natural Gas (CNG) as a Transport Fuel;
- Expansion of Bus Rapid Transit System, which is already well tested in Lagos State.

The World Bank identified areas of investment opportunities in the clean energy development sector which can fetch Nigeria over $18 billion if properly exploited. The potential for this sector is huge in the country and it could bring about the reduction of GHGs of about 100 million tonnes of CO_2 equivalent annually.

3.3.2 Forestry and Land Use Sectors

Land use change and forestry sector contributes significantly to the net emissions of GHGs, particularly CO_2, to the atmosphere. One reason is that Nigeria is an agrarian country, which means that a lot of interferences with vegetation and to soil carbon dynamics go on from time to time. But perhaps more importantly is that Land use is changing very rapidly in the country reflecting in extensive deforestation, de-vegetation and expansion of cultural features particularly houses. These are having impacts on GHG on carbon storage in soils and vegetation.

One area in which the government is addressing emissions in this sector is in its forestry programmes both to meet growing demand for wood and enhancing the vegetation cover with all the attendant benefits. For instance, as shown in Chapter 1, fuel wood is still the most dominant source of domestic energy and a land area of 6,717.2 kha is estimated would be needed to meet the demands over the next 40-year period. There is also additional need for the balance of wood supply for poles, pulpwood, sawn logs and veneer.

Tree cultivation in forestry is an indisputable efficient mechanism for carbon sequestration. Although fuel wood production eventually releases carbon into the atmosphere once wood is harvested and used, other longer lasting wood products such as sawn logs and veneer can store away carbon for as long as they are used for their special purposes. For instance, a piece of sawnlog could be on a roof for many decades. Governments' effort at increasing tree cover in the various parts of the country including the different shelter-belt projects, must continue as a strategy both to meet the growing wood needs of the country and sequester carbon from the atmosphere.

Three forestry practices are commonly pursued by forestry agencies in the country. These are afforestation, agroforestry and forest protection. Afforestation is a practice in which selected tree species are planted for creating or recreating forest cover. Some of the most commonly grown species are *Gmelina arborea* and *Tectona grand*is. In Agro forestry woody perennials with desirable properties are deliberately integrated with crops and/or animals on the same parcel of land to produce multiple benefits. *Forest Protection* emphasises the preservation of biodiversity usually in gazetted reserves around the country. All these three methods are being used as appropriate in the various parts of the country. Beyond these nevertheless, urban and peri-urban forestry need to be re-engaged by governments at the State and Local Government levels. The greening of urban areas has great potentials for increasing tree presence apart from supporting vital arboreal wildlife (Adesina 2008).

3.3.3 Mitigation in the Agricultural Sector

The agricultural sector is a significant contributor of anthropogenic GHGs. Among others, the sector plays an important role in the oxidation of biomass, organic matter and the combustion of fossil fuels in the automation of agricultural activities. N_2O is produced by the denitrification of nitrogen compounds in soils, fertilizer, and manure, and by biomass burning (Lal et al. 1998). CH_4 is a by-product of ruminant animal digestion, manure storage systems, rice cultivation, biomass burning, and the anaerobic breakdown of soil organic matter. Both CH_4 and N_2O are far more potent as GHGs than CO_2 based on their Global Warming Potentials (GWP).

Soils contain high levels of soil organic matter (soil carbon) and agricultural practices release CO_2 from the breakdown of the soil organic matter. Thus, with suitable agricultural management practices such as zero- or minimum-tillage, improved fallows, crop rotation and retention of residues on the soil surface, soils can be enhanced to replenish their lost organic matter. That is, they can be managed to become effective CO_2 'sinks'. Oladele and Braimoh (2013) in a review and analysis of soils across Africa have shown that differences in soil management practices produce large differentials in carbon sequestration. For instance, improved fallows are shown to be able to sequester 2,413 Kg C ha^{-1} compared with the use of residues which can only sequesters on the average about half of this (1,266 Kg C ha^{-1}). In view of the foregoing using appropriate agricultural management practices is a good mitigation option in the agricultural sector.

3.3.3.1 Mitigation Options for Rice Cultivation

Most of the rice consumed in the country comes in as imports. Governments have been concerned to reduce the dependency on imports through programmes to accelerate local production of the commodity. Apart from providing improved seeds such as the NERICA, good land management in upland rice cultivation promises to reduce emission from rice production. Some of the practices that are being encouraged include

- Improvement in nutrient management including the retention of rice residues
- Improved water management in irrigation projects
- Use of organic fertilizers to boost soil fertility
- Improved cultivation practices while maintaining the productivity of rice fields

3.3.3.2 Mitigation options to control emission from livestock

The raising of livestock is a key source of GHGs particularly CH_4. According to FAO, about 7,516 million tons of CO_2e per year is attributable to livestock production, an amount established by adding up GHG emissions involved in clearing land to graze livestock and grow feed, keeping livestock alive, and processing and transporting the end products. In Nigeria, the population of livestock has increased tremendously. For instance poultry production especially around the urban areas has become important sources of income to many. Some of the proven options for reducing methane emissions from livestock are:

- Increasing animal production efficiency through proper veterinary care, sanitation, ventilation, nutrition and animal comfort;
- Provision of modern abattoirs to keep slaughtering processes clean and hygienic;
- Encouragement of production of moths and other insects to reduce consumption and demand for livestock products;

- Improved production of mushrooms as substitute for meat;
- Focus on small stocks like snails and fish which give animal protein but produce lower emissions compared with big livestock.

3.3.4. Mitigating in the Savannas and Rangelands

The management of the savannah and rangelands is an important part of mitigation efforts in Nigeria. The greatest challenge is dry season bush fire which is used by herdsmen to provide fresh fodder for their animals. It is also used to prepare farmland for new round of cultivation as well as chase games out for hunting. The burning of the savannah releases considerable carbon every year and efforts are being made to reduce the incidences and severity of fires. These efforts include

- Massive sensitization on the dangers of bush burning
- Awareness creation on methods to avert bush fires
- Designation of grazing zones where the herdsmen can manipulate fodder production without interference with farmlands

Another option that could be used to increase carbon sequestration in the savannas and rangelands is to enrich rangelands and reduce degradation by afforesting the rangelands. There is a need to provide extension services to assist farmers and herdsmen in the adoption of agro-forestry practices to improve the savannah and rangelands. There should also be increase in research activities into woody species with high quality fodder, high fodder productivity, good wood yield and tolerance of long dry periods.

Emission of GHGs from the savannas and rangelands can also be achieved through the rehabilitation of degraded areas, reduction in livestock numbers, changing the mix of animals, and effective watershed management.

3.3.5 Service Sector

The potentials for climate change mitigation in the service sector of Nigeria are also enormous. When energy efficient and low carbon procedures are adopted in the various service sectors, the economy of the country will be strengthened and the environment more benign. These will in turn strengthen sustainable development processes in the country.

3.4 Financing Climate Change Mitigation

Mitigating climate change impacts in the country requires a huge financial commitment. Unfortunately, the economic situation of the country Nigeria makes it challenging for the government to allocate sufficient funds for climate change programmes. Fortuitously, the country has been able to secure some funds through bilateral and multi-lateral relationships in the international arena to meet some of her obligations under climate change Convention. When a proper cost estimate of climate change response needs for the country is conducted, additional investments needed should be sourced from national, regional and international levels.

At the national level, there is an increasing realization of the need to mainstream climate change into national development. For instance, the Federal Government is devoting part of its national budget to addressing issues in climate change sensitive sectors of the economy. At the regional level, Nigeria is actively involved in the climate change activities especially through ECOWAS and African Union, in part, to source additional and complimentary

financial resources for climate change response. At the international level, funding is being sourced through UNFCCC and other global sources of finance for the environment.

3.5 National Policies on Climate Change Mitigation

The development and implementation of environmental and other policies in Nigeria to support mitigation measures are yet to be fully realized. Most of the existing policies are very broad and are not specifically focused on responding to climate change concerns of the country. While climate change is mentioned in some key government policies, there is yet to be specific policies or strategies for climate change mitigation in the country.

Nigeria's response to climate change threats in the context of policy development framework remains a major challenge. Despite its high dependence on fossil fuel and high vulnerability to climate change, Nigeria is just in the process of putting in place a climate change policy or a response strategy that could address the issues of mitigation measures and financial requirements and mobilization. The draft policy document has been approved by the federal executive council and currently with the legislators for passage into law.

At the Convention domestication and policy development level, the Federal Ministry of Environment of Nigeria (FME) set up a Special Climate Change Unit which has now been upgraded to the Department of Climate Change. It was established in recognition of the importance of climate change issues in the country and to guide Nigeria in meeting her commitment to the UNFCCC. Most of climate change activities in the country have been driven through this arrangement.

The National Environmental Policy (1989) which was revised in 1999 to make room for new and emerging environmental concerns has also been a key policy drive to stem greenhouse gas emissions. The policy was formulated to address the challenges of environmental problems such as deforestation, desertification and coastal and marine environment erosion, air and water pollution, urban decay and municipal waste, as well as hazards of drought, coastal surges, floods and erosion (FMENV, 2010).

The continued gas flaring in the oil producing areas has left a devastating effect on the surrounding environment (Adeniye et al., 1983). Apart from contributing to global warming, the GHGs released in the process as earlier discussed, it also reduces air quality and poses a threat to living in the area (Okoh, 2000; Obi, 2001; Odjugo, 2004b). The Federal Government of Nigeria has made series of efforts to discourage gas flaring, including setting a time limit to phasing out gas flaring by the end of 2008. In addition, various stakeholders in the Nigerian Oil and Gas industry have engaged in different flaring reduction projects. Some of these projects include: the Nigerian Liquefied Natural Gas (NLNG) projects, the Escravos Gas Project (EGP), and the Escravos Gas to Liquid (EGTL) project.

3.5.1 Natural Gas Flare out Policy

The Natural Gas Flare out Policy, as contained in the National Energy Policy (ECN, 2003), aims, among others, at:

- Cessation of gas flares in Nigeria by 2008
- Expand natural gas utilization as industrial feedstock, industrial and domestic fuel, and for central electricity generation
- Use natural gas to diversify foreign exchange earnings
- Encourage indigenous entrepreneurs to participate in the end-use devices for natural gas utilization

The strategies of the Nigerian government to accomplish this include, among others to:

- Encourage oil producing companies to gather and utilize more associated natural gas
- Impose appropriate and effective penalties to discourage flaring
- Encourage establishment of infrastructure for effective gathering, transmission and distribution of natural gas
- Provide incentives to facilitate participation of local and foreign investors in gas utilization
- Develop suitable infrastructure to support gas export
- Formulate suitable urban and regional planning regulations to ensure effective distribution/utilization by domestic and industrial consumers.

The Nigerian Government believes that Flare reduction/Flare-Out could be attained with the Clean Development Mechanism using the following categories of projects (ICF, 2006):

- Power Generation Schemes
- Expanded LNG Programme for Export
- Introduction of Gas to Liquids programme
- Increased supply to industrial markets (for feedstock and energy)
- Supply to domestic residential/commercial markets
- Introduction of CNG in the transport sector

Other policies that are relevant to national climate change mitigation response efforts include:

- National Policy on Drought and Desertification;
- Drought Preparedness Plan;
- National Policy on Erosion, Flood Control and Coastal Zone Management;
- National Forest Policy;
- National Biodiversity Strategy and Action Plan;
- The National Forestry Development Programme;
- The National Capacity Self-Assessment (NCSA);
- The Presidential Afforestation Initiative;

In addition to these plans and policies, the country has also put in place many laws and regulatory measures to promote sustainable environmental management in many sectors of the economy. Some of these laws have implications on climate change response efforts. Some of these laws include:

- National Park Service Act – retained as Cap N65 LFN 2004 (for conservation and protection of natural resources (wildlife and plants) in national parks;
- Endangered Species (Control of International Trade and Traffic) Act- retained as Cap E9 LFN 2004 (conservation of wild life and protection of threatened and endangered species).

3.6 Mainstreaming Climate Change into Sustainable Development

Climate change impacts pose a lot of threats to Nigeria's economy. Given the overwhelming reliance on fossil fuels for foreign exchange earnings and the government's focus on further expansion of this sector, the impact of the global shift away from fossil fuels could have

adverse effect on the Nigerian economy. For instance, it could lead to a huge loss of revenue as a result of a heavy reduction in demand for petroleum. Independent studies estimate the loss at tens of billions of US dollars per year for OPEC's members of which Nigeria is one. This situation could affect the Nigeria's economic and social infrastructures, impacting negatively on development plans and entailing huge cutbacks in such vital services as education and health care. It would also affect its ability to invest in future production capacity.

A possible sea level rise as reported in Chapter 1 could result in loss of 75% of the Niger Delta and Lagos. It could also result in a loss in GDP of between 6% and 30% by 2050, which is estimated to be between US$ 100 and 460 billion dollars. By 2020, if no measures are implemented, up to 211% of Nigeria's GDP could potentially be lost.

With these potential impacts, climate change is no longer just an environmental issues but a core development issue. It has become a major threat to the sustainable development of Nigeria, like many other developing countries. The main challenge is to keep climate change from reversing all the development gains achieved over the years (FMENV, 2010).

The National Environmental Policy (1999) was developed in part, to strengthen developmental initiatives in the country. The goal of the policy is to achieve sustainable development in the country and, in particular to (i) secure a quality of environment adequate for good health and well-being; (ii) promote the sustainable use of natural resources; (iii) restore and maintain ecosystems and ecological processes as well as preserve biodiversity; (iv) raise public awareness and promote understanding of linkages between environment and development; and (v) cooperate with government bodies and other countries and international organizations on environmental matters (FMENV, 2010).

3.7 Relevant National Development Plan to Climate Change

Nigeria has just developed a strategic framework that is based on its Vision of becoming one of the twenty largest economies by the year 2020. The policy document is in three volumes (FGN, 2010):

- The First volume (Volume I) contains three main parts. The First Part presents the strategic framework for the Plan. The Second Part II is the macroeconomic framework while the third deals with implementation arrangement, monitoring and evaluation strategy and the Financing Plan.
- The Second volume details the sectoral Plans of four thematic areas: Physical Infrastructure; Productive Sector; Human Capital and Social development, and Knowledge-based Economy; Policy thrusts, objectives, strategies and targets, as well as the programmes and projects that will be implemented during the Plan period.
- The Third Volume contains two thematic areas: Governance and General Administration, and Regional/Geo-political Zones Development. In addition, the Plan integrates the States' proposed programmes and investment plan, for the Plan period.

In order to achieve this vision, the policy document has six main policy trusts (FGN, 2010). These include:

- Bridging the infrastructural gap to unleash economic growth and wealth creation
- Optimising the sources of economic growth to increase productivity and competitiveness
- Building a productive, competitive and functional human resource base, for economic growth and social advancement

- Developing a knowledge-based economy
- Improving governance, security, law and order and engendering more efficient and effective use of resources and promoting social harmony and conducive business environment for growing the economy
- Fostering accelerated, sustainable social and economic development in a competitive and environmentally friendly manner

This policy at full implementation will help reduce the impact of climate change on socio-economic development processes in the overall context of preserving the environment for socio-economic development. In this regard, it would:

- Entrench environmental governance;
- Create awareness and promote environmental education about climate change; and
- Maximise economic benefits from sustainable environmental management.

In spite of all the aforementioned plans, strategies and programmes, some of the specific activities envisioned for Nigeria to be able to combat climate change in the country include: -

- Strengthening of the existing institutional framework to ensure effective coordination of climate change activities/programmes
- The development of a climate change policy to provide the basis for the articulation of national programmes and action plans
- Provision of sustainable funding through budget allocation
- The provision of improved infrastructure for research, data collection and sharing
- Improved human capacity development in all areas of climate change analysis

3.8 Uncertainties

There are expectedly a lot of uncertainties in our discussion of mitigation response arising primarily from the fact that the options have not been analysed using objective quantitative matters. Because of this gap, the determination of which option should be of priority remains at best a guess work. Also, the quantitative assessments of the economic impacts of potential mitigation actions have not been reported. In future reports, detail analyses of the mitigation options would be provided to further sharpen the country's focus at mitigating climate change.

3.9 Conclusion

Nigeria has made efforts in her drive towards climate change mitigation. In the discussion of the mitigating measures in the country, significant CO_2 emission reduction could be achieved in the residential, transport and industrial sectors of the energy system. However, with increased political will and financial assistance from the international organization, the country has a good potential of embracing sustainable development path in its socio-economic endea**vours.**

CHAPTER FOUR

CLIMATE, CLIMATIC TRENDS AND CLIMATE CHANGE SCENARIOS

4.0 Introduction

Climate change and climatic variability in Nigeria have become issues of considerable concern. More than before, there is an increasing realization that the country is vulnerable to climatic fluctuations and climatic changes. For instance, as a result of the variations and changes in the climate of the Sudano-Sahelian region since the 1970s, a lot of impacts have manifested on the various environmental processes and human activities in the country. To a large extent, these variations and changes have impacted critical sectors including water resources and agriculture and other related activities. However, the degree of the changes particularly in temperature and precipitation is not well known. The First National Communication (2003) has examined some aspects of the climate science with a view to providing useful information. This report adopts new methodologies to further assess the changes in the climate of the country using historical and real-time data including projections and scenarios.

The report here is guided by the definitions of the United Nations Framework Convention on Climate Change (UNFCCC), the Intergovernmental Panel on Climate Change (IPCC) and other reliable sources in discussing the present and expected changes in climate over Nigeria. ***Climate*** is the statistical description in terms of the mean and variability of relevant quantities, most often surface variables, such as temperature and precipitation over a period of time ranging from months to thousands or millions of years. In a wider sense, climate also describes the statistics of the climate system. ***Climate trend*** is used to describe fluctuations or variations in the climate over time. This may be upward or downward in the value of the climatic element concerned. When such variations are cyclical or periodical in nature, the term climatic cycles is used. Climate change refers to ***a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods***. IPCC defines it as ***a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. It refers to any change in climate over time, whether due to natural variability or as a result of human activity.***

The variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events are referred to as climate variability (Ayoade, 2003; Bates *et al,* 2008). Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability) (Bates *et al*, 2008). Climate variability can cause extreme events, such as floods, droughts, or tropical storms (USAID, 2007).

Climate change is a slow process and its study normally covers long timescale, in order to be able to identify changes in pattern from the baseline conditions. This requires data and information on long term future climate condition. Such data sets are also needed to assess the risks and impacts that may be induced by climate change in the future. However, precise prediction for long timescale is beyond the capability of any current forecasting technique. Climate scenarios have been employed to address this challenge.
No matter the level of uncertainties in the knowledge of the characteristics and future trends of climate, climate change will have significant impacts locally, regionally and globally, increasing the problems of environmental and socio-economic sustainability. It will also exacerbate problems of population and associated consumption patterns. In Nigeria, climate change poses very serious threats to several socio-economic and natural systems from the coastal zones to the Sudano-Sahelian regions. These are examined in detail in Chapters 5 and 6. Thus, the concern for the present and future of natural resources and sustainability of the environment of the country is well placed.

All these indicate the need to document information on the characteristics of climate, climate variability and climate change. In particular, the main questions that should be of concern in Nigeria include:

(a) The characteristics of present climate, climatic variability and significant characteristics of the present climatic conditions especially as related to rainfall and temperature and

(b) The characteristics of the changes expected in the climate of the country over the next 50 - 100 years. In considering these, emphasis is placed mostly on rainfall and temperature, even though issues related to other climatic parameters are implied.

4.1 Methodology

4.1.1 Data Collection

The climatic data used for this analysis are on daily, monthly and annual rainfall totals as well as minimum and maximum air temperatures. The data were obtained from the Nigeria Meteorological Agency (NIMET), Lagos. Station data were available for fifty four stations of variable lengths across the stations for the period between 1951 and 2006.

4.1.2 Data analysis

The methodological framework of this chapter is divided into two main parts. The first part provides statistical analyses and downscaling carried out to obtain observed climate characteristics such as trend, variability, and change. The second part uses Atmosphere/Ocean Global Climate Models (AOGCMs) to explore possible future climate scenarios of greenhouse gas emissions. A set of high-resolution scenarios was created through the process of downscaling, which derived local climate response to the larger scale atmospheric dynamics. These methods are in conformity with tools available in UNFCCC documentations used for regional statistical/dynamical downscaling, so that local scale climate data could be generated. In addition, reference periods are typically 3 decades long (30 years). The period 1961-1990 is used in this report as a climatologically baseline period to quantify the anomalies in the future. These periods are of sufficient length to adequately represent the climate of the period, and are used to compare fluctuations of climate between one period and another. Also, given the substantial inter-decadal climatic variability exhibited by most GCMs, it is often difficult to distinguish a climate change signal from the background noise (i.e. the internal variability of the model or the model's representation of natural variability). For this reason, the IPCC has recommended the use of at least 30-year averaging periods for GCM output data. The reference period differences (future climate minus baseline climate) are used for model scenario comparison of the climate variables. The differences can also be expressed as ratios (future climate/baseline climate), or percentage differences between periods. Two fixed time slices in the future are produced from model output, e.g., the 2050s (2046-2065), and the 2090s (2081-2100). This chapter has considered some of these time slices including the baseline time slice of 1961-1990.

4.2 Observed Trends

Instrumental observations over the past 150 years show that temperatures at the surface have risen globally, with important regional variations. In Nigeria, temperatures have been on the increase in the last five decades and have been very significant since 1980s. After the drought of 1983, temperatures have been above normal except in 1989 and 1992. The 55-year (1951 – 2005) linear trend (Figure 4.1) indicates a change of 1.01 (0.52 to 1.5) ^{o}C. The linear warming for the same period for 30-year averages on a decadal slice further reveal changes in temperature by an average of 0.2^{o}C. Temperature anomalies over the country (Figure 4.2) show that except in1973 when the country experienced a significant drought, temperatures were below normal between 1951 and 1978. From the 1980s upward, except in 1989 and 1992, temperatures have been above normal by as much as 2^{o}C in 1998 which is considered as the hottest year in instrumental records.

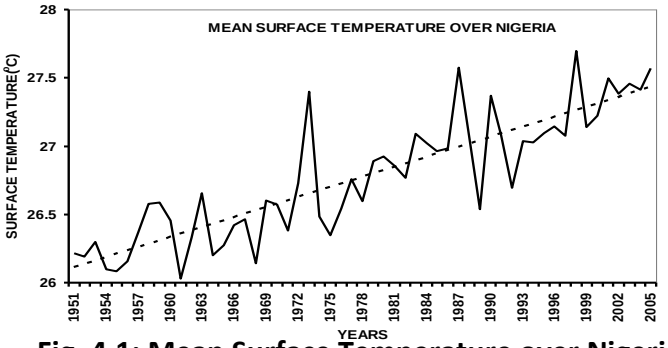


Fig. 4.1: Mean Surface Temperature over Nigeria

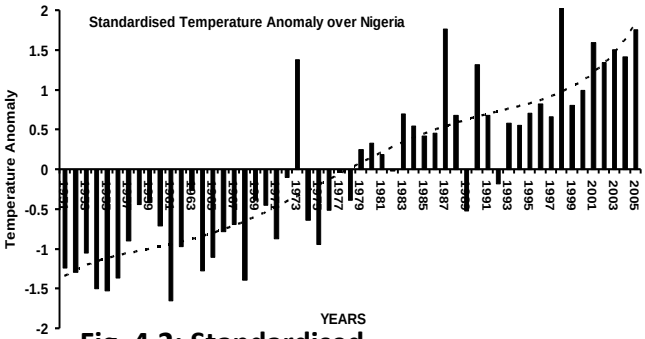


Fig. 4.2: Standardised Temperature Anomalies over Nigeria

Detailed investigation of the long-term changes in daily temperature over the country since 1951 shows strong variability from the 1970s to the present.

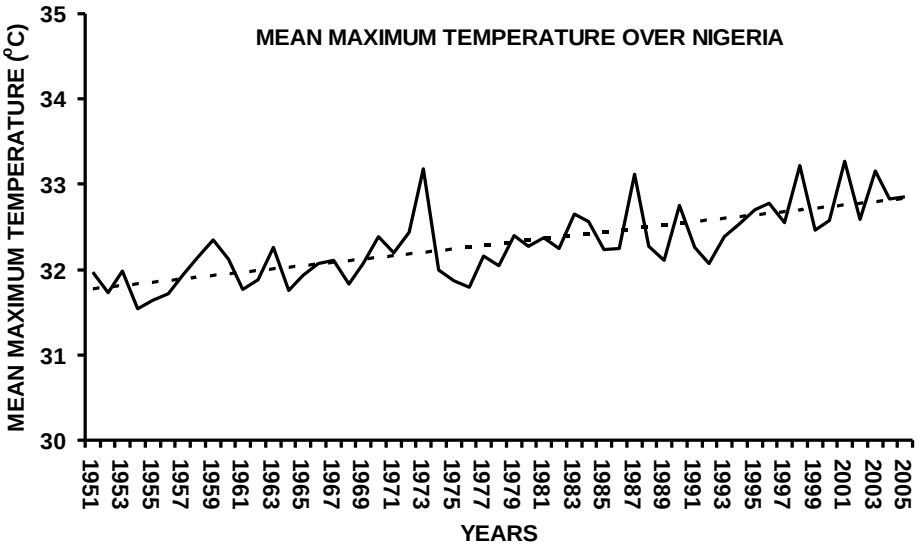
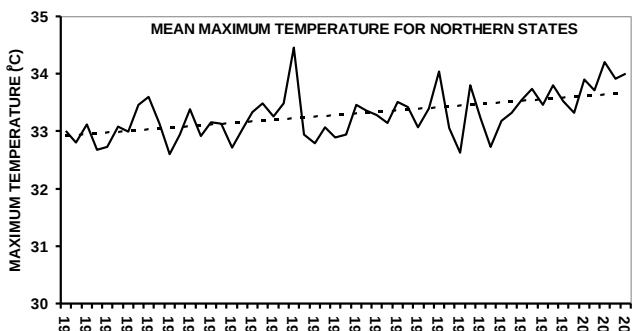


Fig. 4.3: Mean Maximum Temperature over Nigeria

In line with the surface air temperature, there has been a steadily increasing trend in maximum temperature in the country with values ranging from 31 to 33°C (Figure 4.3). Further regional investigations show that in the north, maximum temperature values lie between 32 and 35°C while in the south, values lie between 30 and 33°C (Figures. 4.4 and 4.5).

Although the minimum temperatures (Figure 4.6) also show increasing trend, the increase is much stronger in the southern part of the country than the north as shown in Figure 4.7 and 4.8, indicating much colder nights in the north. In addition, temperature range is higher in the north of the country than the south.

On the whole, minimum temperature over the country has increased slightly faster than the maximum temperature resulting into smaller temperature range. The net effect is warming of the environment. A study conducted by New *et al.* (2006), from 1961 – 2000, has shown that there was an increase in the number of warm spells over West Africa and a decrease in the number of extreme cold days. The temporal temperature distributions in the figures above corroborate these findings.



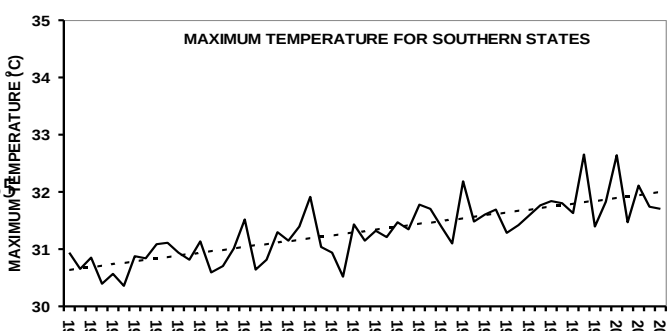


Fig. 4.4: Mean Maximum Temperature over Northern Nigeria

Fig. 4.5: Mean Maximum Temperature over Southern Nigeria

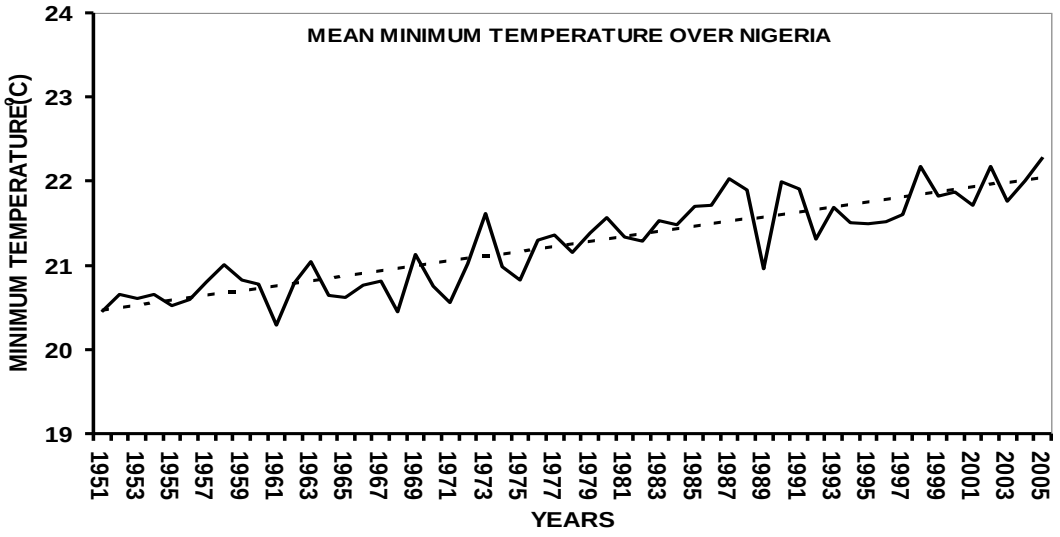


Fig. 4.6: Mean Minimum Temperature over Nigeria

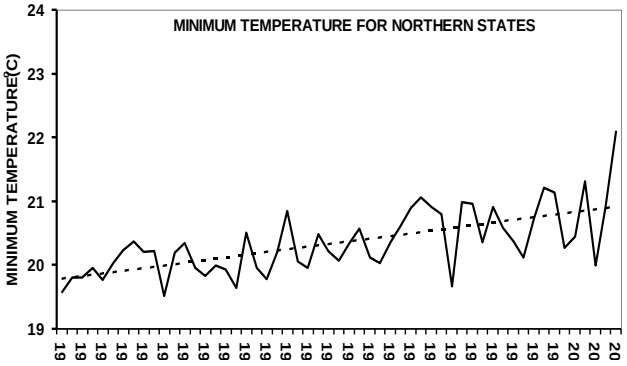


Fig. 4.7: Mean Minimum Temperature for Northern Nigeria

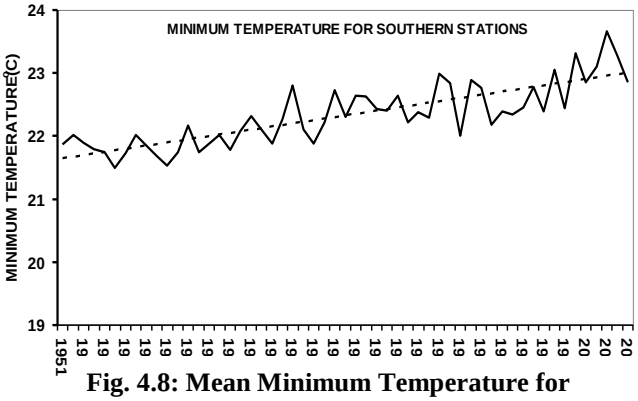
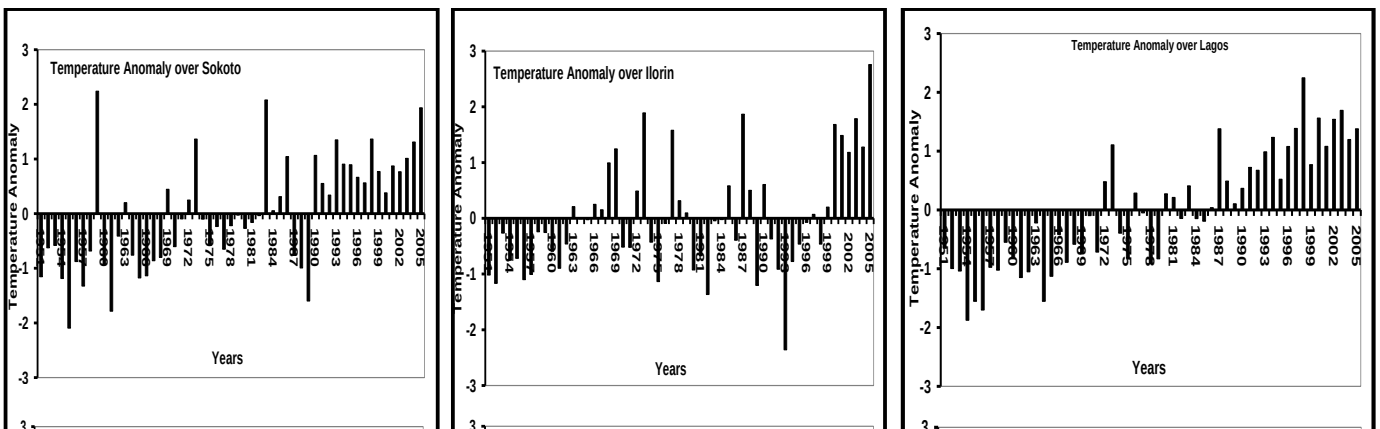


Fig. 4.8: Mean Minimum Temperature for Southern Nigeria

4.2.1 Temperature Anomalies

For the purpose of this work, the country has been divided into three regions namely South, Central and North (see Fig. 4.9). The South refers to locations to the south of approximately 9°N; the Central refers to those locations between latitudes 9°N and 11°N, while the North refers to locations to the north of Lat. 11°N.



(a) **(b)** **(c)**

Fig. 4.9: Temperature Anomalies (a) North, (b) Central and (c) South

Except in few cases, anomaly trends show a range from about -2.0σ to about +2.0σ. Temperatures in the country have generally been above normal since 1976. The diagrams in indicate that although the Positive anomalies started by mid-1970s (Figures 4.9 (a-c)). However there are marginal differences even in each of the regions. Over the north, the year 1989 was relatively colder than corresponding period over the central and southern states. The central states have defined positive anomalies from the 1970s except in Ilorin where colder conditions generally prevailed till around the beginning of the 1990s. However, the temperature anomalies generally show that the conditions have been consistently above normal since 1993.

4.2.2 Rainfall Trends

Figure 4.10 shows the rainfall variability and trend over the country. There exists a number of inter-annual fluctuations observed in the annual rainfall over the country which is responsible for dry and wet years or extreme climate events such as drought and flood. The fluctuations during the first relatively wet period which occurred between 1951 and 1968 had high values of rainfall in 1954, 1955, 1957 and 1963. The lowest value of rainfall during this period was in 1958.

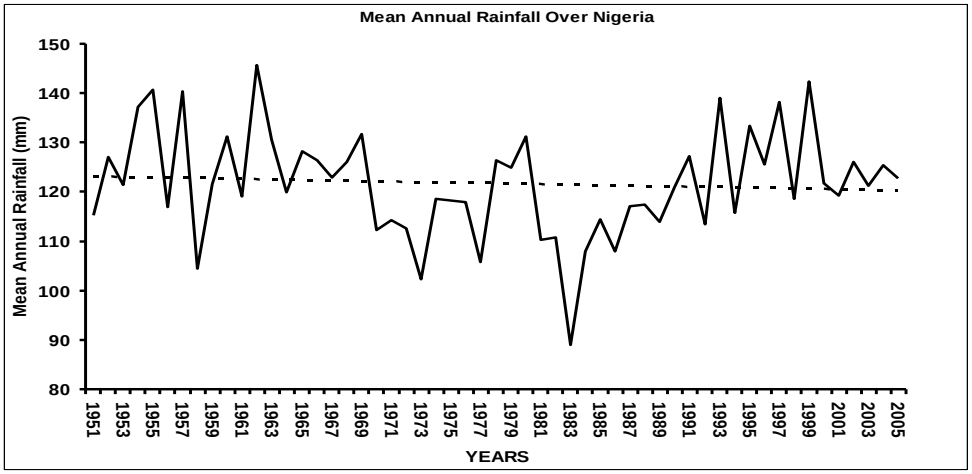


Fig. 4.10: Mean Interannual Rainfall Variability over Nigeria

The period 1970 – 1990 was dry except between 1978 – 1980 and coincided with the Sahelian droughts of early 1970s and 1980s. From 1990s to present, rainfall has been above normal. However, rainfall was much better in the 1990s than the present. The general trend indicates a decline in rainfall over the country even though some locations may experience better rainfall than what has been expressed for the country.

4.2.3 Rainfall Anomalies

There are three periods, which are depicted in Figure 4.11. These include (a) a relatively wet period, which occurred between 1951 and 1968 (b) a relatively dry period, which occurred between 1969 and 1992, and (c) another relatively wet period, which indicate some 'recovery' between 1993 and present day. These periods are similar to the earlier ones discussed for the rainfall variability of the country for emphasis, it is necessary to examine the anomalies to obtain a complete assessment of extreme climate condition over the country for the period under consideration.

Between approximately 1968 and 1992, Figure 4.11 shows relatively low rainfall values with the lowest rainfall below average in 1973 and 1983 as well as a slight recovery in 1978 and 1979. It is informative that the period of lowest rainfall in 1973 and 1983 coincided with the severe droughts in West Africa. In spite of the general recovery in rainfall, since 1993, the general trends show slight decrease in rainfall especially since 2001.

The climatic cycles in the northern and southern Nigeria (see Figs 4.12 and 4.13) have similar temporal pattern with that over the country but the amplitudes are much higher in the northern than in southern Nigeria.

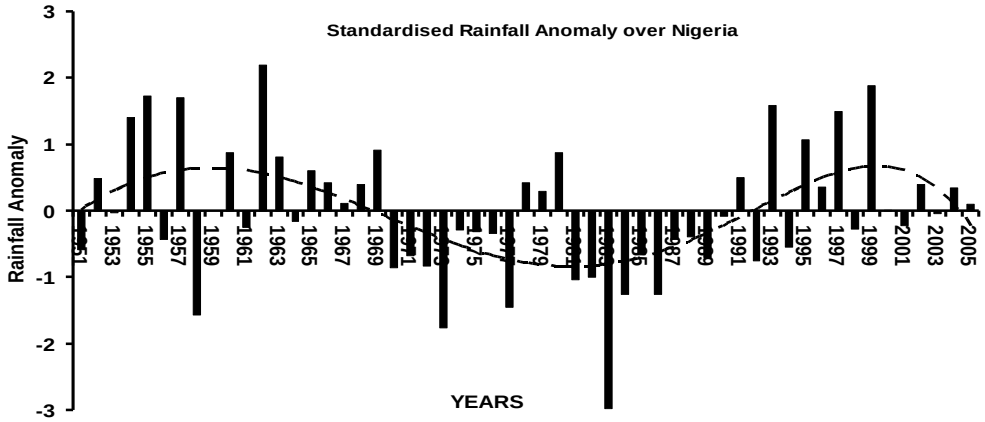
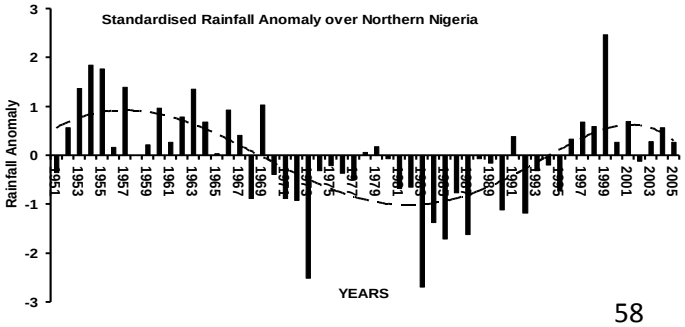


Fig. 4.11: Standardised Rainfall Anomalies over Nigeria



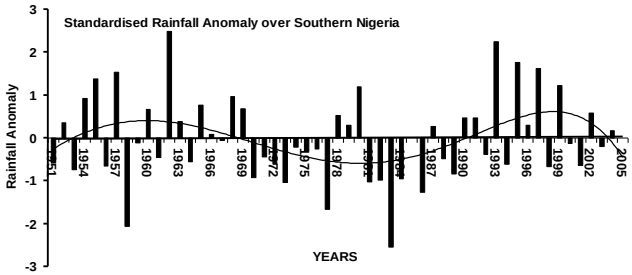


Fig. 4.12: Standardised Rainfall Anomalies over Northern Nigeria

Fig. 4.13: Standardised Rainfall Anomalies over Southern Nigeria

Although, the present rainfall amounts are generally higher than the baseline period, the amount and distribution are much better in the 1990s than the beginning of this century (Figure 4.11 - 4.13).

The standardised rainfall anomalies for the North, Central and the South (Figure 4.14 a-c) are briefly discussed here:

(a) The standardized anomaly for the northern parts of the country show similar characteristics to that of the whole country. Three distinct periods of rainfall characteristics may be noted. These include relatively wet period between 1951-1969 (b) relatively dry period between 1971-1995 and relatively wet period between 1996-2005

(b) During the first wet period of 1951-1969, there were relatively more wet years than observed for Southern Nigeria

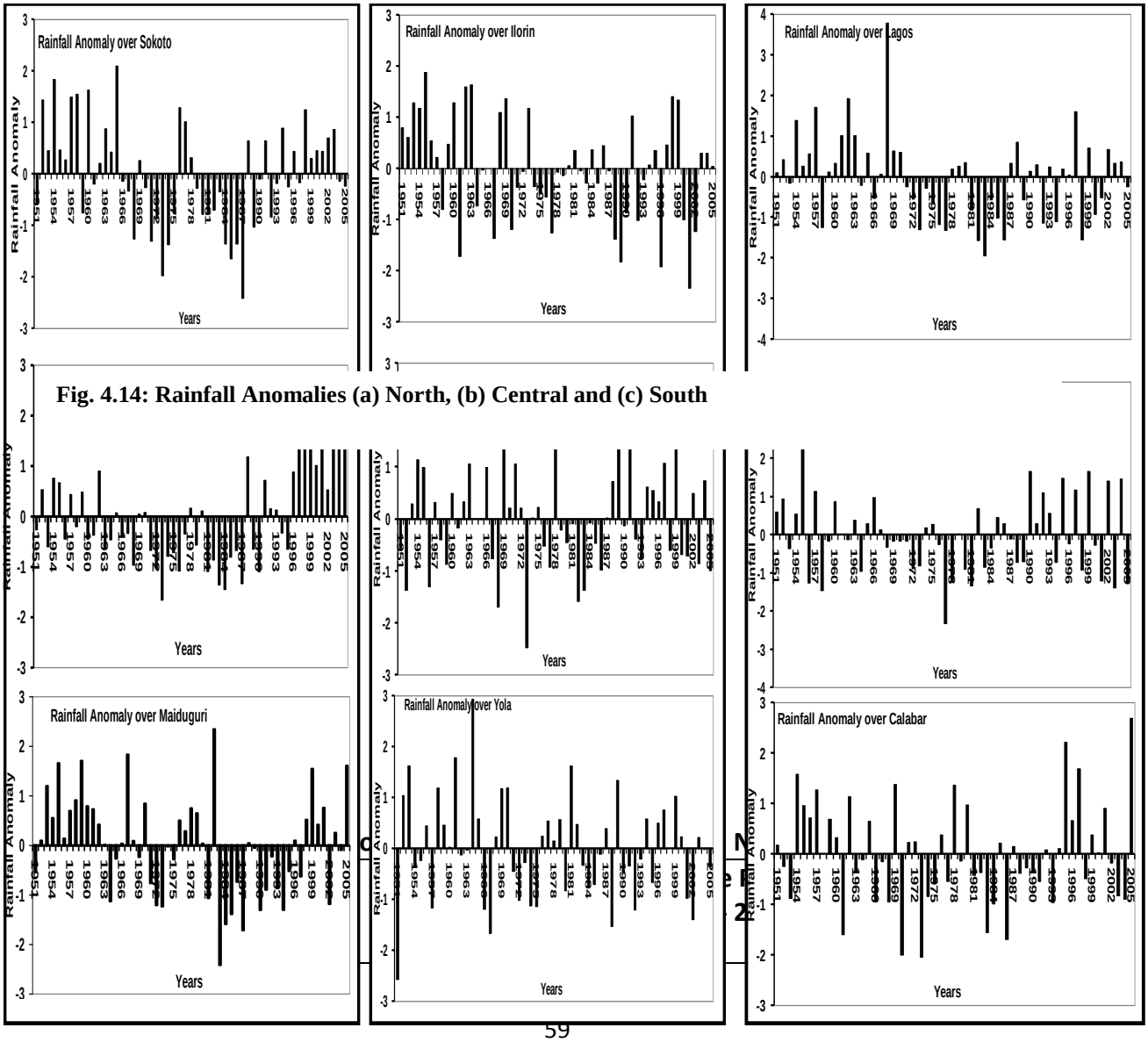


Fig. 4.14: Rainfall Anomalies (a) North, (b) Central and (c) South

Actual Temperature % Temp. increase	26.7^{o}C	27.2^{o}C ~ 2% increase of the baseline period	28.2^{o}C 5.6% increase of the base period and ~ 3.7% increase of present day value
Rainfall % Rainfall increase	1400mm	1500mm ~ 7% increase of the baseline period	1420mm ~1% increase of the baseline period and ~ 5% decrease of the present day value

The projection in Table 4.1 was based on statistical equations from the trend of the datasets. The present observed mean temperature over the country is about 27.2 ^{o}C. When compared with the baseline period, an approximate 2% increase has taken place and a further 3.7% increase is expected from the present day value and a likely 5.6% increase from the baseline period. Even though, temperatures are higher in the north and therefore warmer, the temperature changes are higher in the south than in the north. While temperature change in the north is about 0.5^{o}C from the baseline period, in the south it is about 0.6^{o}C. However, the present day rainfall increased by 7% from the baseline period but it is expected to fall by about 5% by 2020s from the present climate condition and about 1% increases from the baseline period.

It is important to note that the results of these statistical analyses do not depend on changes in the concentration of the greenhouse gases, population, energy consumption, landuse, etc. These issues and other uncertainties are discussed in the next section.

4.3 Climate Change Scenarios

4.3.1 Projections of Future Climate Changes

The projection of the response of the climate system to emission or concentration scenarios of greenhouse gases and aerosols, or radiative forcing scenarios, often based upon simulations by climate models could simply be considered as climate projection. It is distinguished from climate prediction in order to emphasise that climate projections depend upon the emission/concentration/radiative forcing scenario used, which are based on assumptions, concerning, e.g., future socio-economic and technological developments, that may or may not be realised, and are therefore subject to substantial uncertainty.

Climate scenario **is a plausible and often simplified representation of the future climate, based on an internally consistent set of climatological relationships that has been constructed for explicit use in investigating the potential consequences of anthropogenic climate change, raw material for constructing climate scenarios, but climate scenarios usually require additional information such as the observed current climate. A *climate change scenario* is the difference between a climate scenario and the current climate.**

The storylines used in this section obtained from the IPCC Special Report on Emission Scenarios (Nakicenovic´ *et al*., 2000) are briefly presented below:

> *The A2 storyline describes a very heterogeneous world. The underlying theme is self reliance and preservation of local identities. Fertility patterns across regions converge very slowly, resulting in high population growth. Economic development is primarily regionally-oriented, and per capita economic growth and technological change are more fragmented and slow compared to other storylines.*
>
> *The B1 storyline describes a convergent world with rapid change in economic structures toward a service and information economy, reduction in material intensity and the introduction of clean and*

resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

4.3.2 Climate Change Scenarios development from GCMs

In the previous section, the mean state, variability and trends including statistical projection in the near future climate were discussed in order to provide the required benchmark for future climate scenarios using B1 and A2 scenarios. The future period considered are 2046 – 2065 and 2081 – 2100 and these time slices will provide useful information at the middle and end of the 21st Century. The data from synoptic stations over the country have been subjected to statistical analyses to determine the current climate. The climate scenarios downscaled from GCMs has also been developed and therefore the climate change scenarios can be computed by taking a difference between the current climate and future climate scenarios for B1 and A2. The section will consequently discuss projected annual and seasonal maximum and minimum temperature changes, rainfall changes and extreme temperature and rainfall events. The climatic extreme events (flood, drought, heat waves, ocean surges, etc.) are vital to determining vulnerable regions of the country and potential impacts on the environment.

4.3.2.1 Temperature

Surface temperature in the country is on the increase as indicated from the temperature trends in the previous section. The time series of projected minimum and maximum temperature changes during the periods of 2046-2065 and 2081-2100 using the B1 and A2 scenarios are as shown in Figure 4.15. The anomalies are obtained from the difference between the present day climate and the projected climate scenarios. The two scenarios, B1 and A2, show an increasing temperature and therefore a warmer climate. However, it is relatively warmer in A2 scenario than in B1 scenario. It is evident that B1 scenario indicates an increase of +0.20°C per decade from 2000 to the end of 2100 and A2 shows +0.40°C per decade from 2000 up to the middle of the century (2046-2065). Thereafter, an increase of +0.80°C per decade is projected till the end of the century (2080-2100) (Figure 4.15). It is worthy of note that by the middle of the century, the projected annual surface temperature changes in Nigeria are +1.5°C and +0.2°C for B1 and A2 scenarios, respectively. These values are within the range of those obtained over Nigeria in the IPPC (2007) report.

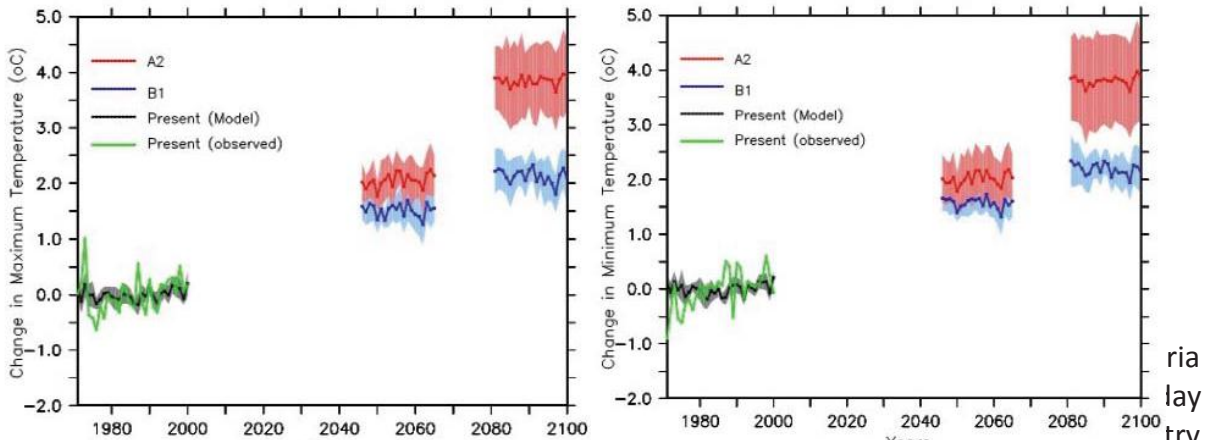


Figure 4.15: Time series of changes in maximum and minimum temperature for present-day and future climate in Nigeria under B1 and A2 scenarios. The dashed lines show station observation; the full lines represent the models mean, while the shaded regions are areas of a standard deviation away from the mean (source: Abiodun et al. 2011).

that the coastal regions would warm lesser than the inland areas. This is a reversal from the current observed temperature changes where the coastal areas have higher rate of warming than the northern region by about 0.1°C. In the northeast, according to the B1 scenario, the temperature change will increase by +1.8°C by the middle of the century and by +2.2°C by

the end of the century. For the A2 scenario, the temperature change will rise significantly from +2.2°C by the middle of the century to +4.5°C by the end of the century. Again, these temperature distributions are in agreement with the report of IPCC for Nigeria.

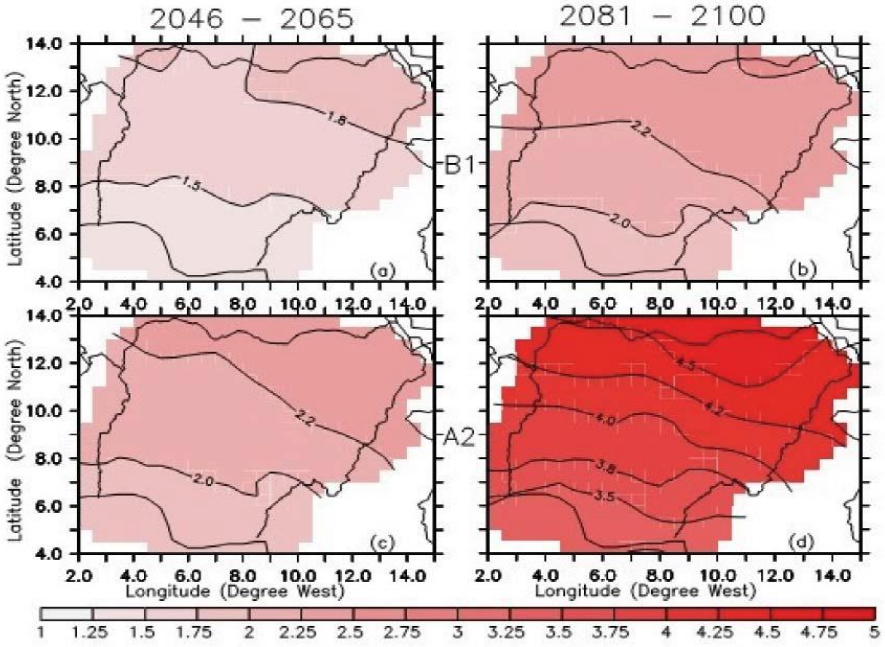
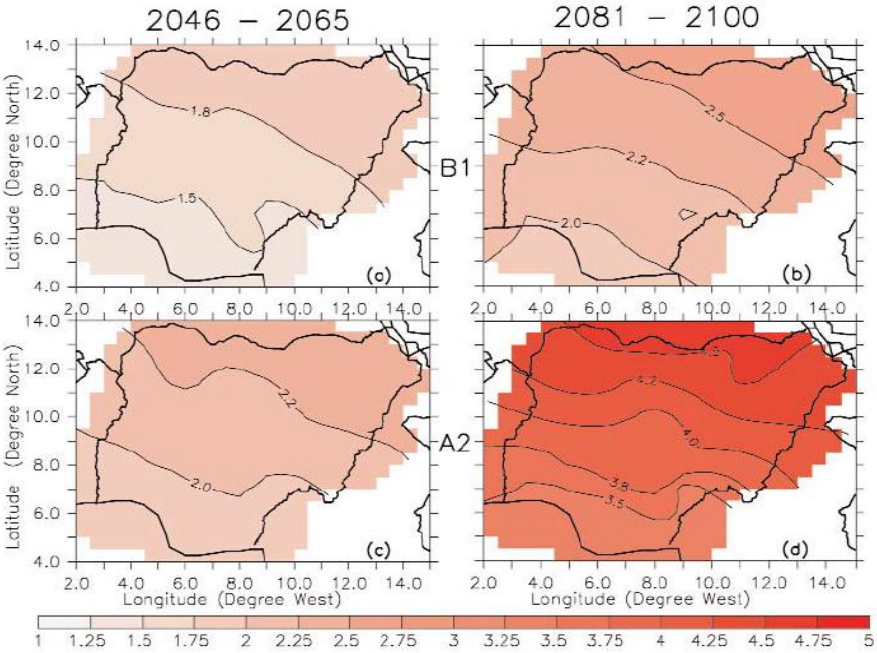


Figure 4.16: Projected changes in maximum temperature for Nigeria in the future (2046-2065 and 2081-2100) for B1 and A2 scenarios (source: Abiodun et al. 2011).

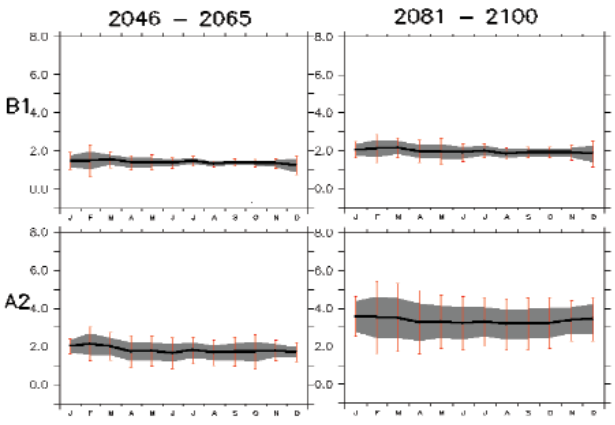


The seasor over four agroclimati). The four zones are: (a) Mangrove; (b) Rainforest; (c) Tall grass (Guinea Savanna); and (d) Short grass (S The bold line represents the model average, while the shaded region re

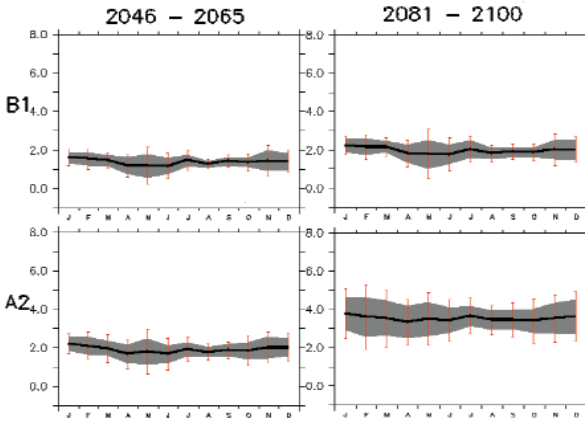
Figure 4.17: Projected changes in minimum temperature over Nigeria in future (2046-2065 and 2081-2100) for B1 and A2 scenarios (source: Abiodun et al. 2011).

maximum and minimum values from models' values. The temperature change is uniform throughout the year in the Mangrove and Rainforest zones, but has a tendency to be higher in February and March over the Savanna (Tall Grass and Short Grass) zones. However, over all zones, the projections of the models show a wider spread (i.e. larger deviations from mean) in A2 than in B1 scenario. This means that there are larger uncertainties in the A2

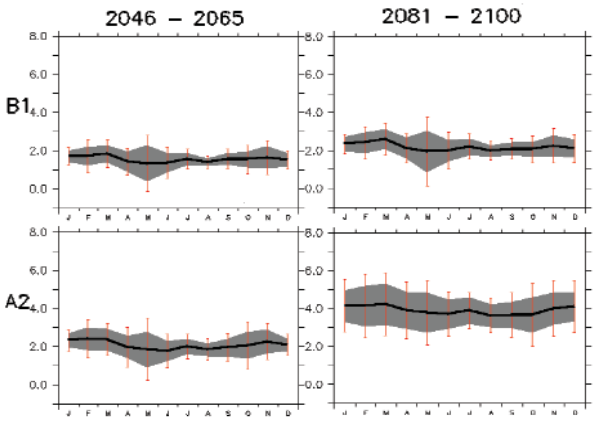
projections than in the B1 projections and these uncertainties are generally lower at the end of the century than in the middle of the century.



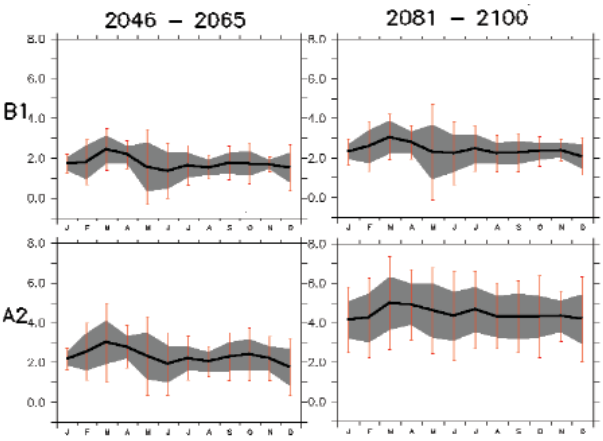
(a) Mangrove



(b) Rainforest

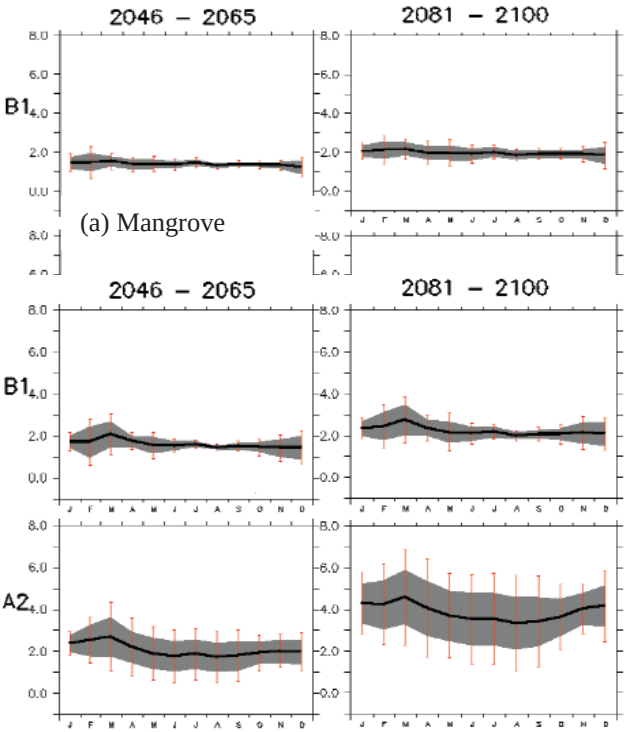


(c)Tall Grass Savanna

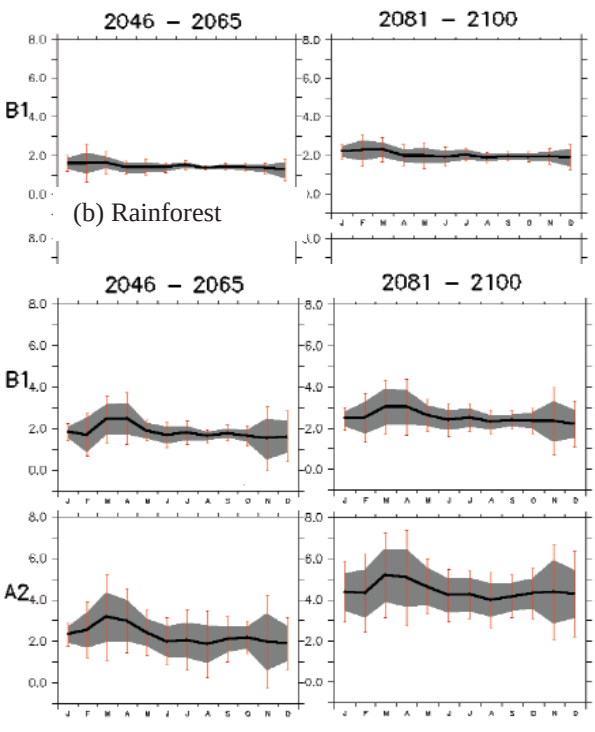


(d) Short Grass Savanna

Figure 4.18: Projected changes in seasonal variation of maximum temperature in future using B1 and A2 scenarios for the ecological zones in Nigeria (source: Abiodun et al. 2011).



(a) Mangrove



(b) Rainforest

(c)Tall Grass Savanna (d) Short Grass Savanna

Figure 4.19: Projected changes in seasonal variation of minimum temperature in future using B1 and A2 scenarios over the agro climatic zones in Nigeria (source: Abiodun et al. 2011).

4.2.2.2 Rainfall

The time series of mean rainfall changes over Nigeria for both B1 and A2 scenarios with particular reference to the 2046-2065 and 2081-2100 time slices are shown in Figure 4.20. The anomalies are as usual calculated with respect to the means of the present-day climate. In the figure, the full line represents the models' average, while the shaded region represents the area of a standard deviation away from the mean. The figure demonstrates that there is no specific trend in future rainfall anomalies and this pattern is similar to the current mean state of rainfall in the country. The increases in the observed rainfall in recent years are not everywhere in the country.

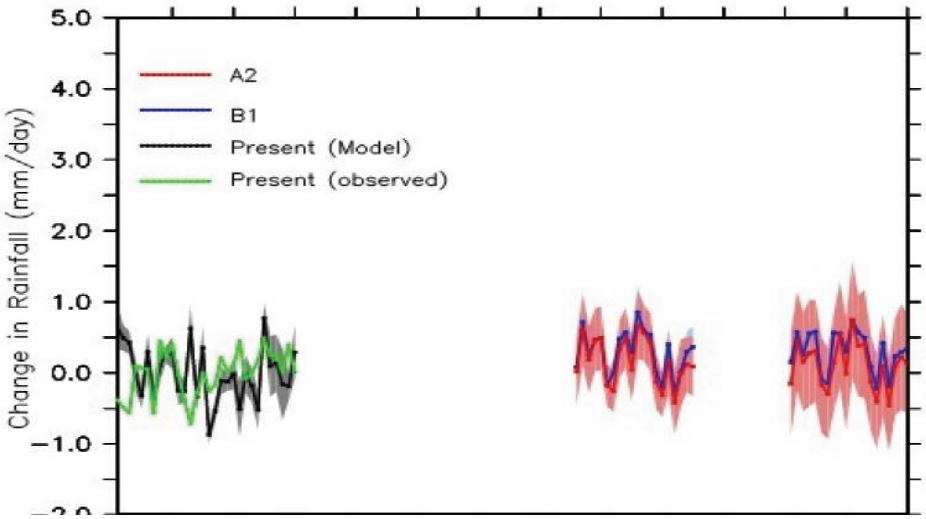


Figure 4.20: Time series of changes in rainfall (mm/day) for present-day and future climate of Nigeria under B1 and A2 scenarios. The dashed show station observation; the lines represent the models mean, while the shaded regions are areas of a standard deviation away from the mean (source: Abiodun et al. 2011).

The spatial distribution of the changes in rainfall patterns is presented in Figure 4.21. The models show wetter climate over the entire country in B1 scenario than in A2 scenario. In B1 scenario, the highest increase (mm/day) is in the coastal region and the lowest (mm/day) value in the northeast region. Although, the rainfall pattern does not change significantly between the middle and end of the century, it is slightly wetter at the end than at the middle of the century over the coastal region. With A2 scenario, the models suggest a wetter climate over most regions in the country, except in the northeast, where they predict a drier climate. They also show the possibility that the Jos plateau may have a drier climate by the end of the century. Again, similar to the pattern in B1 scenario, the coastal region is slightly wetter at the end than at the middle of the century. The model results for both scenarios are consistent with changes in the rainfall pattern.

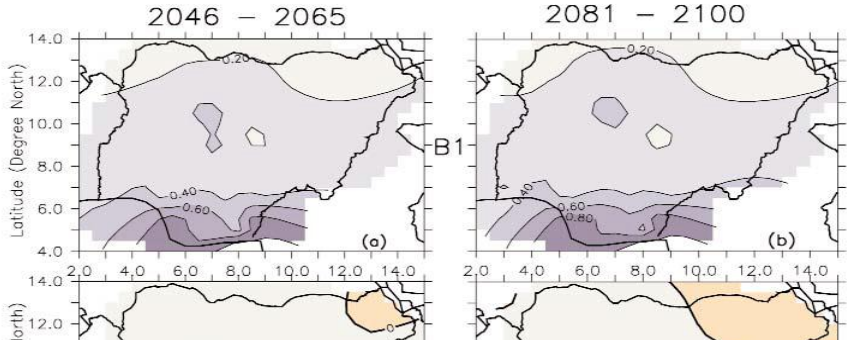
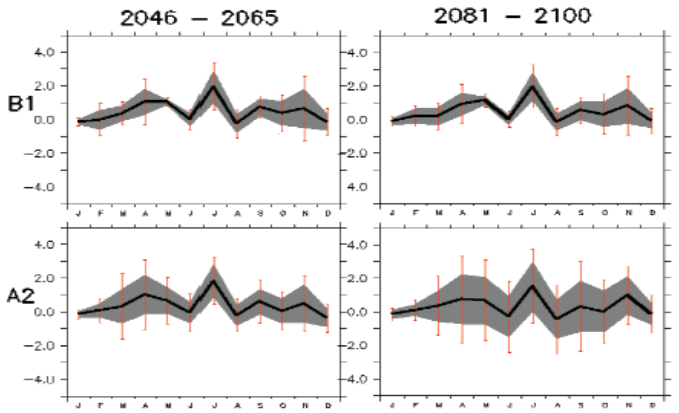
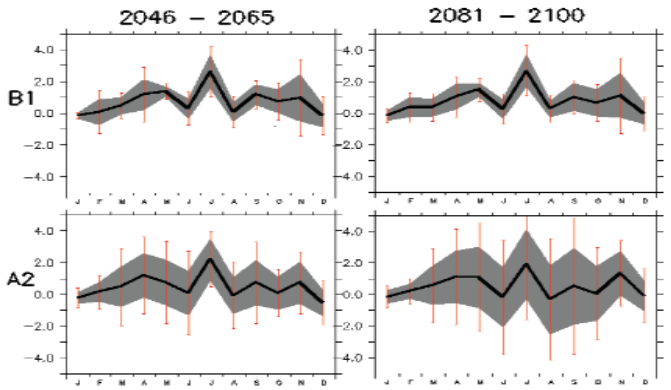


Figure 4.21: Projected changes in rainfall over Nigeria in future (2046-2065 and 2081-2100) for B1 and A2 scenarios (source: Abiodun et al. 2011).

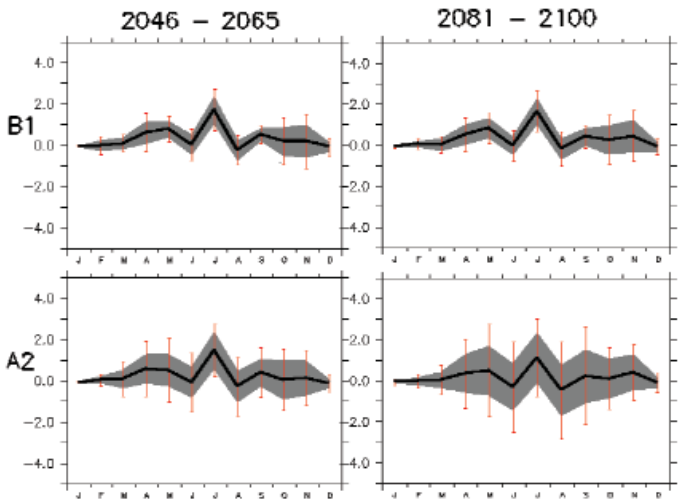
The seasonal variation of rainfall changes in each of the four agro climatic zones under B1 and A2 scenarios are presented in Figure 4.22. The solid line shows the models' mean, while the shaded region represents the area of a standard deviation from the mean. The line bars indicate the maximum and minimum values from model values. Over each zone, the models suggests a peak increase of approximately 2 mm/day in August in the Mangrove and Rainforest zones and about 1 mm/day in the same month over Short Grass Savanna and Tall Grass Savanna zones



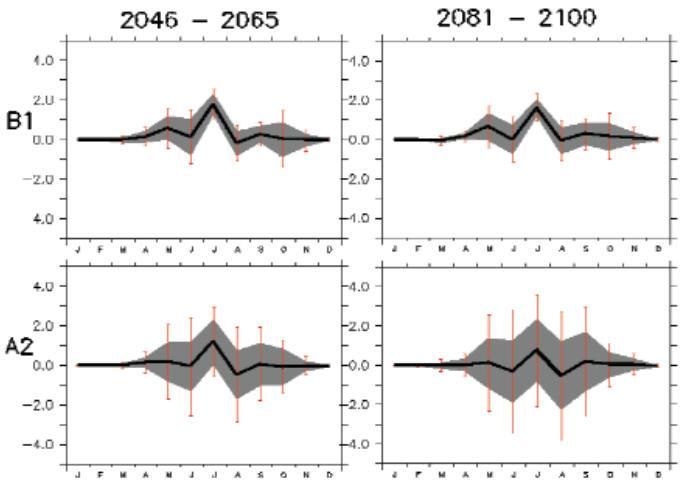
(a) Mangrove



(b) Rainforest



(c) Tall Grass Savanna



(d) Short Grass Savanna

Figure 4.22: Projected changes in seasonal variation of rainfall in future using B1 and A2 scenarios in four of the agroclimatic zones in Nigeria (source: Abiodun et al. 2011).

4.3.2.3 Extreme Temperature and Rainfall Events

Extreme climate events have constituted serious threat to global economic growth over the past years, especially to the socio-economy of developing nations. In Nigeria, severe floods, drought, windstorms, heat waves, ocean surges and several other climate extremes have impacted negatively on the socio-economic activities of the country. Therefore, examining the extreme climatic characteristics in the projections provide useful information for possible guidance in socio-economic activities.

The models project an increase in future occurrences of extreme temperature and rainfall events over all four of the agro climatic zones in Nigeria in both B1 and A2. The findings in the scenarios are that by the middle of the century, the number of days with temperatures greater than 38^{o}C would increase by 3, 5, 33 and 67 days over Mangrove, Rain Forest, Short Grass Savanna, and Tall Grass Savanna respectively under B1 scenario. Under the A2 scenario, the increases would be 7, 23, 40 and 82 days respectively. The number of days with heat waves would increase by 23, 32, 43 and 68 days respectively under the B1 scenario by the middle of the century, and by 39, 51, 60 and 85 days respectively according to the A2 scenario.

These values are nearly doubled by the end of the century. The number of days with extreme rainfall (50 mm/day) increases by 1-2 days over all the agro climatic zones for both scenarios, except over the Savanna zones by the end of the century when a decrease of one day is projected. The projected increase in extreme rainfall events is consistent with what is expected, especially in the coastal regions. Furthermore, both scenarios show an increase of 1-2 weeks in the length of the rainfall season over the zones by the middle and end of the century, except over the Short Grass Savanna, where both scenarios project a decrease of less than one week. In most cases, the increase in the length of the rainfall season is due to the early onset of rain.

Table 4.2: Extreme Events in Mangrove zone

Parameter	Extreme Event	Baseline Values	Changes with B1		Changes with A2	
		Baseline (1981-2000)	2046-2065	2081-2100	2046-2065	2081-2100
Rainfall (Intensity precipitation and drought)	Rainfall Onset Date (Julian day)	67.7	-7.3	-10.3	-9.7	-11.3
	Rainfall Cessation Date (Julian day)	314.6	7.0	6.0	5.7	5.9
	Length Rainfall Season (days/year)	247.3	14.5	15.4	15.6	16.5
	Number of rainfall event (days/year)	125.4	24.5	25.1	20.8	21.2
	Number of days with rainfall greater than 50 mm/day (days/year)	8.8	1.8	1.7	1.1	1.3
	Number of days with rainfall greater than 100 mm/day (days/year)	1.2	0.1	0.1	-0.1	0.0
Temperature (Heat waves and cold events)	Number of days with maximum temperature greater 35°C (days/year)	20.3	65.1	92.4	88.8	169.6
	Number of days with maximum temperature greater than 38°C (days/year)	0.3	2.5	7.7	7.1	46.4
	Number of days with minimum temperature less than 10°C (days/year)	1.6	-0.5	-0.5	-0.1	-0.1
	Number of days with minimum temperature less than 5°C (days/year)	1.6	-0.5	-0.5	-0.1	-0.1
	Number of days with heat waves (days/year)	1.8	22.7	42.4	39.4	108.6
(Intensity precipitation and drought)	Number of rainfall event (days/year)	118.3	9.8	10.6	6.2	4.9

;

Table 4.4: Extreme Events in Tall Grass Savanna zone

Parameter	Extreme Event	Baseline Values	Changes with B1		Changes with A2	
		Baseline (1981-2000)	2046-2065	2081-2100	2046-2065	2081-2100
Rainfall (Intensity precipitation and drought)	Rainfall Onset Date (Julian day)	118.0	-6.6	-9.7	-7.0	-4.1
	Rainfall Cessation Date (Julian day)	295.4	1.1	1.3	-1.7	0.1
	Length Rainfall Season (days/year)	177.7	11.3	10.8	5.1	4.2
	Number of rainfall event (days/year)	85.1	6.9	7.0	3.5	2.1
	Number of days with rainfall greater than 50 mm/day (days/year)	3.7	0.3	0.3	0.1	0.0
	Number of days with rainfall greater than 100 mm/day (days/year)	0.2	0.0	0.0	0.0	0.0
	Number of days with maximum temperature greater 35°C (days/year)	100.5	47.6	68.9	66.9	137.3

Parameter	Extreme Event	Baseline Values	Changes with B1		Changes with A2	
		Baseline (1981-2000)	2046-2065	2081-2100	2046-2065	2081-2100
Rainfall (Intensity precipitation and drought)	Rainfall Onset Date (Julian day)	150.2	-4.2	-5.1	0.7	3.4
	Rainfall Cessation Date (Julian day)	272.5	-5.0	-4.2	-6.1	-3.6
	Length Rainfall Season (days/year)	122.8	-0.7	0.8	-6.3	-5.5
	Number of rainfall event (days/year)	57.3	0.4	0.4	-3.1	-3.7
	Number of days with rainfall greater than 50 mm/day (days/year)	2.7	0.1	0.2	-0.2	-0.3
	Number of days with rainfall greater than 100 mm/day (days/year)	0.1	0.0	0.0	0.0	-0.1
Temperature (Heat waves and cold events)	Number of days with maximum temperature greater 35°C (days/year)	153.0	75.6	98.3	92.8	154.6
	Number of days with maximum temperature greater than 38°C (days/year)	68.0	66.7	87.5	82.2	151.6
	Number of days with minimum temperature less than 10°C (days/year)	3.5	-2.1	-2.1	-1.5	-1.9
	Number of days with minimum temperature less than 5°C (days/year)	3.5	-2.1	-2.1	-1.5	-1.9
	Number of days with heat waves (days/year)	89.7	68.3	90.6	85.1	163.0

In summary, the Nigerian climate has been examined, including its variability and change, trends, anomalies in the last half century or more and projected to the end of the 21st Century using statistical and global models (Atmosphere/Ocean General Circulation Models, AOGCMs) and regional Models (statistical and dynamical downscaling). The observed climate indicates that temperatures in Nigeria have been on the increase in the last five decades and have been very significant since 1980s. The increasing temperatures will continue till the end of the century. However, temperature increases are more in northern than southern Nigeria. There exist a number of inter-annual fluctuations observed in the annual rainfall over the country, which is responsible for dry and wet years or extreme climate events such as drought and flood. Rainfall changes indicate a generally rising trend especially in the extreme northern parts of the country, the near future projection in 2020s, suggests a reduced rainfall. However, by the middle and end of the century, increased rainfall is anticipated

There are strong indications that Nigeria is highly vulnerable to climate change resulting from both its location and the level of human resources and institutional capacity for adaptation. Therefore, mitigation options need to be adopted and adaptation strategies developed. However, some areas of the country may experience higher levels of change seasonally than others. The present extreme weather and climate events such as floods, droughts, desertification, coastal erosion and salt water intrusion from sea level rise may become severe if the future projections in the 21st Century are taken into consideration. Projected adverse impacts based on models and other studies include: reduction in potential crop yield in the country; decreased water availability for more than 90% of the population in the next two decades, particularly in the rural areas; an increase in the number of people exposed to vector-borne and water-borne diseases, and an increase in heat stress mortality; widespread increase in the risk of flash floods for many human settlements both from high rainfall events and sea-level rise; increased energy demand for cooling due to high temperatures.

For developing countries like Nigeria, climate change is a major threat to socio-economic development. For example, the country in its geographical location, is already in a warm climate region and further increase in temperature will have economic and health implications. Also, high rainfall variability will lead to extreme weather and climate conditions which are likely to affect agriculture and water resources. For a country that depends on agriculture, it is urgent to put in place measures to mitigate the causes and articulate adaptation strategies to alleviate the present and anticipated impacts of climate change.

4.3.2.4 Uncertainties in the climate change scenarios

Uncertainty as an expression of the degree to which a value (e.g. the future state of the climate system) is unknown can result from lack of information or from disagreement about what is known or even knowable. In the analyses of future climate scenarios in this report, there are inherent uncertainties in the key assumptions about and relationships between future population, socio-economic development and technical changes that are the bases of the IPCC SRES scenarios. This work has undertaken simulations driven with SRES A2 and B1 emissions, which cover most of the range of uncertainty. The imperfect understanding of some of the processes and physics in the carbon cycle and chemical reactions in the atmosphere generates uncertainties in the conversion of emissions to

concentration. A potentially even larger uncertainty arises in the feedbacks between climate and the carbon cycle and atmospheric chemistry. To reflect this uncertainty in the climate scenarios, the use of atmosphere-ocean general circulation models (AOGCMs) that explicitly simulate the carbon cycle and chemistry of all the substances is considered.

There are challenges which scenario developers do not understand about the workings of the climate system, and hence uncertainties arise because of the incorrect or incomplete description of key processes and feedbacks in the model. This is clearly illustrated by the fact that current global climate models, which contain different representations of the climate system, project different patterns and magnitudes of climate change for the same period in the future when using the same concentration scenarios. It is for this reason that multiple AOGCMs have been used as input in this work, despite their poor resolution, to reflect (at least in part) this "science uncertainty". The uncertainty attributed to the global climate response is the other major uncertainty currently identified along with the uncertainty of future emissions discussed above.

Therefore, the values obtained for future climate scenarios for Nigeria are not exact but provide guidance to aid socio-economic planners and decision makers. It is important to emphasize that the climate of Nigeria varies on timescales of years and decades due to natural interactions between atmosphere, ocean and land, and this natural variability is expected to continue into the future. For any given period in the future (e.g. 2046-2065) natural variability could act to either add to or subtract from changes (for example in local rainfall) due to human activity. This uncertainty cannot yet be removed, but it can be quantified. This is done by running ensembles of future climate projections; each member of the ensemble uses the same model and the same emission or concentration scenario, but each run is initiated from a different starting point in the "control" climate. The results of this ensemble for a particular 10- or 30-year period will give a range of possible futures which are likely to span the actual evolution of the climate system, assuming the representation in the climate model to be correct.

CHAPTER FIVE

EVALUATING VULNERABILITY TO AND IMPACT OF CLIMATE CHANGE

5.1 Introduction

This chapter describes the strategies adopted in evaluating Nigeria's vulnerability to, and impact of, climate change in the country. The data capturing processes are first presented with their analyses. This is followed by a review of uncertainties in the analyses.

5.2. Assessing Vulnerability to and Impact of Climate Change

The assessment of vulnerability in this report relies on existing framework for socio-economic analyses and planning as suggested in the IPCC (2000). Data analyses and characterization were considered at the geopolitical zonal levels. Climatic data were also treated at the geopolitical zonal level. Although this deviates from the largely zonal pattern of climatic belts, it was needful in order to integrate climatic data into the estimates of vulnerabilities in the country's geographic space

5.3 Data Analysis

The assessment of impacts of, and vulnerability as well as adaptation to climate change involve considering specific climate scenarios and projections for each geopolitical zone. For rainfall- and temperature-based scenarios, data were obtained from second-order polynomial analyses of climatic data from 1961 to 2007 for temperature and from 1961 to 2008 for rainfall. Table 5.1 contains the polynomial equations on the two parameters for each of the six geopolitical zones.

Table 5.1: Trend Equations of the Total Annual Rainfall and Mean Annual Minimum and Maximum Temperatures in Nigeria by geopolitical zones

Geopolitical Zone	Climatic Parameter		
	Total Annual Rainfall	Mean Annual Minimum Temperature	Mean Annual Maximum Temperature
Northwest	Y=-19043.668+9.999X	Y=-7.340+0.014X	Y=-1.395+0.018X
Northeast	Y=-13011.452+6.874X	Y=-44.416+0.033X	Y=12.532+0.011X
North-central	Stationary	Y=-5.299+0.013X	Y=3.058+0.014X
Southwest	Stationary	Y=-12.041+0.017X	Y=-14.780+0.023X
Southeast	Stationary	Y=-9.814+0.016X	Stationary
South-south	Y=-18018.506+10.316X	Y=-12.780+0.018X	Y=-1.297+0.016X

With respect to other parameters including sea level, average yield of millet and sorghum, cereal yields, rice yield, cropping season, agricultural losses, lengths of growing period in agricultural areas within the livestock-only systems, lengths of growing period in rain-fed mixed crop/livestock systems, yields from rainfed agriculture, sensitivity of African mammals, settlements, and global total of those earning below US$1/day, various sources including the NBS and other published consistent data sets were used (Table 5.2).

Table 5.2: Climate Change Scenarios for Nigeria

Elements	Location	Baseline	Projection Time Horizon	Projected Change	Source
Average yield of millet and sorghum	Sudano-Sahelian Zone	Not Provided	By 2080	Fall by 15 to 25%	Atlas on Regional Integration in West Africa, (2008)
Cereal yields	Sudano-Sahelian Irrigated Areas	Not Provided	By 2080	10-25% increase	Atlas on Regional Integration in West Africa, (2008)
Rice	Sudano-Sahelian Rainfed Rice Areas	Not Provided	By 2080	2-10% increase	Atlas on Regional Integration in West Africa, (2008)
Sea levels	Coastal area	1990	By 2100	30-50 cm rise	Atlas on Regional Integration in West Africa, (2008)
Cropping season	Sudano-Sahelian zone	Not Provided	By 2050	Reduced by over 20%	Sahel and West Africa Club/OECD Briefing Note, (2009) IPCC, (2007)
Agricultural losses	Western Africa	Not Provided	By 2100	Between 2 & 4% of GDP	Mendelsohn *et al*., (2000); Stockholm Environment Institute (2008)
Length of growing period within the livestock-only systems	Arid and semi-arid areas of Nigeria	Not Provided	By 2050	Undergo >20% reduction	Thornton *et al*., (2006); Boko *et al* (2007); Stockholm Environment Institute, (2008); after.

Length of growing period in rain-fed mixed crop/ livestock systems	semi-arid areas of Nigeria	Not Provided	By 2050	Undergo >20% reduction	Thornton *et al*., (2006); Boko *et. al.* (2007); Stockholm Environment Institute, 2008); after.
Yields from rainfed agriculture	Sub-Saharan Africa	Not Provided	By 2020	Fall by up to 50 percent	Brown, (2007); IPCC *Working Group II,* (2007)
Rain-fed agriculture	All African Countries	2000	By 2020	Deficiencies in yields up to 50%	IPCC, (2007)
Species sensitivity of African mammals	Sub-Saharan Africa	Not Provided	For 2050	A fall of between 10-15%	Thuiller *et al*., (2006); IPCC, (2007)
Species sensitivity of African mammals	Sub-Saharan Africa	Not Provided	For 2080	A fall of between 25-40%	Thuiller *et al*., (2006); IPCC, (2007)
Settlement	Coastline between Accra and the Niger delta	Not Provided	By 2020	Will become a continuous urban megalopolis of more than 50 million inhabitants	Hewawasam, (2002); IPCC, (2007)
Global total of those earning	sub-Saharan Africa	Not Provided	By 2015	Rise from 24% today to 41%	UNDP, (2005); IPCC, (2007)

below US$1/day					

5.4 Developing the Vulnerability Indices

The approach adopted here in assessing vulnerability is the econometric method which uses the household-level socio-economic data to assess the level of vulnerability of different social groups to climate change (e.g. Hoddinott and Quisumbing, 2003; Carter *et al.,* 1994). It does this by constructing a measure of welfare loss that can be attributed to shocks, in this case, climate change. For this assessment, the indicators were weighed using expert judgments and reviews of literature. Three parameters informed the choice of indicators:

i. The peculiar nature of Nigeria's local environment: The UNFCCC Guideline for the preparation of National Communication on Climate Change (NCCC) specifically requests that reports take cognizance of the peculiarities of local conditions in each reporting Party (UNFCCC, 2003);

ii. Availability of data: The indicators used were those that covered appreciable length of time, in many cases up to 30 years up to 2006. The data sets are also adjudged to have desirable integrity for the anticipated assessment; and

iii. Literature reviews focusing on the applications of the various indicators under different conditions (Downing and Patwardhan 2004; Cutter *et al.,* 2000, 2003; O'Brien *et al.,* 2004: Lucas and Hilderink 2004; Brooks *et al.,* 2005; Patnaik and Narayanan 2005; Thornton *et al*., 2006).

The scores for the various indicators were aggregated and overall estimations considered using panel judgment in each case to control the errors that may come up with averaging the data. The assessments were also benchmarked as climate change is expected to impact various locations differently (e.g. Sivel *et al.,* 2008). To assess coastal environment, the matrix developed by Gornitz (1991) was used. The matrix contains five levels of vulnerability in relation to coastal parameters such as relief, rock type, landforms, sea level rise, shoreline displacement, tidal range and annual maximum wave heights in meters.

5.4.1 Calculating Vulnerability

Vulnerability is considered as a function of Adaptive Capacity, Sensitivity and Exposure. Following Gbetibo and Ringler (2009), the mathematical expression for this is:

$$V = f(I - AdC)$$

here:

V = vulnerability,

I = potential impact, and

AdC = adaptive capacity.

If vulnerability is a function of Adaptive Capacity, Sensitivity and Exposure, then Potential Impact (I) is the addition of Exposure and Sensitivity.

For *exposure,* three parameters, using water demand for agriculture and domestic purposes as a proxy, were considered. These parameters are actual and potential irrigation opportunities, rainfall trend and access to safe water. For rainfall, the beta coefficient of the linear regression of total annual rainfall with time from 1983 to 2008 was used.

The key input variables for *sensitivity* analyses were quality of dwelling units, fertilizer usage, home ownership, crop diversity and population density. A large number of socio-economic

and physical features are put in the model for the assessment of the *adaptive capacity.* For instance, level of education and access to health facilities were considered as measures of adaptive capability. The indicators and proxies are shown in Tables 5.3.and 5.4.

Table 5.3: Indicators of Proxy Variables used in Vulnerability Analysis

Type of Indicator*	Indicator	Scale of Analysis**	References
HHC	Level of education or literacy rate	HH, D, N	Haan *et al.,* (2001); Nyong *et al.*, (2003); Kuhl (2004); Paavola (2004); Brooks *et al.,* (2005);
HHC	Age	HH	Haan *et al.,* (2001); Naess *et al.,* (2006)
HHC	Labor unit/consumer unit	HH	Nyong *et al.*, (2003)
HHC	Assets, land value, house value standard)	HH, D	Moser (1998); Aandahi & O'Brien (2001); Nyong *et al.,* (2003);
HHC	Household size, female-headed households	HH, D	Nyong *et al.,* (2003); O'Brien *et al.*, (2004); Paavola (2004); Kuhl (2004)
HHC	Drinking water source	HH	Aandahi and O'Brien (2001); Paavola (2004)
HHC	Household members	HH	Adger (1996, 1999); Nyong *et al.,* (2003)
HHC	Non-farm income, diversity of income sources	HH, D	Haan, *et al.,* (2001); Eakin (2004); Ford, *et al.,* (2005)
HHC	Food Sufficiency	HH, D, N	Nyong *et al*., (2003)
HHC	Adjustment measures	HH	Ford *et al*., (2005)
BP	Soil Conditions	HH, D, N	O'Brien *et al.*, (2004)
BP	Current climate	HH, D, N	O'Brien *et al.*, (2004)
BP	Vegetation	D, N	Haan Farmer and Wheeler (2001)
INST	Social networks (member of group/ association)	HH	Nyong *et al.*, (2003); Ford *et al*., (2005)
INST	Institutional arrangements	D, N	O'Brien *et al*., 2004; Ford *et al.,* (2005)
FC	Livestock ownership	HH	Paavola (2004)

FC	Crop types, cropping systems, fertilizer use	HH	Aadahi and O`Brien (2001); Bantilan and Anupama (2002)
FC	Irrigation rate, irrigation source	HH, D	Aadahi and O'Brien (2001); O'Brien *et al.*, (2004)
BP	Drought and flood-prone areas	D, N	CIDA (2003); O'Brien *et al.*, (2004)
ECO	Percentage of households below poverty line	D	Adger (1996), Haan *et al*., (2001)
ECO	Percentage of households below poverty line	D	Adger (1996); Aandahi and O'Brien (2001)
ECO	Food expenditure	HH	Paavola (2004)
ECO	Infrastructure	HH, D, N	Haan *et al.,* (2001); O`Brien *et al.*, (2004);

Source: Nhemachena *et al.* (2006)

*Type of indicator: HHC = household characteristics, INST = institutional, FC = farm characteristics, BP = biophysical, ECO = economy

**Scale of analysis: HH = Household, D = district, N = national

Table 5.4: Vulnerability Indicators, Units of Measurement, and Expected Direction

Determinants of Vulnerability	Vulnerability Indicators	Description of Each Indicator Selected for Analysis	Unit of Measurement	Hypothesized Functional Relationship Between Indicator and Vulnerability
Adaptive capacity	Wealth	Livestock ownership, Ownership of radio, Quality of residential home, Non-agricultural income, Gift & remittance	Percentage of total population who own or have access to the selected wealth indicators	The higher the percentage of total population with asset ownership, and access to these income sources the lesser the vulnerability
	Technology	Insecticide and pesticide supply Fertilizer supply Improved seeds supply	Percentage of total population within 1-4 kilometers of supply sources	The higher the percentage of total population of the region within 1-4 kilometers, the lesser the vulnerability.
	Infrastructures and institutions	All-weather roads Health services Telephone services Primary & secondary schools Veterinary services Food market Micro-frame	Percentage of total population within 1-4 km of these infrastructures and institutions	The higher the percentage of total population of the region within 1-4 kilometers, the lesser the vulnerability
	Irrigation potential	Irrigation potential	Percentage of potential	The higher the irrigation potential, the lesser

			irrigable land irrigable land divided by total area)	the vulnerability
	Literacy rate	Literacy rate age 10 years and older	Percentage of total population	The higher the literacy rate, the lesser the vulnerability
Sensitivity	Extreme climate	Frequency of droughts and floods	Number of occurrences	The higher the frequency, the more the vulnerability
Exposure	Change in climate	Change in temperature & precipitation	Change delta (T) in degrees from base value (2000)	Increasing temperature and decreasing precipitation increase vulnerability

5.5 Measuring Vulnerability of Coastal Areas

The coastal areas of the country present a unique zone for vulnerability assessment. This derives from its distinctive ecology and the strong influence of the Atlantic Ocean on the dynamics of its physical environment. The vulnerability of the region is also related to the challenges of survival of its many communities in relation to increasing Sea Level Rise (SLR). Most analyses around the world support the view that SLR is the most important factor of change in the coastal environment.

As earlier indicated, the matrix developed by Gornitz (1991) was used (Table 5.5) in assessing the vulnerability of the coastal environment. The matrix contains five levels of vulnerability in relation to coastal parameters such as relief, rock type, landforms, sea level rise, shoreline displacement, tidal range and annual maximum wave height.

Table 5.5: Matrix for determining coastal vulnerability index

Category	Very low	Low	Moderate	High	Very High
COASTAL PARAMETERS	1	2	3	4	5
Relief (m)	≥30.1	20.1 - 30.0	10.1 - 20.0	5.1 - 10.0	< 5.1
Rock Type	High-medium grade metamorphic	Low grade Metamorphic sandstone	Mostly sedimentary rocks	Coarse unconsolidated sediments	Fine unconsolidated sediments
Landforms	Rocky, Cliffed coasts	Medium cliffs, Indented coasts	Low cliffs, Salt marsh, coral reefs, mangrove	Beaches (pebbles), Estuary, lagoon	Barrier and bay beaches, mudflats, Deltas
Sea Level Rise Change (mm/Year)	≤-1.1 'Land rising'	-1.0 – 0.99	1.0 – 2.0	2.1 – 4.0	≥4.1 'Land sinking'
Erosion/Deposition Rate (m/Year)	≥2.1 accretion	1.0 – 2.0 stable	-1.0 – 1.0 erosion	-1.1 - -2.0 erosion	≤-2.1 erosion

Adapted from the coastal risk classes of Gorntiz (1991)

5.6 Uncertainties

There are a number of uncertainties in estimating vulnerabilities. These include government policies which can affect the characteristics of key indicators such as home ownership, health care delivery, fertilizer utilization, sanitation, water supply and maintenance of facilities. It is also unknown whether the quality of the irrigation infrastructures can sustain cropping into the future. The trends in temperature and rainfall distributions are known from the analysis presented in table 5.1 above. However, their future behaviours are uncertain.

CHAPTER SIX

VULNERABILITY TO AND IMPACT OF CLIMATE

6.1 Introduction

This chapter presents the vulnerability to, and impact of, climate change on Nigeria. It attempts to evaluate the extant and potential impacts of climate change on the country's ecological system and the associated socio-economic infrastructures; and examine its vulnerability to climate change.

6.2 The Concept of Vulnerability

Vulnerability is "the extent to which a natural or social system is susceptible to sustaining damage from climate change, and is a function of the magnitude of climate change, the sensitivity of the systems to changes in climate and the ability of the systems to adapt to changes in climate" (IPCC, 2000). Turner *et al.,* (2003) extended this idea by relating the concept to three overlapping properties: exposure, sensitivity and adaptive capacity

6.3 Adaptation

An understanding of vulnerability is crucial to deploying adaptation strategies. Adaptation refers to adjustments in ecological, social or economic systems in response to actual or expected climatic stimuli and their effects (Smit *et al.,* 2001). It is the process by which people reduce the adverse effects of climate change on their socio-economic well-being, and take advantage of the opportunities emerging from the changes in climate (Burton, 1992). *Adaptability* is the degree to which adjustments are possible in practices, processes, or structures of systems to climate change. Building *resistance* and *resilience* contributes to adaptation, as does the *readiness* to exploit on the potential opportunities.

6. 4 Impacts of Climate Change

Impacts are residuals of autonomous responses to vulnerabilities in natural systems. There are however*, potential* impacts which are estimated by projecting climatic conditions into the future and taking into consideration projected vulnerabilities. It follows that knowledge of possible and potential adaptation options is crucial to assessing the vulnerabilities to and impacts of climate change in a country or community (Smit *et al*., 1999; Pittock and Jones, 2000). It is therefore important to consider in an integrative manner, the three phenomena i.e. Vulnerability, Impact and Adaptation. This is the approach used in this assessment.

6.5 Evaluating Vulnerability and Impact Assessment

The assessments here are all tied to agricultural productivity because of its significance in the socio-economy of the country. Agriculture sector employs a larger proportion of the nation's population. The assessment involves extracting data from various sources and projections for each geopolitical zone on vulnerability indices. The parameters considered are already described in chapter 5.

6.6 Vulnerabilities in the Various Sectors

6.6.1 Coastal vulnerabilities

Data for the main parameters were assembled from documentary sources including topographic maps of the region. The TOPEX/POSEIDON altimetry data were also accessed to

define rates of sea level rise per annum. The sea levels ranged from about 2mm in areas around Lagos in the west, 3mm in Warri to about 5mm in Calabar to the east. Landform characteristics were quantified and ranked based on information from the literature (Iloeje, 1981; Matthews, 2002). The rock-types of the region belong to the Sedimentary formation and are therefore largely homogenous for the most parts of the coastal region. The dominant landforms are beaches/lagoons, barrier, bay beaches and delta (Folorunsho, 2010). Talbot (1910) provided useful information about landforms of the eastern end of the country's coast. The three locations used as sampling sites i.e. Lagos, Warri and Calabar have similar values for relief, rock types and erosion/deposition. With respect to erosion indices, erosion is far more severe in the Strand Coast (Figure 6.1) than in the Niger delta. It is 4.6-20.7% for the Strand Coast, while it is 0.8-3.5% for the delta (Awosika *et al*., 1992; French *et al*., 1995).

Table 6.1: Coastal Vulnerability

Vulnerability Index	Locations and Vulnerability Scores			
	Lagos	Warri	Calabar	Overall Average
Relief	5	5	5	5
Rock type	4	4	4	4
Landform	4	5	3	4
Sea Level Rise	3	4	**5**	4
Erosion/Deposition	5	5	5	5
Average	4.2	4.6	4.4	4.4

1= Very Low; 2= Low; 3= Moderate; 4= High and 5= Very High.

Table 6.1 shows a characterization of the vulnerability factors of the environment while Figure 6.2 depicts a spatial pattern of vulnerabilities along the coast. The landform characteristics and the rate of sea level rise vary. The indices for landforms are lowest around Calabar and highest around Warri. Also, the index for SLR is highest around Calabar and lowest around Lagos. Warri which is located within the Niger delta has the highest overall vulnerability, and the Niger delta as a sub-region has the largest spread and depth of vulnerabilities in the South-south geopolitical zone of the country. Many

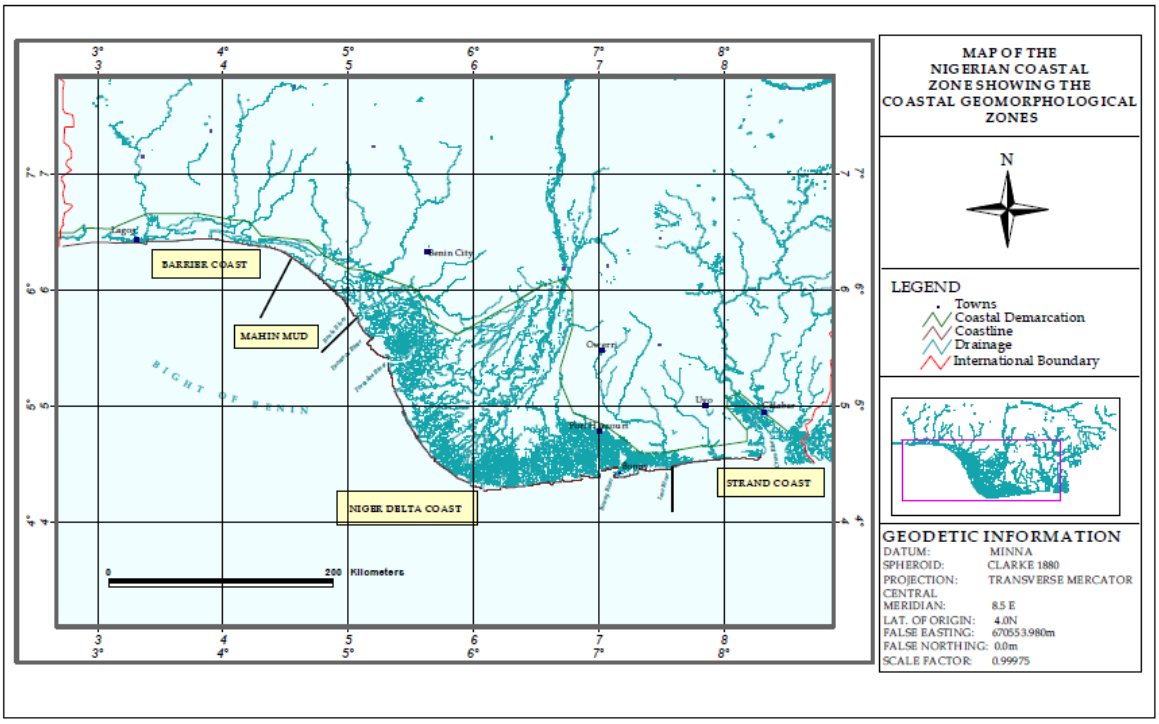


Figure 6.1: The coastal areas of Nigeria

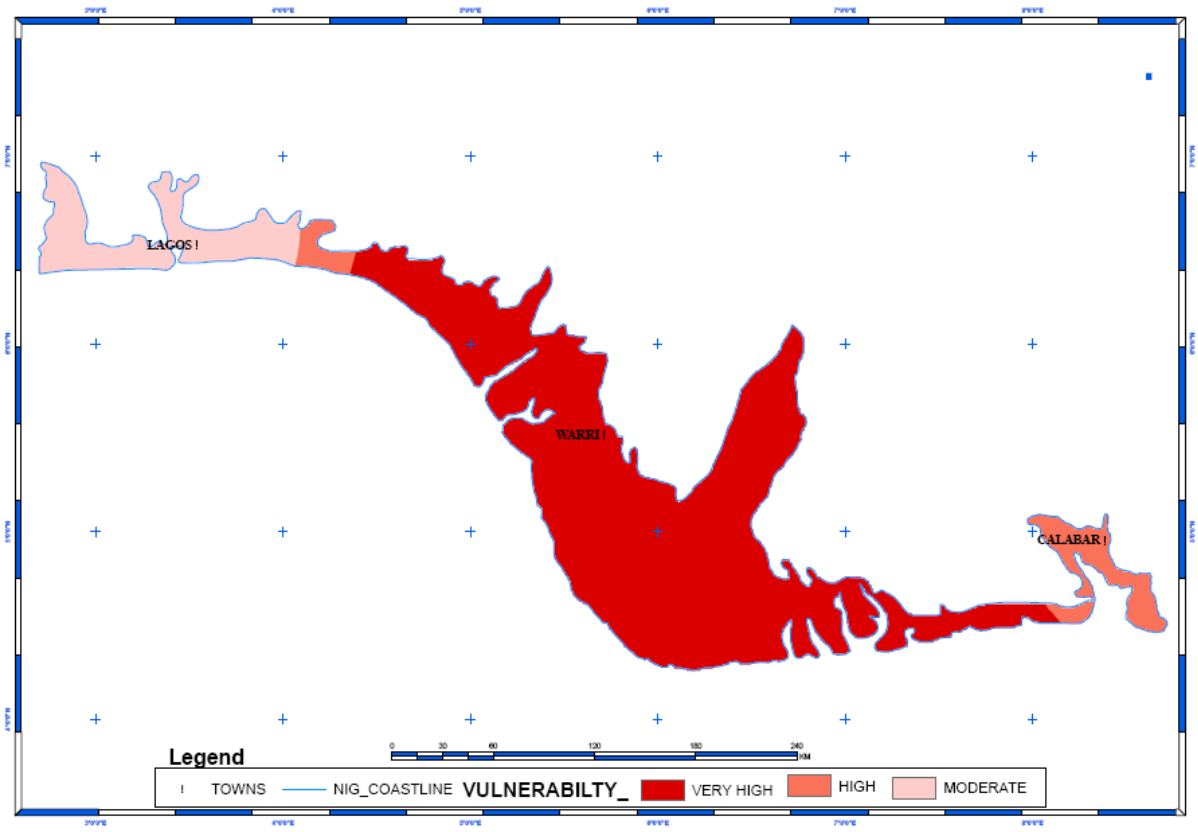


Figure 6.2: Spatial variation in the relative vulnerabilities along the coast

Studies (Okude and Ademiluyi 2006; Etuonovbe 2008; Uyigue and Agho, 2010) have alluded to this, surmising that the greatest challenges of climate change along the coast are expected in The Niger delta.

Inundation by ocean water is the most important threat to the coastal land. Up to 600 km^2 of land could be impacted with a metre rise in sea level in the region (Awosika *et al.,* 1992 and French *et al.,* 1995). This land area includes substantial parts of Lagos, Warri, Port Harcourt and other coastal cluster of communities in the Niger delta.

6.6.2 Vulnerability over Nigeria's mainland

The analyses of vulnerability over the mainland are first presented at three component levels: adaptive capacity, sensitivity and impact. A summary of vulnerability pattern in the country's geographic space is then computed.

6.6.2.1 Adaptive capacity

Adaptive capacity is a function of several parameters, which may be summarized under *wealth*, *access to technology* and *infrastructures*. The variability in the adaptive capacities across the country is shown in Figures 6.3a & b. The Northeast zone has the least adaptive capacity followed by the Northwest. It is highest in the Southwest, followed by the Southeast. The pattern is generally consistent with the geography of the country. For example the vastness of the land area in the Northeast tends to 'thin' out what could be described as adaptive capacity in the zone, whilst compactness and historical development trends in the Southeast and Southwest put the two of them ahead of other zones. The implication of these analyses is that climate change response should continue to be implemented in such a way that they are flexible and sensitive to spatial variations over the country's space.

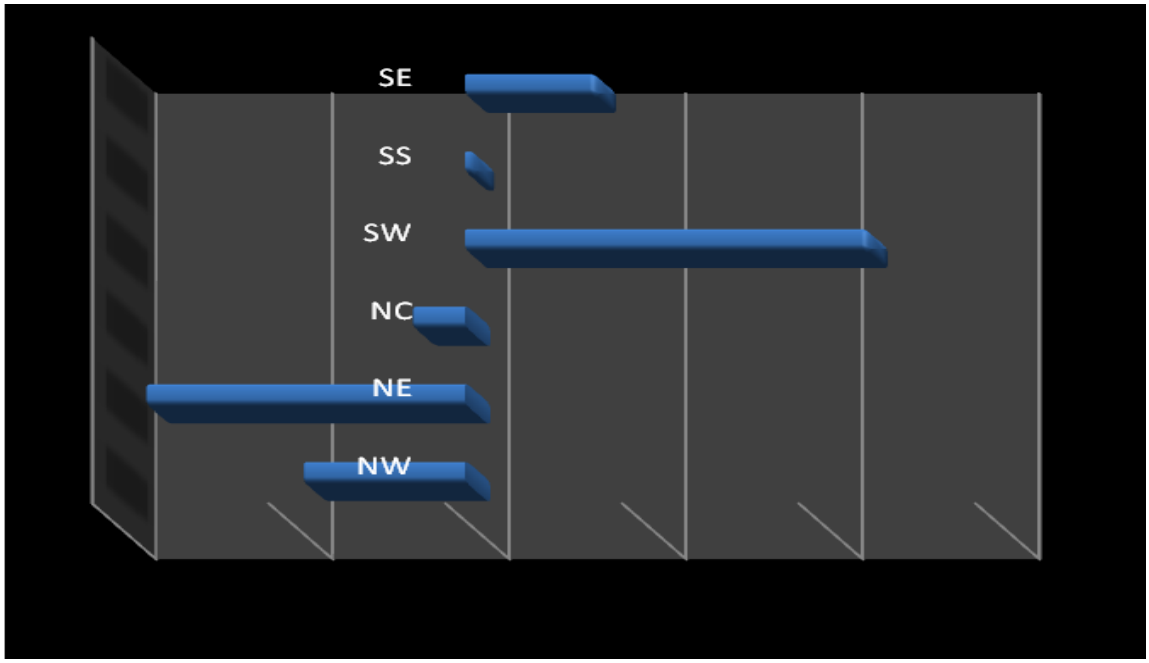


Figure 6.3a: Graphic Analysis of relative adaptive capacity for climate change in Nigeria

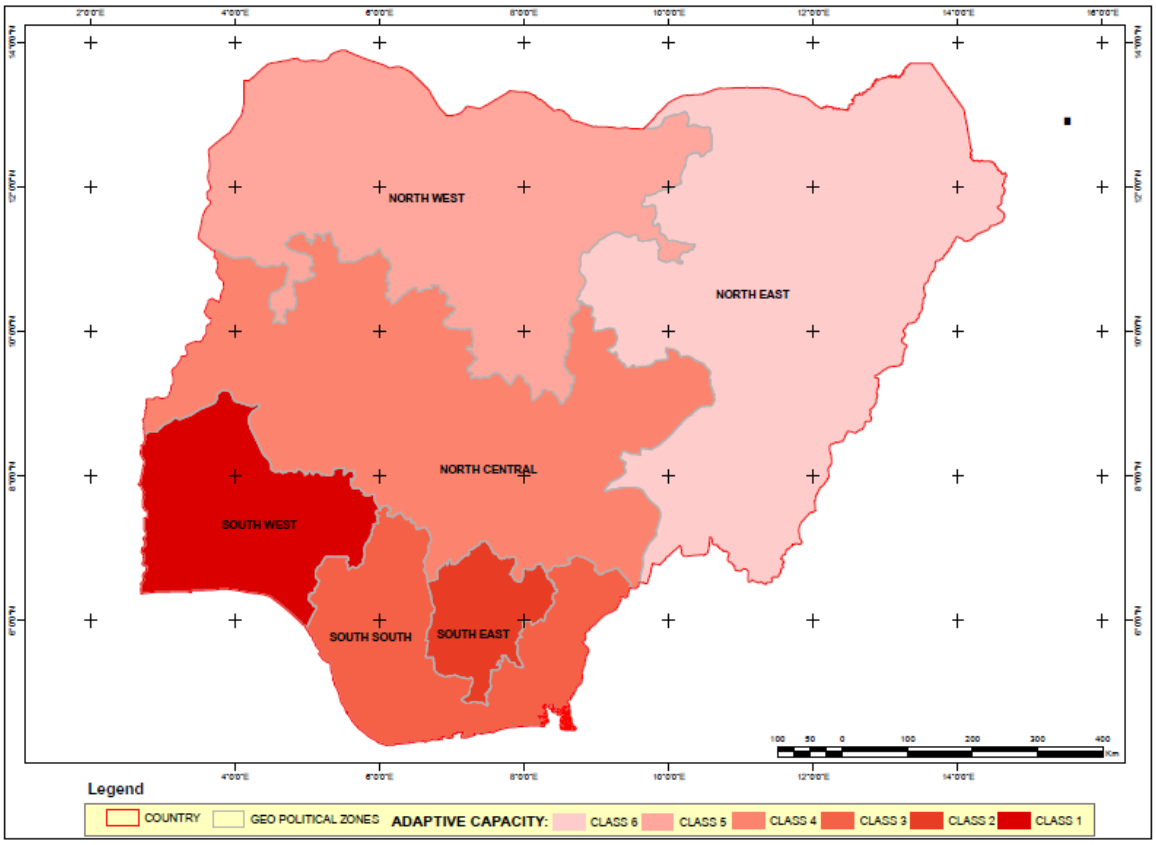


Figure 6.3b: Spatial Variation in relative adaptive capacity for climate change over Nigeria

6.6.2.2 Sensitivity to Climate change

Sensitivity to climate change relates to how readily a particular system such as agriculture would react (usually negatively) to changes associated with climate. Generally, the main category of factors of sensitivity is climatic extreme. This could be drought, floods, or reduced amount of rainfall in a particular season (Figures 6.4a & b). Of the six zones, the North-central has the lowest sensitivity and the South-south the highest. The lower sensitivity in the North-central is probably associated with its relatively stable seasonal rains. This rainfall attribute emanates from the fact that this zone usually enjoys sufficient incursion of the moisture laden wind and a relatively longer period of ITD band of rainfall that promotes copious rainfall. These lakes provide opportunities for all year round irrigation agriculture in the sub-region and help to compensate somewhat for rainfall that could be below expectation (Henderson-Seller and Robinson, 1988). The high sensitivity of the Southeast zone is connected with the porosity of its soils. Consequently, even a short dry period normally have severe effects on availability of soil moisture. Adaptation must focus on such actions that would help to lessen the sensitivity of systems in the different zones in the country.

6.6.2.3 Exposure parameter of Vulnerability

Exposure refers to the extent of climate stress to which a particular unit or system is exposed. Figures 6.5 a & b show the relative exposure of the various parts of Nigeria. The least exposed is the Southwest while the most is the Northeast. However, the Southeast is almost as exposed as the Northeast. Two issues are important in this purview. The first is

that exposure to climate change is not a regional phenomenon in terms of north/south dichotomy: it is a national as well as global phenomenon. The second is that exposure factors must be addressed in every part of the country. For instance, rainfall decline which would affect water supply in rain fed agriculture is an exposure issue that is of priority in the north while water loss due to high soil porosity is a major concern in the Southeast.

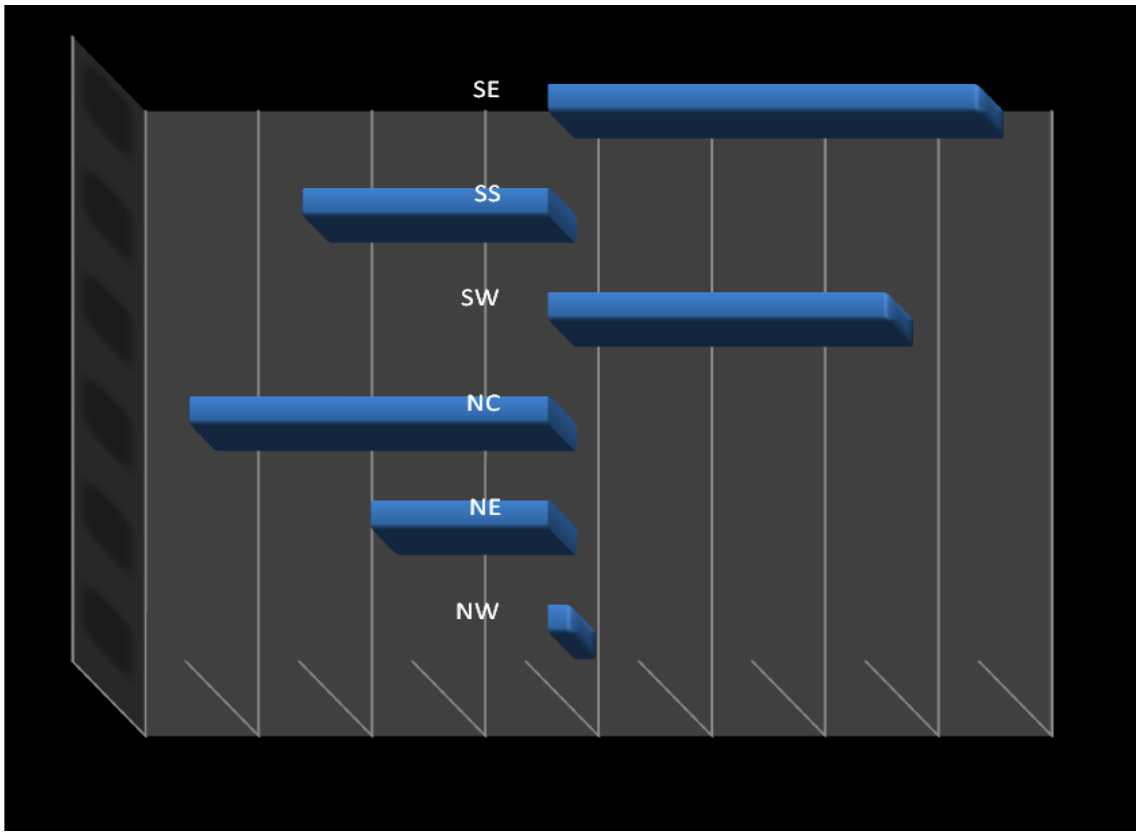


Figure 6.4a: Graphical analysis of relative sensitivity of different zones to climate change in Nigeria.

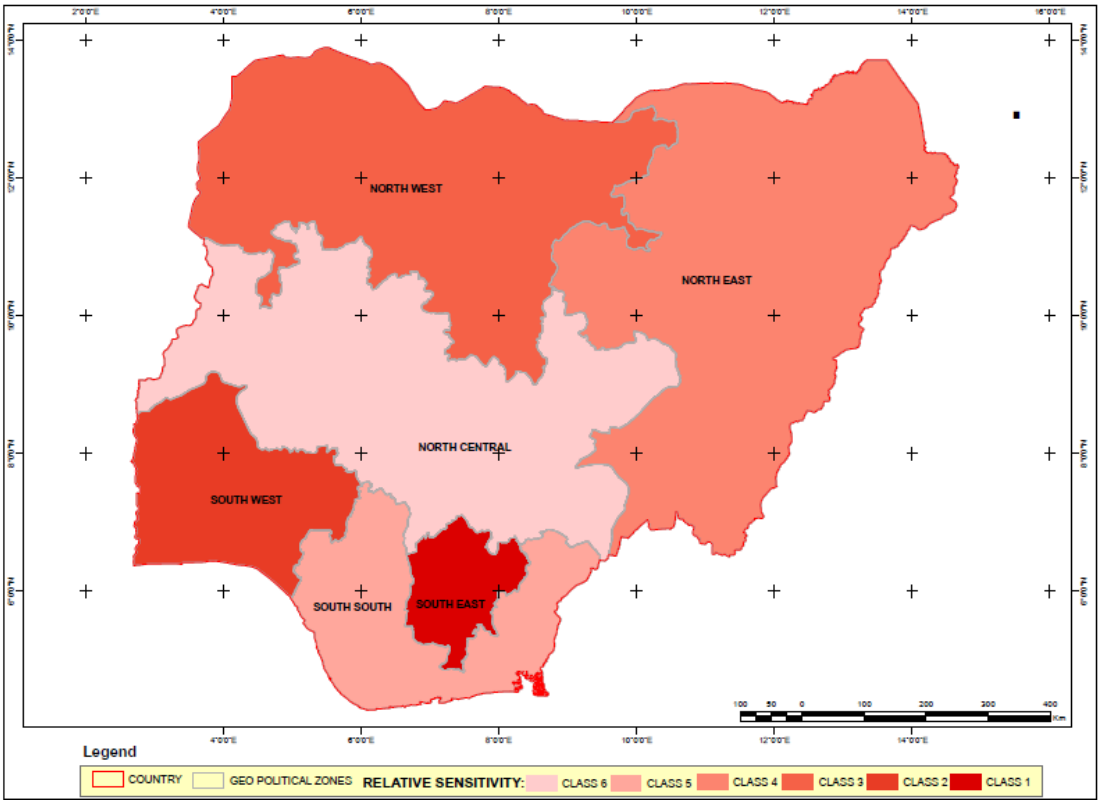


Figure 6.4b: Spatial Variation in Relative sensitivity to climate change over Nigeria

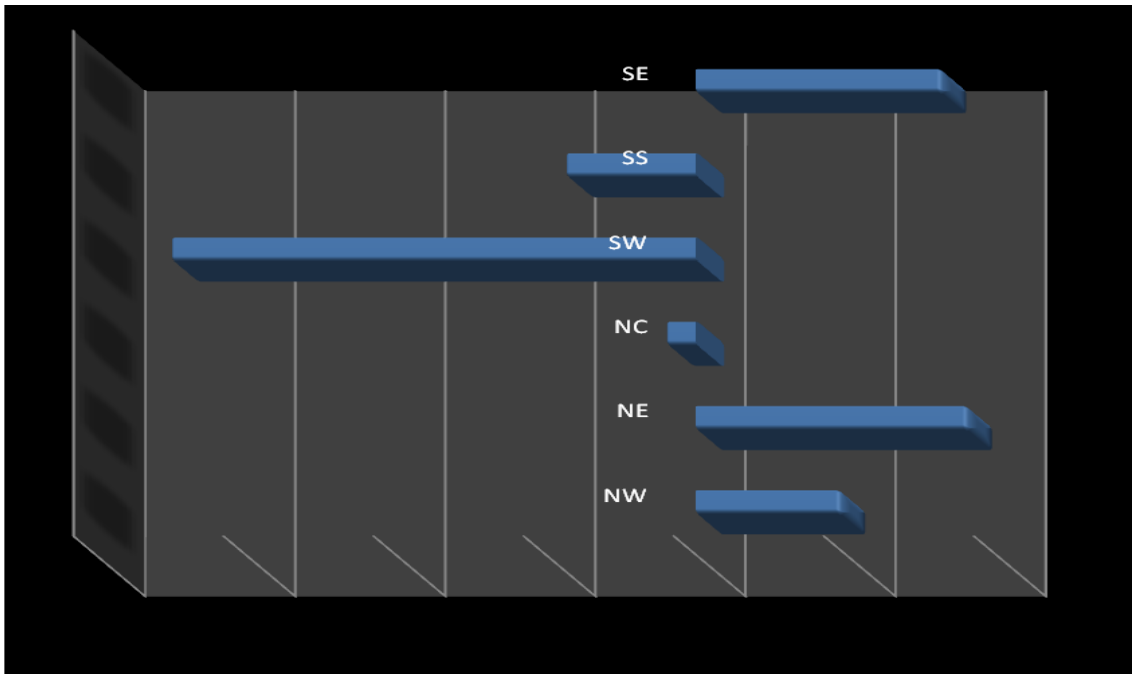


Figure 6.5a: Graphic analysis of relative exposure to climate change in Nigeria.

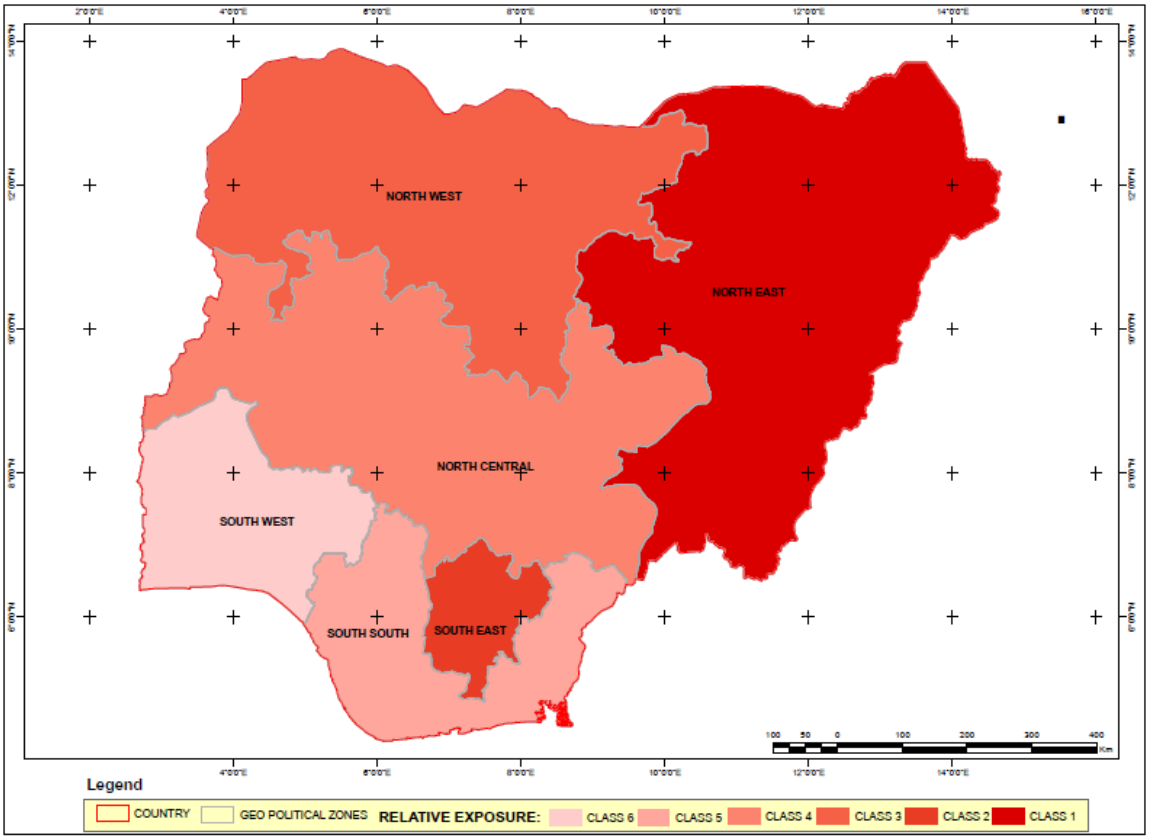


Figure 6.5b: Spatial Variation in relative 'exposure' to climate change over Nigeria

6.7 Vulnerability to Climate Change

Figures 6.6a & b depict the vulnerability values for the six geopolitical zones of Nigeria. The Southwest is relatively the least vulnerable with the three zones in the north having higher vulnerabilities. The South-south is the most vulnerable of the three zones in the south. This is most probably linked with the challenges of coastal flooding and erosion as well as problems associated with petroleum exploration in that part of the country.

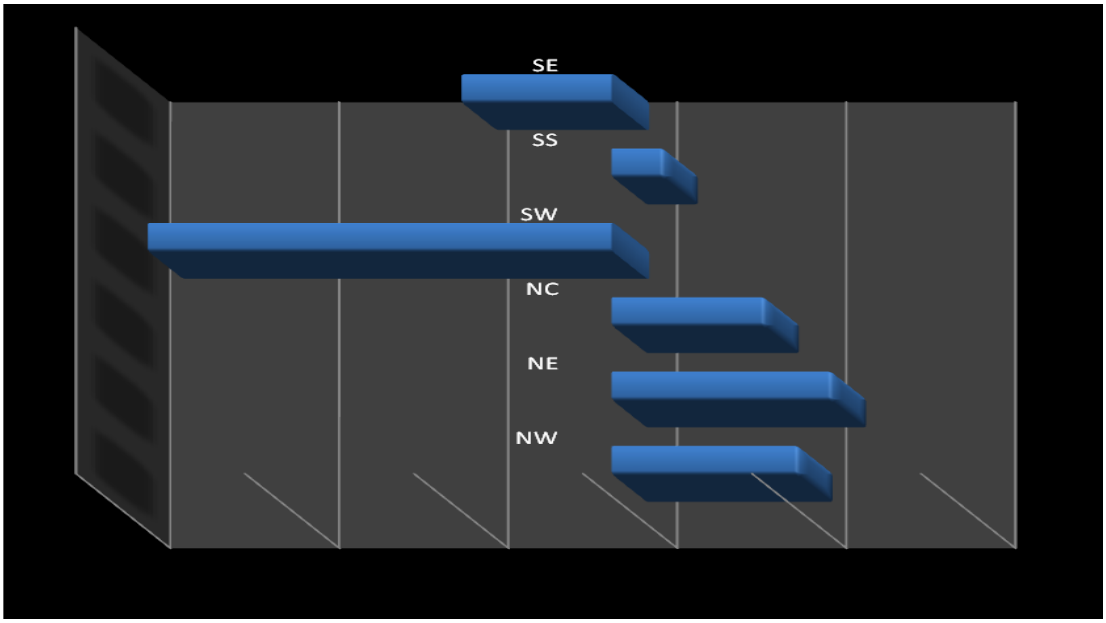


Figure 6.6a: Graphic Analysis of relative vulnerability to climate change in Nigeria.

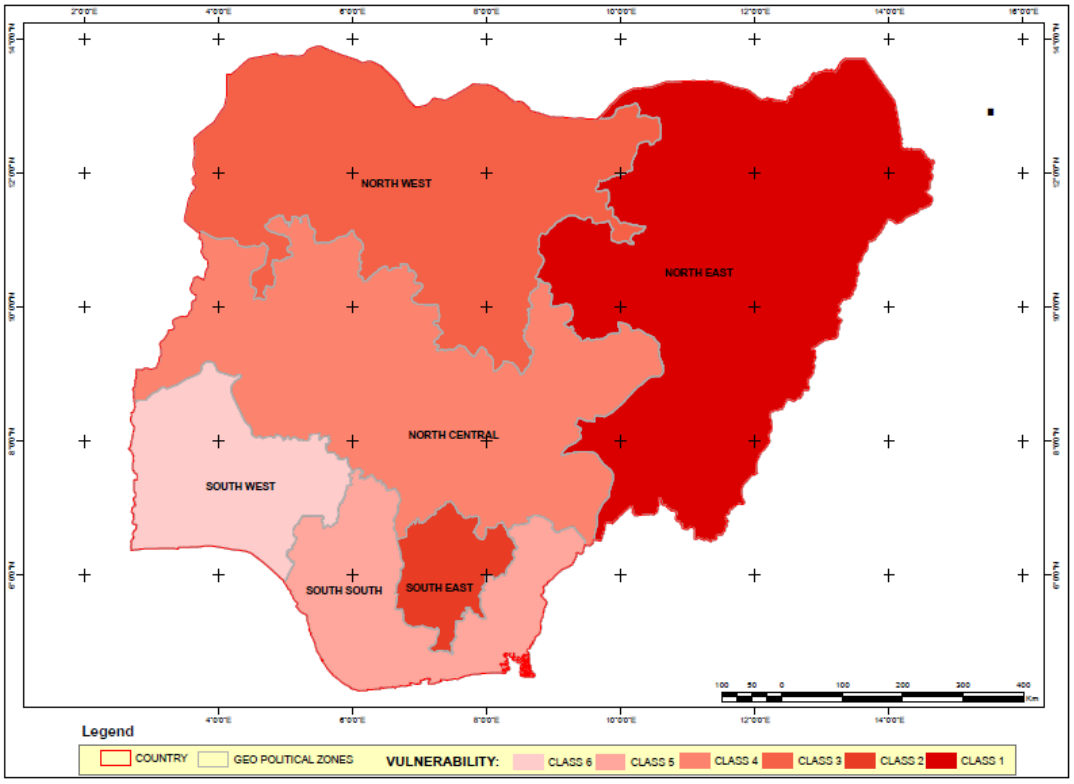


Figure 6.6b: Spatial Variation in relative vulnerability to Climate Change over Nigeria

6.8. Conclusion

The foregoing shows that the challenges associated with the climate change are not the same across the country. The Southwest and Southeast are relatively less vulnerable than most other parts of the country. On the other hand, the Northeast is the most vulnerable. The extreme vulnerability of the Northeast is associated with extant conditions such as the decline of socio-economic activities around Lake Chad and the loss of the erstwhile flourishing Hadejia-Nguru wetlands. The understanding of these is crucial to efficient deployment of adaptation actions, which are presented, in the next chapter.

CHAPTER SEVEN

ACTIONS TO ADAPT TO IMPACTS OF CLIMATE CHANGE

7.1 Introduction

This chapter presents a suite of adaptation options that are being used or can be deployed in the various sectors of the country's socio-economy based on extant and potential vulnerabilities to climate change. Among other things, it describes the significance and appropriateness of the different adaptation options. For Non-Annex 1 Party countries, this component is critical in responding to the UNFCCC. Considerable attention has thus been devoted to addressing key issues relating to it.

7.2 Water Resources

7.2.1 Issues in the Sector

Nigeria has a vast expanse of fresh water surfaces of more than20 million hectares. These are capable of yielding more than 214 cubic kilometres of fresh water (Earthtrends, 2003). The fresh water resources include some 200 dams storing more than 31 billionm^3. About 53 cubic kilometres is additionally available from groundwater and rainfall. Despite these, the country is highly vulnerable in the area of fresh water supply. Water supply has not been able to meet demands for domestic, industrial and agricultural purposes (Figure 7.1). Only about 52% of the urban and 39% of rural dwellers have access to potable water (NBS, 2006).

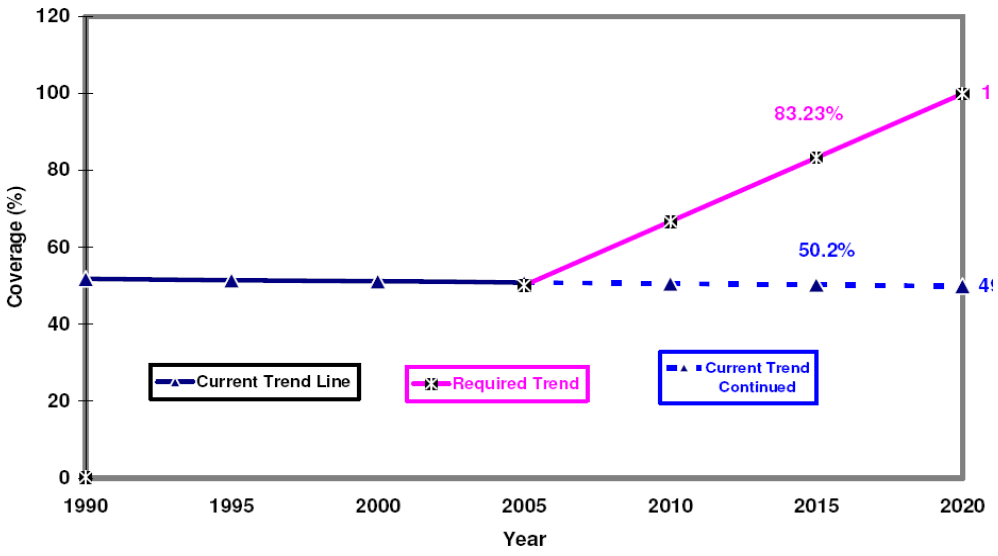


Figure 7.1 Projected Trend in water supply in the country (Vision20: 2020).

Industrial packaging of water, which is providing jobs for many in the different parts of the country, has become a significant feature of domestic water supply. However the disposal of its empty sachets and bottles has been a challenge in the environment. There are also direct health effects of poor water supply in the spread of water borne diseases such as *Schistosomiasis* and *Onchocerciasis* in many areas.

The vulnerability in the water sector is affected by a number of factors the most important of which include changing climate; declining trends in the in-flow of water into dams due to lengthening dry seasons, increase in flooding incidences especially along the Niger and Benue valleys and the country's limited rural water distribution infrastructure which is hampering efficient community level use of its water resources for irrigation; the pollution of fresh water sources mainly through the disposal of domestic and chemicals wastes into them and the widespread occurrence of floating weeds such as water *Eichhorniacrassipes*, *Pistiastratiotes* and *Typhalatifolia* in drainage channels and lakes.

With respect to the changing climate, both minimum and maximum temperatures have been increasing over the last few decades and could increase significantly further, into the future in the three climatological belts i.e. Sudano-Sahelian, Guinea savannah and the Forest belts. For instance, the mean minimum temperature is projected to rise from 20.75^{o}C in the climatological period of 1961 to 1990 to 23.21^{o}C in 2030 over the Sudano-Sahelian region. The trend is similar in the two other belts. From the rainfall trends, some decrease is anticipated in annual amounts from the value in the climatological normal period of 1961 to 1990 up to Year 2030.

Another factor is the declining trends in the in-flow of water into dams due to lengthening dry seasons (Mark *et al.,* 2007; Nyong*et al*., 2008). This has been amplified by increasing demand for irrigation water upstream (e.g. Karyabwite, 2000). Also, the increase in flooding incidences especially along the Niger and Benue valleys is a major concern. The losses due to flood have continue to rise as the cost of making appropriate amendments increases. The country's limited rural water distribution infrastructure is hampering efficient community level use of the huge water resources of the country for irrigation. Fresh water sources are polluted mainly through the disposal of domestic wastes and chemicals into them. Oil spills kill shore life and other aquatic life forms. Several communities in the Niger delta continue to suffer the negative effects of oil spills (Plates 7.1a-c). Pollution from industrial effluents is significant in large industrial/commercial cities like Lagos, Port Harcourt and Kaduna. The isolated industries in the different parts of the country are also significant water polluters.

Plate7.1a: Aftermath of oil spill in a part of the Niger Delta

Plate7.1b: Impact of oil spillage in a part of Delta State.

Plate7.1c: Devastation of the Mangrove due to oil pollution

The widespread occurrence of floating weeds such as water *Eichhorniacrassipes*, *Pistiastratiotes* and *Typhalatifolia* in drainage channels and lakes contribute to water loss, inhibit fish breeding and harvest, and reduce the navigability of water ways.

The challenges in the water resources sector have serious negative impacts on the socio-economic activities and infrastructures. Already, in many parts of Northern Nigeria, fresh

water fish production has declined as several fishing sites collapsed (Welcomme, 2003). Also, HEP production has continued to suffer frequently from low in-flow into major dams particularly Kainji, Shiroro and Guarara. Inland waterways have remained little developed and further impacted by climate-related factors. Low flows stall movements of boats in the dry season and siltation is increasingly a challenge even in the rainy season.

7.2.2 Adaptation Strategies

To contain the challenges in the water sector, there is a wide range of adaptation options some of which is already being applied and requires only intensification. These include:

7.2.2.1 Enhancement of Research in Water Resources Management and Development.

This requires among other things, empowering the National Institute for Water Resources (NIWRI) and other agencies under the Federal Ministry of Water Resources, Research Institutes as well as universities in the country to focus research on strategies for optimizing the use of the country's water resources. Some of these agencies already have mandates that address the issue. They only need to be monitored for better focus on addressing the challenges of adequate availability of fresh water supply in the country. The cost is in the medium range but is of high priority.

7.2.2.2 Reducing Water Loss from Dams

Larger water surfaces characteristic of many of the dams such as Kainji, Challawa, Tiga and Bakolori, support dis-proportionally larger volumes of evaporation. This needs to be curtailed in any new water scheme development. Further investment on water impoundment, which is needed in many parts of the country, should focus on relatively smaller size dunits to minimize loss of water due to evaporation. The cost is high and the option is crucial in many areas.

7.2.2.3 Controlling evaporation with biodegradable suppressants

Suppressants can reduce evaporation by up to 40% and has been tried on parts Lake Chad with some success. The use of the method is not expensive but most applicable where the water surface is not too large as suppressants solidify relatively quickly when applied. It is of high priority in the Sudano-Sahel environment of the country. The financial demand of implementing this will be in the medium range.

7.2.2.4 Adopting efficient irrigation system

The cheap furrow irrigation method is common in the country (e.g. Plate 7.2). However, it is inefficient. Huge volumes of water are lost through infiltration and evaporation. More efficient irrigation methods such as drip irrigation (DI) are needed. DI delivers the right quantity of water at the right time and can increase yields by up to 70%, with lesser water than the traditional methods (Bhattarai et al., 2002). However, it is expensive. The option is useful everywhere but particularly in the Sudano-Sahelian belt. Its financial implication is medium to high but it is of very high priority.

Plate 7.2: Characteristic open channel irrigation in Nigeria

7.2.2.5 Enhancing storage of water in reservoirs.

Storages in the reservoirs can be enhanced using three key strategies:

i. Vegetating the watersheds. This will stop further silting of dams. It can be achieved through re-vegetation and protection vegetation in the water sheds as well as control of farming in critical areas ;

ii. Reinforcing the banks of reservoirs; and

iii. De-silting of the reservoirs.

This option is applicable in every part of the country and costs will vary depending on location and size of dams/water treatment sites. Re-vegetation components of the option can be integrated intoon-going afforestation programmes in many states of the Federation.

7.2.2.6 Expanding water harvesting for agricultural and domestic purposes.

Although the sizes of Nigeria's aquifers are not well known, a large stock of water exists underground that can be tapped in many parts of the country (Somers 2007; Tarhule 2007). As a climate change adaptation response, drilling of boreholes will provide additional clean and safe water. Although boreholes are expensive to drill, when they are located on rich aquifers, they are dependable. The option is viable in many parts of the country. It is of high priority especially in the Sudano-Sahelian areas with long dry seasons.

7.2.2.7 Protecting water bodies from further pollution.

This option is crucial to curtailing silting-up and ensuring that relatively clean water can be obtained from the water sources. Relevant Government agencies have major roles to play here. Oil companies should upgrade their safety procedures and protocols for waste

management to prevent disposal of oil into water bodies. There should be continued awareness creation on the consequences of oil pipe vandalisation and other actions that can dangerously compromise the quality of water available in the different communities. These measures are applicable in all parts of the country. Their costs are in the medium range but of high priority in all areas.

7.2.2.8 Adopting hardier and early maturing fish species.

To address the threats to fish production especially in the Sudano-Sahelian areas, focus should be on cropping hardier and high yielding varieties of fish. This will ensure increased local fish production. The research institutes are important here. They would need support from government to fund relevant studies and dissemination of findings. The cost is relatively low but priority is high. Apart from meeting protein needs it will also enhance economic engagement for people interested in it.

7.2.2.9 Clearing of water weeds

Regular clearing of water weeds is necessary. Arts and crafts that depend on such weeds should be promoted as a way of encouraging demand-driven harvesting of the weeds. Also, research on the use of water weeds for bio fuels should intensify. The cost is in the medium range and the adaptation option is of high priority in all parts of the country. The responsibility of doing this is that of the government and the local communities.

7.2.2.10 Regular Fish culling

This strategy would help to reduce fish population and enhance harvests. It however requires the provision of storage facilities. The cost is in the medium to high as energy is needed for preservation and this can be expensive. The priority is in the medium range. The individuals and communities are responsible with assistance from government in the area of storage.

7.2.2.11 Recycling of waste water particularly for peri-urban agriculture.

This would provide additional water and address sanitation challenges in local areas especially in the drier belts. The challenge of dealing with the domestic and industrial waste is an opportunity, and a resource, for sustainable livelihood. Water recycling is of high priority especially during the dry season. It is attainable and relevant in all major centres of population in the country http://www.earthmagazine.org/article/drinking-toilet-water-science-and-psychology-wastewater-recycling.

7.2.2.12 Strengthening the Fadama Project

This involves further expansion of the Fadama project, which has become a success story in cooperative farming. It would enhance livelihood of poor farmers and improve food production. The option is of medium priority and cost is also in the medium range.

7.2.2.13 Inter- and intra-basin water transfer

Water transfers are helpful in re-distributing freshwater. It is however expensive and requires substantial political understanding especially when different distinct communities are involved. As the environment becomes critically drier in some places, adopting this option will help the nation's supply of fresh water. The responsible agency is the Ministry of Water Resources through the River Basin Authorities. Inter-basin transfer will be of low

priority in many areas whereas intra-basin transfer will be very relevant and of high priority in many parts of the country.

7.2.2.14 Effective Control of the Production of "pure water" (sachet water)

The widespread production of drinking water in sachets and bottles is helpful in dealing with unemployment in the country. However it needs to be effectively controlled using available legal instruments. This will reduce the circulation of poorly packed water and checkmate the littering of the environment with empty sachets and bottles. A complimentary strategy is to invest in efficient municipal water supply that will deliver clean water through pipes. The communities and governments have to partner in implementing this option, and it is of high priority.

7.3. Agricultural Sector

7.3.1 Crop Production

Most of the critical challenges in the agricultural sector arising from climate change are connected with water resources. However, certain features make it compelling to treat agriculture as a separate entity. These include increasing crop failure and or loss of yields due to false start or outright failure of rains, frequent prolonged dry spells during growing seasons, early cessation of rains, crop damages by storms and floods, rising temperatures and pest infestations.

There is a growing food crisis in the country. The country depends heavily on food imports. Malnutrition is widespread and the poor is especially vulnerable to chronic food shortages, unbalanced nutrition, erratic food supply, poor quality foods, high food costs, and sometimes total lack of food (FAO 2006).Given this precarious situation, crop failures and yield losses would only continue to exacerbate the problem creating greater health concerns. They would also have impact on several economic activities associated with processing, distribution and sale of food items and allied products. Throughout the country and in particular in the southern areas, land misuses adding other dimensions to the challenge in the sector. Rapid population growths are causing new areas to be opened up for urban land uses and agriculture. Consequently more and more of the natural areas is lost every day.

7.3.2 Adaptation strategies

Some of the probable adaptation strategies that can be adopted in addressing the challenges in this sector include

7.3.2.1. Expanding and optimizing irrigation infrastructures

Irrigation facilities are limited in the country as only about 1% of irrigable land is irrigated. Fortunately Nigeria has *a National Policy on Irrigation, which* can assist in the effort to expand irrigation facilities. This measure is appropriate in most parts of the country and is of high priority as rain fed agriculture becomes unreliable. It is however financially demanding. Government and the private sector have major roles to play in implementing the option.

7.3.2.2 Adopting drought-tolerant and early maturing varieties of crops

This option would guarantee profitable crop harvest under reduced water supply from rain and or prolonged dry period during the rainy season. It holds great prospects in many ecological regions of the country. The measure is desirable in most areas and therefore of

high priority. It requires medium level financial commitment. Government and research institutes are important.

7.3.2.3 Diversifying livelihoods to improve income.

One aspect of Nigeria's vulnerability is the high prevalence of poverty associated partly with narrow options for coping with economic shocks by the poor. This can be reduced by developing capabilities for livelihood diversification. Government and its agencies such as National Poverty Eradication Programme (NAPEP) and Institutes of Entrepreneurship are important in this respect. NGOs, research institutes as well as the various communities also have roles to play. The option is of very high priority and can be of medium cost.

7.3.2.4. Increasing and upgrading storage facilities for harvests

Nigeria currently meets only a small fraction of its expected grain reserve level for guaranteed national food security (Famine Early Warning Systems Network 2008). As storage facilities are limited, substantial harvests are wasted and or sold at low prices by farmers. Nigeria may be losing about 2.4 billion tonnes of food yearly to poor storage facilities (Olumeko, 1999). In the Grain Strategic Reserve plan, each of the 774 LGAs in the country is expected to have a silo (AU, 2008). The option of expanding storage facilities is relevant in every part of the country and is of high priority.

7.3.2.5 Provision of efficient weather forecasting

The Nigerian Meteorological Agency (NIMET) produces weather information from time to time. This is usually documented in the Agency's Annual Climate Review Bulletin and broadcast every day. NIMET needs to continue to upgrade its facilities to make more robust and reliable forecasts. This would include increasing the density of synoptic stations to meet WMO's specifications. It would also involve expanding the capability of the Agency to disseminate weather information in vernacular and timely to farmers at the grassroots. The option is of very high priority for every part of the country and the cost is medium to high.

7.3.2.6 Effective Pest Control– insects and birds

This is essential to minimizing harvest losses. Pests such as locusts often operate along ecological zones, which traverse national boundaries. Thus controlling them requires joint efforts of countries in a region. It is necessary to keep track of various regional understanding on this to make rapid joint action possible when necessary. The responsible authorities are international agencies and government and the measure is important everywhere but especially in the north. It is of high priority and the cost of implementation high.

7.3.2.7 Using cover crops to protect soils

A major impact of soil erosion is the removal of valuable top soil, which renders the soil poor for crop production. Spreading crops like potatoes, melon and groundnut can be integrated in the farming cycle to control the loss of topsoil. The option can be adopted in every region of the country. It is low-cost and of high priority.

7.3.2.8 Stabilizing gullies and erosion sites

Expanding gullies especially in the north-east (e.g. Hurault, 1998) and the south-east zones are a serious threat to food production as well as human settlements. Gullies can be stabilized using cover cropping and mechanical methods. Also a resettlement of people on

severely threatened locations is a strategy that should be explored. The options are relevant and of high priority particularly in the severely affected locations but the costs are high. The implementers are government agencies, NGOs and local communities.

7.3.2.9 Improving Monitoring and Evaluation of Agricultural Programmes

M&E is crucial to determining the progress and success of intervention programmes. Measurable indicators have to be developed to assess the various efforts. The actors are the farmers, extension officers and line ministries. The cost is in the medium range and the option is of very high priority.

7.3.2.10 Providing Agricultural Insurance

Although the insurance sector is becoming weary of taking up risks in climate-related ventures, the sector has a role to play in helping local people adapt to climate change in Nigeria. The insurance sector needs to be strengthened to assist farmers particularly at the group level to cope with crop failures, damages to buildings and loss of life. Both the government and private sectors will continue to be important in this aspect. The option is of very high priority.

7.3.2.11 Enhancing agricultural extension services

Agricultural extension officers play significant roles in improving agricultural productivity by providing farmers with useful information that can enhance their productivity. In adapting to climate variability and change, this category of professionals would need to be more engaged to improve local agricultural practices through their dissemination of critical farming information including weather related ones. They should become more visible on the field. The cost is relatively low and the option is of very high priority.

7.3.3. Adaptation options for wetlands

The socio-economic and ecological benefits of wetlands are overwhelming. The economic benefits from Hadejia-Nguru wetlands in northern Nigeria can be more than ₦5 billion annually. The growing degradation of wetlands is thus of serious concern and urgent response which can include the following measures:

7.3.3.1 Providing artificial flooding downstream

Regular artificial flooding is useful in recharging wetlands downstream. This measure is practicable in areas with large dams. Responsible agencies are the Ministry of Water Resources andRiver Basin Development Authorities under them. The option should be professionally handled to prevent disasters downstream. It is of high priority in the drier belts of the country.

7.3.3.2 Short-lived hardy crops for higher temperatures and short growing seasons

As soil water level drops in many wetlands, switching to short-lived hardy crops will become important to the farmer. The option is suitable and of high priority across the country. Its cost is relatively low as earlier shown and the responsible agencies are research institutes, extension workers, and the communities.

7.3.3.3 Recharging wetlands, drilling boreholes and providing more irrigation water

This is a possible option for threatened wetlands. It can be achieved by building small reservoirs or mining water from boreholes around the wetlands. The option is useful and of

high priority wherever it can be implemented. Responsible agencies are River Basin Authorities, NGOs and the communities.

7.3.3.4 **Improving rural-urban transportation**

Part of the problem of food insecurity in the country is connected to poor transportation facilities between the rural areas where food is produced and the urban centres where population is concentrated. Improving transport facilities is an adaptation measure to make food more readily available particularly in the urban areas but is capital intensive. It is however of high priority. The responsibility is that of the government and the communities.

7.3.4 Livestock Production and promoting alternatives to animal products

Livestock production faces serious challenges due to climate change and variability as most livestock is raised in free ranges and their population is on the increase. The productivity of the rangeland shave reduced significantly due to overgrazing and frequent prolonged dry seasons especially along the Sudano-Sahelian belt. There have been serious conflicts between herdsmen and local farmers as herdsmen run their livestock on farms when fodders are in short supply. From the rising costs of livestock products, it is obvious that production is lower than contemporary levels of demand. Relevant adaptation strategies include:

7.3.4.1 Introducing semi- intensive livestock keeping

This measure can eliminate or at least reduce the frequent conflicts between animal keepers and farmers. This is useful but may be unacceptable to the poor farmers who keep just a few animals on minimal input to meet their basic needs. The responsibility for adopting the measure is with the individual and community but government can assist in settling down pastoralists to experiment with or adopt the option. The option is of medium priority.

7.3.4.2 Intensification of livestock

The challenge of livestock production is also associated with the cultural practice of transhuman husbandry where large number of livestock move yearly with resource availability (opportunistic grazing management system). This yearly movement creates conflicts. Intensification of livestock production is therefore recommended to ensure environmental sustainability, reduce conflict and increase food security.

7.3.4.3 Rangelands Enrichment with fast growing herbs/shrubs

This involves deliberate encouragement of certain plants with high fodder potentials on the rangeland. If well implemented, it can significantly raise the quantity of fodder available to animals. The responsible agents are the states or Local Government, the communities, and the pastoralists. The cost is in the medium range and the option is of high priority.

7.3.4.4 Expanding rain harvesting practices for livestock.

The local farmers in the dry belt do small-scale water harvesting to provide sustainable watering points for animals. This practice can be expanded to make water available deeper into the dry season. The responsibility is that of the individual and the

community. The cost is low to medium and the priority is very high in the drier northern regions.

7.3.4.5 Building more water harvesting structures and boreholes

The significance of this has been discussed in the section under water resources. Its benefit is that with these, more fresh water can be made available to livestock. It is of high priority particularly in the drier belts. However, growing pressure on underground water resources may be a challenge to this.

7.3.4.6 Designate more areas as grazing zone

Part of the problems of pastoralists is the limited rangeland they have access to in many parts of the country. Governments at the State and LGAslevels should address this to reduce conflict and increase grazing opportunities for livestock. The option is applicable in many parts of the country and government as well as the community are the major stakeholders. It is also of high priority.

7.3.4.7 Building mutual trust and understanding between farmers & herdsmen

One cause of conflicts between farmers and herdsmen is lack of trust and mutual understanding. These two 'bed fellows' need to be able to relate together for mutual benefits. The herdsman ought to know when the farm will be available for him to graze his animals on crop residue. The option is applicable in most parts of the country and is of high priority. The cost is low and the actors are the communities, the pastoralists and the State or local governments.

7.3.4.8 Developing substitute for animal protein

There is a need to focus attention on the production of substitutes for animal products as demands can no longer be met. The options include breeding of edible insects such as the moth - *Cirinaforda* wildly consumed in West Africa. According to the FAO there are more than 250 edible insects in Africa and many of them can be produced in large quantities. Mushrooms can also substitute for beef and can be cheaply produced as well. These options are relevant and of medium cost. The option is of medium priority. The social cost is that of sensitizing people on the safety and desirability of consuming insects and mushroom.

7.4 Coastal Areas

The coastal areas harbour a substantial proportion of the country's population. Nine of the thirty-six states in the Federation share the country's coastal line and are estimated to account for 25% of the country's population (NPC 2006). These are vulnerable especially to increasing sea level rise.

Many settlements along the coast have already been lost to the rising sea level. Plates7.3a, b and show the strengthening ocean pressure in Lagos subduing efforts in controlling ocean surges. The situation is exacerbated by similarly rising floods from rivers draining into the seas in the rainy season and the already weakened economic status of many people in the coastal communities.

Plate 7.3a: Remnant of an Erstwhile Village in a part of Delta State

Plate7.3b: Storm surge control on Victoria Island, Lagos

Plate7.3c: Signs of rising sea level – enriched banks virtually submerged

Apart from the processes associated with sea level rise, a growing factor of serious local coastal erosion particularly in the coastal waters of Lagos State is ship abandonment/ship wreck (NCF, 2010). Plate 7.4shows a ship wreck that had been left for several years before its removal by the Lagos State Government in 2009. Ship abandonment obstructs the normal movement of waves causing severe erosion of the coastline adjoining it.

Plate7.4: A Shipwreck *Agaja Beach Area of Olomo-Meta in Ojo LGA, Lagos*

The coastal areas obviously deserve effective adaptation actions to minimize the impacts of the climate change on the region. In doing this, an integrated coastal development plan has to be put in place. This would not only cover the coastal reaches of Nigeria but would be linked to the efforts in the other parts of West and Central Africa. Specific adaptation strategies that should be adopted within the integrated coastal management framework can be classified into three: abatement designs, ecological enhancement and withdrawal from threatened zones.

7.4.1. Abatement options include:

7.4.1.1 Building barriers

This is specifically to push back ocean surges. The cost is high and it is of high priority in many locations along the coast. Governments have spent billions of naira in fighting back the ocean around Victoria Island. The major implementer of this option is the government and oil companies. The priority is high.

7.4.1.2 Reinforcing the banks of reservoirs

Reinforcement is needed to prevent the collapse of reservoirs along the coast and protect fresh water sources from ocean flooding. The cost of this option is high. It is alsoof very high priority because of the threat to fresh water sources. Government and communities are critical stakeholders.

7.4.1.3 Raising transport routes

Raising roads and rail routes levels to make them passable in times of floods is an important adaptation strategy in low lying coastal areas. This option is of high priority as floods increase in the coastal areas. The cost is however high. The key implementers are governments and international development partners.

7.4.1.4 Strengthening socio-economic infrastructures

The socio-economic infrastructures particularly oil vents in the coastal areas need to be reinforced toenable them withstand stronger storms and winds associated with climate change. Figure 7.2 shows the complex oil infrastructure in the Niger Delta. The priority is high and its costs are equally high. The implementers are government, NGOs and oil companies.

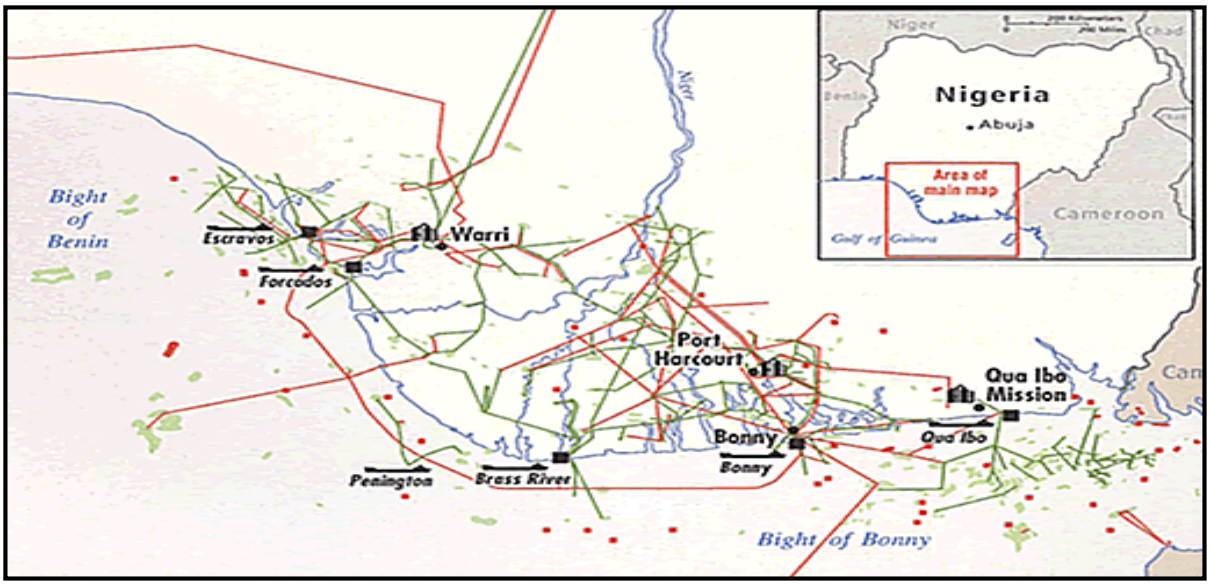


Figure 7.2: Locations of Oil Infrastructure in the Niger Delta

7.4.2 *Biological options include:*

7.4.2.1 Growing more salt-tolerant crops in the cultivable coastal fringes

The significance of this option is to ensure that agricultural production can continue along the coastal fringes as salt water intrusion increases. The priority is very high and the cost is in the medium range. The implementers are government agencies, research institutes and communities.

7.4.2.2 Afforestation in the mangrove

Afforestation is needed to improve biodiversity in the devastated mangrove particularly in the Niger Delta. This would enhance the traditional benefits derived from the ecosystem and help carbon sequestration. The measure is of high priority, the cost is high and the implementers are government agencies and the communities.

7.4.2.3 Raising salt-tolerant fish

As salt water intrusion increases, raising of salt-tolerant fish varieties becomes an option that has to be considered in areas around the coast. The measure is generally of high priority and the implementers are research institutes, the communities and individuals.

7.4.3 Withdrawal or 'do nothing option' include:

7.4.3.1 Relocating vulnerable communities

Relocating vulnerable communities and supporting them to establish in new locations is an important strategy in very vulnerable locations. Although the cost of implementing this option is very high, it is of very high priority to avoid loss of life. The implementers are government agencies, NGOs and the communities.

7.4.3.2 Reducing or stopping expansion of socio-economic development in the coastal areas

This option is significant to minimize loss of lives and damages to socio-economic infrastructures. The option is of high priority, the opportunity cost could be very high and the implementers are government agencies and NGOs.

7.5 Forest, Forestry and Desertification

7.5.1 Loss of forests and their resourcefulness

Forests play major roles in carbon sequestration as a natural 'sink', in biodiversity preservation, supply of wood and non-wood products and environmental protection in different ways (Adesina *et al*. 1999).Currently less than a tenth of the total land area of the country is under Forest Reserves and only about 1% under undisturbed forest covers. Yields from the forests have continued to decline very rapidly especially since 2000 (EC-FAO 2003).

Due to anthropogenic influences, only relics of the tropical forests and woodlands are found in reserves and relatively inaccessible areas. The impacts of the climatic variability and change include the difficulty of tree replanting, retardation of the regeneration process, death of trees, and loss of habitat as well as decline in species diversity. Some of the effective adaptation strategies for dealing with forest loss include the following:

7.5.1.1 Afforesting with fast growing species

The emphasis here is on native and exotic fast growing species. The option is applicable in most parts of the country and is of high priority where there are gazetted forest reserves. The cost is high, the government has to provide or utilize the legal means of protecting the forests and the communities are crucial to the success of the efforts.

7.5.1.2 Protecting forests from further encroachment

This option is to control or prevent access to forests, woodlands and other land reserves in the different parts of the country. Access control would include fencing vulnerable areas as well as implementing appropriate legislations. It may also include biomass enrichment. Fencing can cost as much as ₦520 per hectare (Adesina*et al,.* 1999), apart from the costs of land and tree planting, as well as monitoring. Legislation costs are low but forest surveillance required in implementing the law is expensive. The option is of high priority and is relevant in all ecological belts of the country particularly in the Forest and Guinea savannah belts. The key stakeholders are governments, NGOs and the communities.

7.5.1.3 Social re-engineering

This option would help develop in communities 'appropriate attitudes towards forests and other plant cover for sustainable utilization. When communities are made to own the forests for example, they are empowered to manage the resources in their best interest. The cost is low but it is generally of high relevance.

7.5.2 Drought and Desertification

There is a general consensus that desertification is a critical environmental problem in the arid and semi-arid parts of the country (FGN 2005; 2006). In these areas, population pressure, over-grazing and over-exploitation of marginal lands are aggravating environmental degradation. Entire villages and major access roads have been buried under sand dunes in the extreme northern parts of Katsina, Sokoto, Jigawa, Borno, and Yobe States (Plate 7.5). Some of the relevant adaptations strategies are presented in the section that follows:

Plate 7.5: Expanding desert conditions in a part of Northern Nigeria (Yahaya, 2009)

BBC News website, YobeState (http://news.bbc.co.uk/2/hi/africa/6288444.stm)

7.5.2.1 Re-vegetation of degraded areas

In desert-prone areas, re-vegetation especially tree planting is a critical adaptation strategy. Greening of degraded areas should be intensified to promote biodiversity and halt the spread of desert conditions. The option is expensive but of high priority.

7.5.2.2 Protection of trees in marginal areas

Deliberate protection of trees is important as a strategy for preventing the severity of drought and desertification in the threatened areas of the country. This can be done both by the enforcing relevant legislation and empowering local communities to take responsibility for the trees. Both the priority and cost of the option are very high.

7.6 Energy Sector

7.6.1 Crude Oil and Natural Gas

Nigeria's economy thrives mainly on oil and natural gas. However, the exploitations of these valuable resources are sources of serious environmental challenges particularly in the Niger Delta Region. It is the main source of GHG emission in the country. Many settlements in the region experience high levels of pollution evident in increasing acidity of rain water in the area (Ogunkoya and Efi, 2003).

Growing environmental challenges in The Niger delta have caused considerable social unrest. Aggrieved communities perceive these as a means of attracting attention from government and oil producing companies. They have increased the vulnerability of the people of the oil producing areas and weakened their preparedness for adverse climatic events. Relevant adaptation strategies in this sector include the following:

7.6.1.1 Control of oil spillage

Oil spillage from vents and broken pipes is a major environmental concern associated with oil and gas sector. Oil companies should scale up their technologies for monitoring with remote sensing and GIS to minimize the damages as well as respond promptly when the need arises. The adaptation option is of high priority and the cost high.

7.6.1.2 Awareness creation to prevent vandalisation of oil infrastructures

Pipeline vandalisation is a major source of economic loss and environmental pollution in the oil sector. Increased awareness creation about this is needed to stop the damages. The option is of high priority and the cost of implementation is relatively low. The major stakeholders are oil companies, local communities and government.

7.6.1.3 Enforcement of legislation in oil exploration and exploitation

A number of legislations exists which government agencies such as NESREA are expected to implement to protect the oil and gas sector. These legislations need to be fully implemented to control the activities of the oil and gas companies. The priority is high and the implementers are government and its agencies.

7.6.1.4 Promotion of the use of gas for domestic purposes

At the moment, only a small proportion of the natural gas produced in the country is used for domestic purposes. Much of it is flared. In addressing climate change, there is a need to encourage increased utilization of the natural gas in homes. The option is expensive but of high priority.

7.6.2 Electricity Supply

Nigeria produces very low quantity of electricity compared to its socio-economic needs. Total output is probably less than 2.5GW (Olivia Phillip International Consulting Limited, 2008). However, the generation capacity-build-up under the National Integrated Power Project (NIPP) could bring the output to more than 10GW. Electricity generating infrastructures are old and have become inefficient. HEP is responsible for only 8% of the energy consumed in the country.

There had been a general poor management of power generating infrastructures over the years forcing productivity to decline. Also, the declining electricity generation from major HEP sources particularly Kanji, caused by a drop in the inflow of water into the lakes during some parts of the year is a significant physical factor. Another key factor is the limited development of other sources of energy in the country. The relevant adaptation options include:

7.6.2.1 Deployment of more efficient Hydro Electric Power turbines

Invest in small and efficient HEP turbines that can be installed on small streams for electricity production. The option is of high priority and cost is in the medium range. Both government and private sector are important in the implementation.

7.6.2.2 Encouragement of private electricity producers to access the national grid

Substantial amount of electricity can be generated if private sector is enabled to participate actively in the sector. One way of doing this is to allow private producers to put their supply in the national grid. The option is of high priority and cost effective for the private sector.

7.6.2.3 Development of alternative sources of electricity

Alternative sources such as solar and wind can generate substantial electricity for the country. The exploitation should be actively encouraged through waiver of import duties on equipment required for them. The option is of high priority and cost is in the medium range. The implementers are the government, private sector operators and local communities.

7.6.2.4 Replacement of aging infrastructures

Loss of electricity in transmission due to aging infrastructures, which is at the moment extensive, can be curtailed significantly by investment in new and improved equipment. The cost is high but the option is of high priority.

7.6.2.5 Control of electricity through the use of efficient devices

The deployment of efficient electrical devices such as CFL and LED bulbs will cut down demand for electricity substantially. There should be active encouragement of the use of these products. Responsible agencies are Energy Research Institutes and private sector operators. Government would also need to encourage the importation of relevant equipment. The option is of high priority and the cost is medium to high.

7.6.3 Fuel wood

More than 70% of households in Nigeria depend on fuel wood for domestic cooking (Adesina et *al*., 1999; Eleri, 2006). This has continued to be so as costs of alternatives are high. The relevant adaptation options include the following:

- Development of alternative sources of energy
- Use of efficient stoves to reduce domestic consumption of fuelwood;
- Encourage energy farm and woodlots for active production of fuelwood
- Adopt agro-forestry practices into the farming system

7.7 Human Health

7.7.1 Issues in the Sector

Climate change has direct and indirect consequences on human health, which will aggravate the vulnerability of individuals and households. For example, incidences of vector-borne (e.g. malaria), water-borne (e.g. diarrhoea), heat- and cold-related deaths, injuries and deaths from flooding, and the prevalence of malnutrition would increase. As already shown in the Chapter 1, access to facilities is poor and there is inadequate availability of health personnel at all levels. All of these make the health sector highly vulnerable to the impact of Climate Change. As health issues are multi-dimensional, adaptation measures that can be adopted to address vulnerability in the sector are numerous. These can be summarized as expansion of preventive and curative medicine at the household and community levels.

7.7.2 Adatpation Strategies

Some of the specific adaptation strategies that can be adopted are as follows:

7.7.2.1 Strengthening weather forecasting system

This would include providing information on extreme weather events such as heat-waves, heavy storms and dry spells. The system should integrate and analyze weather and health

thresholds data to issue health warnings, tailored to address challenges in the various ecological regions of the country. The cost of implementation is high but is of high priority.

7.7.2.2 Adapting architectural designs to suit new weather regimes

New buildings should be designed to enable natural cooling and curtail energy use. The design should thus aim at controlling temperatures inside the buildings. Roofs should be stronger to withstand heavy winds and storms. Cost is medium but option is of high priority.

7.7.2.3 Awareness creation about preventive options

Effective awareness creation on critical health issues would enable members of the community to take pre-emptive actions against health challenges that may attend climate change. The cost is in the medium range and is of high priority. Implementers are government agencies, NGOs and Mass Media. The option is relevant nationwide.

7.7.2.4 Increase access to high quality health services

There is a need to improve significantly access to high quality health services particularly at the basic level. This should include an efficient referral system to take care of emergencies and cases that cannot be taken care of at the basic level. This option is applicable nationwide; its cost is high but is also of high priority. The implementers are government agencies particularly the Ministry of Health.

7.7.2.5. Promoting appropriate climate-health education in schools.

Promoting climate-health education in schools would engender good practices in personal and community health care under changing climates. The option is relevant across the country, it is of high priority and its cost is in the medium range. Responsible agents are Governments and the school system.

7.7.2.6 Expand community health services delivery.

This should include efficient mobile clinics particularly in areas with difficult terrains and dispersed settlements. The option is of high priority and its cost also high. The implementers are government agencies and NGOs.

7.7.2.7 Build capacity of health workers for the new challenges

Provide training opportunities at regular intervals for health personnel to enable them gain consciousness of the challenges that could come up in the delivery of their services due to climate change. It is a relevant adaptation option country-wide and is of high priority.

7.7.2.8 Engage private organizations in climate and health issues

Climate change is about everybody. Engaging the private sectors effectively in providing appropriate responses will help take the messages deeper and faster into the communities. It would also help in mobilizing resources needed to respond effectively to climate change challenges. This is a medium level priority and is also low cost.

7.8. Settlements and Physical infrastructures

7.8.1 Issues in the Sector

Settlements all over the country are expanding rapidly due to population growth and are contributing to GHG emissions. Cities are particularly significant sources of GHG emissions due to energy generation from fossil fuels in buildings, vehicular use and

industries. One other challenge of the expanding settlements is that they are taking place with little or no control of the Town and Country Planning authorities. Neighbourhoods are consequently poor since “planning” is left in the hands of the individuals.

There is also an acute shortage of suitable housing units. Even in the relatively well maintained neighbourhoods, most houses are roofed with poor quality materials which make them vulnerable to storms. Settlement expansion is also a threat to the sustenance of adjoining rural lands which supply food and other valuable products. Furthermore, many cities especially along the coasts are becoming less comfortable due to pollution and stress associated with inappropriate planning and excessive urban heat islands.

7.8.2 Adaptation Strategies

The following adaptation strategies are relevant for the various parts of the country.

7.8.2.1 Proper implementation of town and country planning regulations

This will help to curtail the spread of settlements particularly cities and towns unto farmlands. It is a high priority option as land is limited in availability and the cost is in the medium range. The implementer is government through the Town and Country Planning authorities but the communities are important in the process.

7.8.2.2 Enforcement of building standards

The use of building standards should be enforced to address increasing environmental stress and reduce incidences of building collapses. The measure is of high priority, the cost is about medium and the implementers are government, relevant engineering societies and the communities.

7.8.2.3 Exploring indigenous knowledge in building of houses

Indigenous knowledge may offer valuable options for internal cooling and stability of buildings. The option is of low to medium priority, the cost is in the medium range and the implementers are research institutes and the communities. The option is of medium priority.

7.8.2.4 Minimising concrete surfaces around buildings

This is a part of the building standard to enforce. The Town Planning Authorities have to ensure that concrete surfaces in houses are reduced to cool the houses, enhance ground water recharge and at the same time reduce runoff. The option is relevant and of high priority, the cost is low and the implementers are government through Town and Country Planning authorities and the community.

7.8.2.5 Setting green belts around cities and towns

This is needed to limit the lateral growth of settlements. The measure is relevant in every part of the country, the cost is low and the implementers are government, Town and Country Planning authorities and the community. The option is of high priority.

7.8.2.6 Control of settlement on floodplains and watershed

Mapping and monitoring of floodplains and watersheds are urgent to prevent further settlement development on them. The option is of high priority, the cost is high and the implementers are government, Town and Country Planning authorities and the Communities.

7.8.2.7 Provision of Protected Rural Environment in Each LGA

Government should mandate each State and LGA to own and efficiently manage specially designated rural areas. They should also seek to legally protect them. In this way, some natural areas can be preserved in every part of the country. This is a high priority option. The cost is low to medium and the actors are government and local communities.

7.9 Tourism

7.9.1 Issues in the Sector

Tourism is an expanding area of interest in Nigeria's socio-economic development. Many of the tourist sites are nature-based. Such sites depend on the characteristics of their local biodiversity. The preservation of biodiversity is thus crucial to the survival of such tourist sites. A change in climate, which hampers rapid regeneration of vegetation, will reduce the significance of such sites.

7.9.2 Adaptation Strategies

Relevant adaptation strategies include the following:

7.9.2.1 Protect tourism estates from encroachment.

This option is important in every part of the country. Its cost is high and the implementers are government through the Department of Tourism and the local communities. The option is of high priority in the tourism industry.

7.9.2.2 Protecting and enriching biodiversity around tourist sites

This option would restore the biotic characteristics of the tourist area. This can be achieved by deliberately enhancing the biodiversity and through the protection of the tourist sites. The option is relevant in every part of the country and is of medium priority. Its cost is also relatively low. The implementers are the Tourist Board and the Communities.

7.9.2.3 Improving water storage facilities in the tourist sites

One effective option for enhancing the quality of tourist sites is to develop water storage facilities to provide additional water for the flora and fauna in the tourist areas. As previously indicated, such facilities are useful for soil water recharge and biodiversity development. They are also helpful in promoting the health of wild animals in the tourist sites. The option is good, its costs can be high but it is applicable in every part of the country where tourism is flourishing.

7.9.2.4 Use of economic instruments to protect the tourist sites

This can be done by ensuring that all tourists pay appropriate fees for visiting the sites. The option is of high priority and government as well as the local communities are the key stakeholders.

7.10 Transportation

7.10.1 Issues in the Sector

The transport sector is especially vulnerable to climate change. The infrastructures are poorly developed and the road, which is the dominant mode, is not in good shape. Road networks are constrained not necessarily by their sizes but by the increasing number of vehicles on them. Many of these roads are poorly maintained and so frequently get

damaged by heavy volume of vehicles that travel on them daily. Rainfalls with high intensities which now flood the roads more often are increasing the rates at which the roads require repairs. Air travels and safety are also affected by weather and climate variability. The impact is more challenging at both the take-off and landing phases of flights due to poor infrastructure. Possible Adaptation strategies include:

7.10.2 Adaptation Strategies

Possible Adaptation strategies include:

7.10.2.1 Re-investing another transport modes apart from road

The over-dependency on road is a bane of Nigeria's transport system. Availability of rail transportation would reduce the present stress on the road transport mode, bring down the cost of transporting heavy goods and lessen road mishaps. Also, there is need to enhance the navigability of inland rivers to boost water transport. This option is expensive but of high priority. Government is the major implementer.

7.10.2.2 Expand roads for easier vehicular movement.

The lanes on major routes should need to be increased to ease traffic congestions. Many of the roads need reinforcement and their drainages should be constructed or repaired to minimize flooding and frequent damages. The option is expensive but of high priority. Government is the major role player.

7.10.2.3 Develop and implement a sustainable road maintenance plan

This strategy is relevant to ensure sustainable use of the roads. The priority is high and the key actor is the government. The cost is low.

7.10.2.4 Improve lighting at airports to aid safe landings.

Poor lighting of airports is a major challenge for safety at night and during bad weathers. Investment should be made to ensure that electricity is always available at the airports. The option is of high priority and cost is of medium range. Government through the airport authorities is the key player.

7.10.2.5 Set standards for the importation and use of vehicles

Poor safety on Nigerian roads is partly associated with the ages of vehicles that ply the roads. Safety level can be significantly improved by ensuring that spent vehicles are prohibited. The option is of high priority although it might not be really attractive because of the high costs of new vehicles. The implementer is government.

7.10.2.6 Re-organize the public transport system

The Bus Rapid Transport (BRT) model, which is already working in Lagos State, should be replicated in other parts of the country. Among other things, this model ensures that anyone who chooses to use the public transport can get to his destination on time and cheaply. This option is expensive but it is of high priority especially in the major cities. The government is the main actor and also partnering with the private sector would provide better results.

7.11 Industries

7.11.1 Issues in the Sector

Like most other sectors, the industrial sector is vulnerable to climate change. Industries are in many ways affected by factors associated with climate change. For instance, industrial processes require heavy input of energy which is presently largely inadequate in supply and also implicated in the production of GHGs. Also industries whose raw materials are dependent on climate-related features such as agriculture and water resources would be adversely affected by climate change. Thus as climate changes, the general processes of industrialization must adjust in many ways to remain productive and profitable.

7.11.2 Adaptation Strategies

Some of the relevant adaptation options in this respect are as follows:

7.11.2.1 Deployment of economic instruments

Deploying economic instruments such as suitable tax regimes to strengthen industrial activities.This is not usually an attractive option as it increases the unit cost of production. However, it helps to keep production on track. The option is of medium priority and of low to medium cost. It is applicable nationally.

7.11.2.2 Effective control on imports

Put effective control on imports either to make them cheap or otherwise, in order to protect local industries. As already indicated, relaxed importation regime is necessary to support materials needed for instance in the area of energy saving devices. On the other hand, imported items from developed countries and the BRAC are increasingly cheaper as technologies in those countries become more efficient. This is a threat to the struggling local industries which must be protected to keep local jobs. Also, control on rice importation in particular is critical for the survival of industries associated with the production and marketing of locally produced rice. The option is of high priority, its cost is in the medium range and government as well as the private sector are important.

7.11.2.3 Development of inventory of local raw materials

Develop inventory of local raw materials that can support new industries or strengthen the older ones. The option is of high priority and cost is high. Government and research institutions are the main actors.

7.11.2.4 Empowerment of the private sectors

Empower the private sectors to tap opportunities in climate change businesses including in the aspects of green initiatives. For example, CFL will continue to be important as energy saving devices in the country and billions of units would be needed. Local manufacturers should be empowered to invest in the production of these bulbs.

7.12 Conclusion

Climate change adaptation as presented here affects every aspect of Nigeria's socio-economic development. Actions are required to adapt in every sector as recognized under the UNFCCC to minimize the damaging impacts of the change. Many of these actions are already going on more or less autonomously as development initiatives. However, to achieve the much higher desirable level of intervention, the adaptation actions require a lot

more attention than what is on ground. The costs are no doubt daunting, but most of the actions are of high priority. Thus, to ignore adequate commitment to addressing the investment needed now is to negotiate a more dangerous future which will require much more resources than are needed now. All hands must therefore be on deck to ensure that adaptation take place. Nigeria must take advantage of the opportunities offered by Adaptation Fund under the UNFCCC. The country must also be proactive in allocating and monitoring resources for climate action.

CHAPTER EIGHT

CROSS-CUTTING ISSUES

8.1 Introduction

This chapter discusses a number of issues that touch in general upon every aspect of climate change response and initiatives in the country. They are issues germane to effectively addressing the challenges posed by climate change in the country. The issues include Gender concerns i.e. including various vulnerable groups, Technology Transfer (Tech-transfer), Climate Education, amongst others.

8.2. Gender Issues

Gender issues are major cross-cutting subjects in climate change and virtually in all aspects of socio-economic development. In all ramifications, climate change issues are not gender neutral. In Nigeria, the distinct varying constructive roles of men and women in the society are making both sexes not only to have different needs of the environment but utilizing the natural resources in different ways. Women are dominant users of environmental resources because they shoulder the heavy workload needed to meet the basic needs of their families. Thus, women are more potent agents of environmental degradation and management. They play decisive roles in managing and preserving all natural resources including biodiversity, water, land and other natural resources and thus environmental sustainability. It thus implies that women in Nigeria are not only the worst hit by climate change but are a major factor of climate change. Therefore, this section examines some gender aspects of climate change in terms of climate change mitigation, impact and adaptation.

8.2.1 Gender Issues and Climate Change Mitigation

In Nigeria, as elsewhere in the world, energy sector is the single most important sector in terms of climate change mitigation. Men in Nigeria tend to account for the larger proportion of CO_2 emissions and air pollution through energy use. Women generally use much less emission-intensive modes of transport than men, their level of car-ownership is lower, and their share of public transport use is relatively higher. Also, women tend to travel by car less frequently and over shorter distances, and use more of public transport facilities, whereas men tend to travel more by air than women. Evaluating the carbon footprints by gender is not to attribute blame to any sex but rather for the purposes of targeted mitigation strategies which are aimed at behaviour change (Brody, 2008).

Women more than men, engage in many activities that emit GHGs. These include charcoal-making, firewood gathering, waste management, agro-processing and electricity use at homes. The impact of Nigeria's charcoal production on total deforestation is second only to that of Tanzania in the world's rainforest and woodland belts (Figure 8.1). Charcoal business and use of firewood in Nigeria are dominated by women. Women are generally responsible for human waste disposal and cleanliness of toilets and other facilities (Akwa, 2009). With regard to the electricity use at home, women spend more time at home and thus use electrical appliances and some other household energy-demanding devices more than men. Therefore, programmes designed to achieve energy efficiency at the household level must adequately recognize this important aspect of women's use of energy.

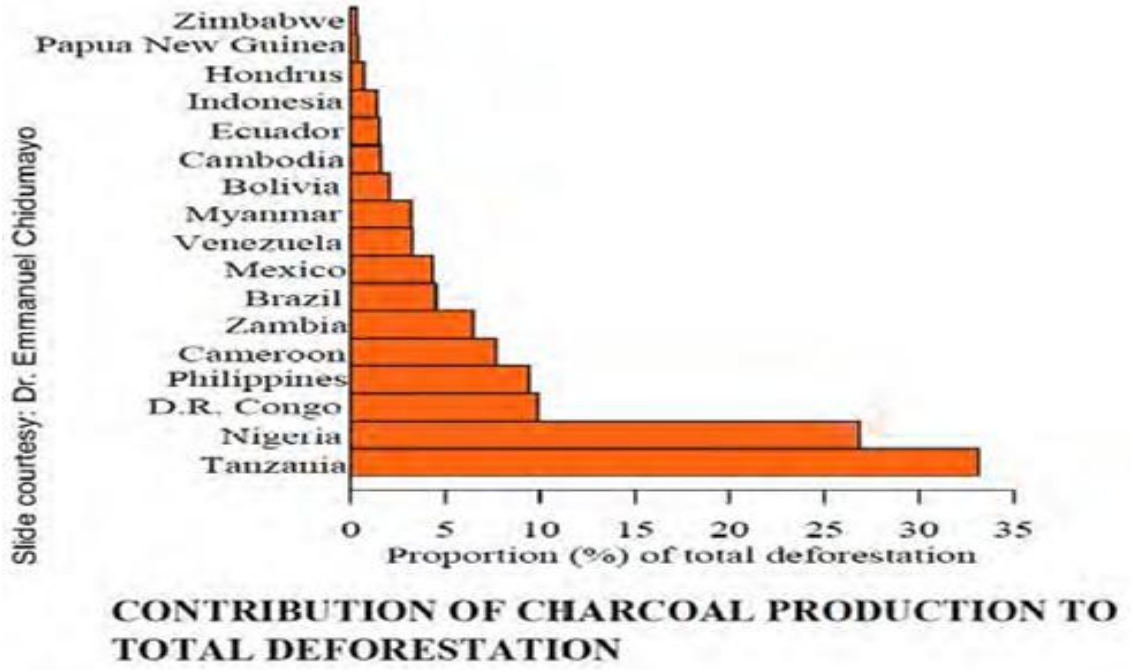


Figure 8.1

8.2.2 Gender Issues in vulnerability and adaptation

Climate change would affect socio-economic groups with varying severity because of difference in access to education, economic opportunities, social and cultural roles and extant policy instruments. Women constitute a larger proportion of the poor and are thus expected to suffer more than men as a result of climate change. Other vulnerable groups would also be disproportionally affected. The main concern is determining how vulnerable the individuals would be to a changing climate, and the strategies to improve their resilience and ability to cope with climate stresses. To properly address this it is important to consider gender differentials as they relate to vulnerability of the individuals and their ability to adapt to the consequences of extreme climatic events. This will guide policies and projects to appropriately enhance the capacities of women, children and other disadvantaged groups in reducing their vulnerabilities to the impacts of climatic variability and change. It will also assist development organizations and local communities to effectively plan and implement intervention programmes.

In Nigeria, gender remains a key factor in the ability to earn an income, obtain credits for financial institution, access to and control of critical resources such as land and water, and access to education (Steady 1995; Okojie, 2002). The influence of gender with respect to being a man or woman arises from the fact that men have greater opportunities to have a better livelihood than women and children conferred on them largely by cultural factors. This makes women and children more vulnerable to the impacts of climate variability. Consequently, to be effective, preparedness for the impacts of climate variability and change in Nigeria must take into consideration the peculiarities of men, women and children.

Research on the gender aspects of climate change is expanding and is proving that women are more vulnerable than men to weather-related concerns (FAO, 2008). Heads of families, who migrate seasonally from the northern part of Nigeria to eke a living in the southern parts during the long dry season, leave their wives and children behind to continue

with the harsh realities at home. Culturally, women are expected to stay back and invariably assume the ensuing responsibility which only adds to their vulnerability. Furthermore, in terms of providing education including awareness creation, women and children tend to be pushed to the background. Usually, men are the targets of such educational awareness creation. Unfortunately, social roles invariably take men away from home, and the knowledge they have acquired may not be available for women and children to take informed and timely decisions.

Nigeria's policy environment has good potentials to support gender equity. The country became a signatory to the Convention on the Elimination of all forms of Discrimination Against Women (CEDAW) in 2001. It has also participated in the International Conventions on the status and role of women, has Ministries of Women's Affairs and Youth Development with desk officers for each sector, and in 2006, adopted a National Policy on Women (FMWASD 2006). This is a major advantage in pursuing adaptation activities in the country.

8.2.3 Gender Responses for Mitigation and Adaptation Plans.

Adaptation efforts should systematically and effectively address gender-specific impacts of climate change in the various sectors. Some of the response elements should include economic empowerment through

i. Increased access to funds for small scale economic engagement by women and pursue gender equity in access to credit facilities that can enhance livelihoods. This can be accomplished through the micro-finance bank scheme which gives loans without collateral at the grassroots. As they tend to be more stable member of the local communities, women stand a greater chance of benefiting from such a scheme.

ii. Facilitating women access to other factors of production particularly land in the rural areas as well as transportation through efficient and more flexible public transport services.

iii. Targeting both men and women with unbiased attention in intervention programmes such as awareness creation on energy saving devices and practices, access to early warning information.

iv. Provide enhanced opportunity for girl-child education especially in environmental sciences and engineering to aid innovation for climate change mitigation.

v. Addressing the special needs of women during and after environmental disaster. Women usually need more attention than men in the wake of disasters as they have the additional responsibility of taking care of their children and properties.

vi. Pursing the current effort at mainstreaming gender into national development Plan (Ministry of women Affairs 2008).

vii. Recognizing various disadvantaged groups and supporting them in coping with new challenges of climate change through systems (e.g. transport) that are sensitive to their special needs.

8.3 Science, Technology, and Innovation

To effectively adapt or mitigate, we need to fully understand the science of climate change and its linkage with the environment, the appropriate technologies required and what innovations are needed.

8.3.1 Technology Transfer

The purpose of this section is to discuss issues relating to technology transfer in climate change actions in Nigeria. Technology is already playing a major role in the ability of communities to cope with or adapt to climate change impacts. As climate change could occur at such a fast rate that adjustments of the normal way of life in most communities will not be able to match the severity of the impacts, technology is required to enable communities react more promptly and effectively to the problems of climate change. For instance, clearing and expanding canals would contain increase in flooding regime along the coast under a limited increase in coastal flooding, whereas a significant rise in sea level would render even the biggest of canals useless. The scale of desirable response would therefore be far higher than what is on ground. Under a scenario like this, advanced or superior technology becomes really critical. Such technologies may however not be available in the local area and have to be sourced from elsewhere.

8.3.1. 1 The Nature of Technology Transfer

Technology transfer is the diffusion and adoption of technology and know-how between parties, typically private companies, universities, financial institutions, governments and non-governmental organizations (Shephard, 2007). In a broader sense it is not limited to the movement of technology from a 'source' i.e. an organization, party, institution or region to another that adopts, adapts and uses it (Adams 2009). Rather, it also involves innovation that enhances the individual as well as societal abilities to carry out certain functions more efficiently.Technology transfer is critical to accelerating socio-economic development in any economy particularly in the developing countries. It is also crucial in addressing all aspects of climate change. Technology transfer is therefore a major cross-cutting issue. In the sections that follow, a number of issues that affect technology transfer in Nigeria are examined.

8.3.1.2 Nigeria in Technology Transfer

Technology transfer as a tool for development has attracted considerable attention in Nigeria. The country has an agency under the Federal Ministry of Science and Technology that has been charged with the responsibility of overseeing the acquisition, promotion and development of technology in the country. This Agency is known as the National Office for Technology Acquisition and Promotion (NOTAP). The activities of the Agency are an important platform for accelerating technology transfer in climate change activities in Nigeria.

8.3.1.3 NOTAP

NOTAP was established by Decree No. 70 of 1979 first as the National Office of Industrial Property (NOIP). The agency envisioned moving Nigeria from the periphery to the centre of global industrial power structure and making her a major global power house of the 21st Century through an efficient Technology Acquisition Strategy and a vibrant innovation and R&D commercialization programme. Its mission is to ensure the acceleration of Nigeria's drive towards a rapid technological revolution by an efficient acquisition and or absorption

of foreign technology and a concerted development of indigenous technological capability through promotion of innovation and commercialization of technology.

NOTAP is mandated to encourage a more efficient process for the identification and selection of foreign technology, develop negotiating skills of Nigerians with a view to ensuring the acquisition of the best contractual terms and conditions in the transfer of foreign technology agreements and to provide a more proficient process for the adaptation of imported technology. NOTAP also does the following:

- Registration of all foreign technology transfer agreements having effect in Nigeria;
- Monitoring on a continuous basis the implementation of any contract or agreement registered pursuant to the Act setting up the Office;
- Commercialization of R&D Results and Inventions;
- Promotion of locally generated technologies;
- Promotion of Intellectual Property; and among others
- Promotion and encouragement of the development of creative and inventive skills among Nigerian Scientists, Researchers, Inventors and Innovators.

Some accomplishments of NOTAP

NOTAP has had a number of noteworthy accomplishments. These include the establishment of intellectual property technology transfer offices (IPTTOs), Intellectual Property Rights (IPR) Awareness Program, Promotion of Patenting of Inventions, establishment of the Patent Information and Documentation Centre (PIDC) - WIPONET Computerized Registry Information System (CORIS), Evaluation and Registration of Technology Transfer Agreements, and Monitoring the Implementation of Technology Transfer Agreements.

All of these are advantages for Nigeria in her effort to respond to climate change. For instance, the existing platforms make it possible for engaging in processes of locating and legally acquiring new technologies for developmental purposes.

8.3.2. Climate change and technology transfer

The primary purpose of Climate Change Technology Transfer (CCTT) is to promote sustainable development among the world's developing countries so that the environmental challenges accompanying changes in climates can be effectively addressed (Deal, 2007). The process involves disseminating the knowledge gained by the developed nations during their development and exploring the technology efficiency gains that have since occurred.

8.3.3 Barriers/Gaps/Challenges to technology Transfer in Nigeria

As desirable and critical as technology transfer is in addressing the need to mitigate, cope with or adapt to the impacts of climate change, very little appears to be happening in Nigeria. This of course is not peculiar to Nigeria. Most of the technology transfer observed in the international arena is between developed countries and less than a fifth between developed countries and developing countries (Meyer-Ohlendorf and Gerstetter). This is caused by a number of barriers. Therefore, as suggested by Meyer-Ohlendorf and Gerstetter (2009) additional efforts to existing initiatives are needed to boost technology transfer.

Barriers specific to technology transfer in the context of Nigeria's need to mitigate and adapt to climate change are as follows.

i. Poor knowledge and inadequate training which often lead to a lack of awareness of the available technologies. Related to this is limited human and financial capabilities to domesticate new technologies;

ii. Poor organizational skills and capacities to coordinate transfer and adoption of new technologies;

iii. Intellectual property rights which often act as both incentives and obstacles to the transfer of technology;

iv. Tariffs and Tax are often problematic. When import duties on items needed for specific technological development are too high, relevant transfer may be inhibited;

v. Technology transfer, in the framework of Clean Development Mechanism (CDM) projects, is most successful when a subsidiary of a company from a developed country is involved; and

vi. Studies of CDM projects also show that technology transfer is more prevalent in some sectors than in others, depends on the domestic availability of certain technologies, and occurs more frequently in large-scale projects than in smaller ones.

A few of these barriers are explored at some depth below:

8.3.4 Intellectual Property Rights (IPR)

Intellectual Property (IP) is potentially both an incentive and an obstacle to the transfer of technology. Intellectual Property Rights (IPRs) were seen as private rights to reward innovation and promote the dissemination of knowledge in the context of broader societal goals (International Centre for Trade and Sustainable Development (ICTSD), 2008). From the view point of offering protection against a loss of control of information in technology-related transactions, IP is partly an instrument aimed at facilitating the transfer of technology.

While developing countries continue to emphasize the negative role that IPR play in technology transfer, developed countries have a keen interest to protect patents developed by their domestic industries (Meyer-Ohlendorf and Gerstetter, 2009). Given the apparent conflict between the protection of Rights and transfer of technology, a "balancing act" is necessary to ensure that international IP rules advance broader public policy objectives.

8.3.4.1 Tariffs and Trade Barriers

Imposition of Tariff is naturally a part and parcel of International Trade. It should be understandable that Climate Change Technology Transfer is not immune to tariffs and other trade barriers. However, tariff rates could significantly increase costs of transfer and make transfer unattractive depending on the country and the technology being transferred. Government of Nigeria needs to pay attention to this. Technology-related imports must be protected from high tariffs.

8.3.4.2 Subsidies to Fossil Fuels

Subsidies for fossil fuels are common in many countries including Nigeria and have various negative effects (Meyer-Ohlendorf and Gerstetter). For instance, they distort international trade, impede innovation, significantly hamper the deployment of clean energy production and absorb scarce resources for other policies that are vital for development, e.g. education, health, infrastructure or environmental protection. Given that fossil fuel subsidies can act as barrier to climate technology transfer, the reduction, and ultimately the abolishment of subsidies for fossil fuels is a significant measure for protecting the environment and liberalizing international trade, while enhancing long term development goals. It is however important for governments to note that the social side of energy prices are subject to considerable domestic pressure when reducing subsidies and therefore have to be properly factored in.

There is probably a need to explore innovative ways of reducing and abolishing subsidies for fossil fuels. This could involve offering compensations in various ways for increased energy prices. Measures such as direct compensation for health or education costs should be given high priority in this respect. Government would need to spend more and demonstrate the effectiveness of its investment in the subject. In terms of national GHG emission budget, this is important. By removing fuel subsidies, demand and therefore use of fossil fuel is naturally reduced and emissions from the transport sector cut down.

8.3.5 Critical Sectors where Technology Transfer is required

Technology transfer is relevant in all sectors of Nigeria economy to accelerate productivity and ensure low carbon production. However, the need is strategically more crucial in a number of sectors in order to appropriately prepare for the challenges of climate change. These are;

i. Weather forecasting and information sharing particularly in the agricultural sector;
ii. Health: Prevention and treatment of illnesses and diseases;
iii. Rapid response during disasters including climate-related accidents
iv. Agriculture – in (i) Irrigation, (ii) pest and diseases control (iii) food processing and preservation (iv) water storage (v) intensive animal husbandry
v. Energy: (i) Harnessing clean and renewable energy sources (ii) Energy efficiency;
vi. Waste: Waste management including turning waste to wealth;
vii. Building design and construction as well as road engineering;
viii. Water storage, treatment and supply.
ix. Monitoring the physical environment for rapid response using remote sensing and GIS skills.

In these respects both indigenous and imported technologies are relevant and should be sourced. Further studies of indigenous practices are thus needed. Many such practices by local people have important implications that can help in finding solutions to the challenges of locating appropriate technologies for climate change response. NOTAP will have to provide the desired leadership.

8.4 Mainstreaming Climate Information into National Planning and Policy Making

With a view to promoting evidenced-based decision making, especially national development policies, and programmes, the government will facilitate greater collaboration

and coordination among MDAs with direct and indirect mandates for climate change. The Ministry of Environment shall mainstream climate change concerns into sectoral policies and programmes, while funding for R & D will be increased through direct budgeting process and international development assistance. The Ministry of Environment in collaboration with other stakeholders plans to develop and introduce climate change curriculum for students in secondary schools and tertiary institutions. The government intends to establish virile climate observation network for better application of climate information for development planning in the country.

The Department of Climate Change has also constituted an Academic Support Group and Science and Technology Committee to provide a platform for mainstreaming climate change into schools and research centres.

8.5 Capacity Building for Early Warning Systems

The Nigerian government recognizes the role of training institutions~~,~~ at different levels including pre-primary, primary, secondary and tertiary levels, in training, research, capacity building and public awareness regarding climate change adaptation and mitigation. Decisions regarding interventions need to be informed by scientific knowledge. Research institutions, therefore shall play an important role to generate relevant climate change scientific information that shall be accessible to the public and decision makers. The government envisions that tertiary and research institutions shall undertake research to quantify likely impacts of climate change and develop practical solutions for adaptation to and mitigation of climate change. Training institutions at different levels will contribute to research and capacity building of well-trained scientific, technical and managerial persons who will understand and become actively engaged in climate change adaptation and mitigation. The critical importance of early warning systems to Climate Change mitigation cannot be overemphasized. Therefore the following actions deserve attention of government and other stakeholders;

i. Raising public awareness of climate change and adaptation as well as mitigation measures in all cities, towns and villages in the country.

ii. Training members of the public and civil society organizations on adaptation and mitigation measures including simulation of disaster events.

iii. Institution of scholarship programme and other incentives in tertiary institutions in order to motivate students to study climatology and disaster risk reduction.

iv. Government will further carry out vulnerability studies in all settlements based on a programme of phasing followed by development of vulnerability models using reliable climatic data.

v. Making meteorological data available to farmers for planning purposes.

8.6 Creating Local Capability for Mitigating the Externalities Associated with Climate Change

(i) Use the climate observation network to collect meteorological data and disseminate same widely.

(ii) All existing MDAs and organizations working on climate change issues will be strengthened.

(iii) Climate Change Committees will be set up for establishment of a reliable monitoring and evaluation framework for all facets of CC including mitigation and adaptation programmes and projects.

(iv) Improvement in the capacity building of institutions teaching and researching meteorology and disaster risk reduction.

(v) Government will accord priority to afforestation and re-afforestation programmes by involving the private sector and individuals. Such programmes will also emphasize early maturing crops as well as variety of suitable crops.

(vi) The government will develop and foster international networks for the sharing of experience and information.

(vii) The output of research will also be used for planning mitigation and adaptation policies and strategies.

(viii) Continuous training can improve modern mitigation strategies.

(ix) Sensitization of communities on climate change and good environmental governance.

8.7 Establishing Reliable and Inclusive Climate Research Framework

(i) Establishment of National GHG Inventory systems

(ii) Provision of adequate funding for climate change and related research programmes.

(iii) Enhancement of managerial skills, strengthening the existing climate change R & D centres and MDAs.

(iv) Establishment of local and international linkage or networks in order to enhance exchange of data, learning and innovation.

(v) Government will conduct a scoping study to determine the number, location structure and challenges of climate change R & D institutions following which their facilities including manpower and laboratories will be upgraded and also assign specific responsibilities to each in order to avoid duplication and maximize resources utilization.

8.8 Development of Indigenous Technology for Climate Change Mitigation and Adaptation

(i) Government will adequately fund climate change research and development centres in the country.

(ii) Identification of indigenous researchers in the area of climate and further spreading the awareness campaign among various potential Engineers (formal and informal).

(iii) Development and promotion of local technologies for climate change mitigation and adaptation.

(iv) Young researchers will be encouraged to participate in climate change programmes.

(v) Establishment of indigenous knowledge network such as IKAD and technology adaptation in regional centers across the country.

(i) Provision of adequate funding for the development of locally developed renewable energy technologies such as biogas production facilities, solar PV systems, improve wood burning stove etc.

8.9 Education and Public awareness (Communication)

Media coverage of climate change issues is pivotal to ensure adequate availability and supply of climate change information to communities, which shall empower local communities to undertake appropriate action or interventions. The media will play a key role to inform and educate the public regarding climate change. The media shall be encouraged to take an active role to obtain accurate information about the causes and impacts of climate change world-wide and in Nigeria and interventions to address climate change adaptation and mitigation. The media would be at the forefront of facilitating public awareness about climate change. The media shall be at the interface of translating scientific information on climate change and disseminating it to various stakeholders in a manner that is easily understood.

8.10 Anticipated Projects for Climate Change Adaptation and Mitigation

In order to effectively address the problem of climate change in the country, there is need to address specific problem issues. The objective is primarily to strengthen the country's resilience to climate change impacts. Some of the key projects ideas are as follows:

1. Develop an extended and coordinated high-speed rail networks as alternative to local flights. This would also relief the road networks of traffic burden and boost the local economy.
2. Establish regional and local numerical weather forecasting centres
3. Increasing the density of the Nigerian synoptic meteorological stations to meet the WMO standard and enhance the accuracy of weather forecasts.
4. Develop a dense network of early warning system for climate-related disasters at at national, regional and local levels
5. Establish efficient and effective communication of local risk-based climate information.
6. Structural interventions projects (such as embankments along the coasts and major drainage channels) to reduce the effects of climate-related extreme events.
7. Strengthen the extant capacity for national, regional and local weather forecasting
8. Establish national and regional research and development centres for climate change in each geopolitical regions of Nigeria to coordinate regional interventions.
9. Upgrading the existing meteorological stations to meet the international standards
10. Integrating climate change issues into development plan and implementing at national, regional and local levels
11. Empowering women in the various facets of food production to enhance food security.
12. Developing a gender-sensitive climate disaster management plan under different scenarios.
13. Providing energy-efficient cooking and drying devices for women.
14. Urbanization is a major factor of vegetation loss in the country especially in the erstwhile rich tropical rainforest belt. This needs to be addressed in many fronts including in the development and implementation of urban forestry programmes. The intervention would require sensitization to encourage informed participation at the grassroots; it would also entail identifying and producing suitable tree seedlings for the purpose. The project implementation would be coordinated at the Local Government Area level with a reward plan and a robust M&E component.

15. Climate-proofing the country's agricultural development programmes: Agricultural programmes and practices need to respond flexibly to changing climate in terms of input, farming schedules, choice of crops and development of irrigation programmes. Intervention projects that would involve rich process learning components would be developed for the various phases of food production to respond to the challenges posed by climate change.
16. Land use control programmes to protect the remaining rural land as well as fresh water resources. This will require mapping of the land areas and developing community-driven plans for setting greenbelts and specifying rural land uses for various locations. It would also be to checkmate ineffective utilization of land for activities like gas filling stations.
17. Population health vulnerabilities to vector-borne diseases under climate change conditions in the Sudano-Sahelian Region (SSR) of Nigeria This project will carry out an assessment of the vulnerabilities of populations in the country to vector-borne diseases through the provision of evidenced based data. The data useful for building effective adaptive capacity to climate change at the community, state and national levels. The study will also develop adaptation strategies to reduce population health vulnerabilities under climate change conditions in the region.
18. Assessment of Green Skill Needs and Absorptive Capacity in Nigeria. The purpose of this study will be to identify major sectors with greening potentials in Nigeria and assess their programmes, frameworks, greening policies, strategies and absorptive capacity for industrial development in the country. It will also assess the current and emerging clean technology workforce needs in Nigeria. The goal of the project is to recommend potential solutions to workforce challenges that can be addressed by clean technology sector.
19. Assessment of climate change impacts on urbanization Nigeria change. This project will examine the drivers of urbanization and explore the linkages of urbanization with climate change. It will evaluate the vulnerabilities of urban areas to at the regional level and develop response measure to pre-empt disaster that may attend the growing impacts of climate change.
20. Climate change technology needs assessment for Nigeria: The project will identify climate change technology priorities for the country by sector. Its primary goal will be to create a framework for climate change technology development and diffusion for effective adaptation and mitigation activities.
21. Promoting low carbon energy access in Nigeria: This project will explore pathways for a technological leapfrog that will avoid lock-ins to carbon-intensive technologies in Nigeria. It will focus on making accessible low cost basic technologies for energy efficiency at the domestic and industrial levels.
22. Development of Land use database for adapting to and mitigating climate change impacts. The project will develop/update land use information needed to monitor emissions in Land use and Land use change sector. It will assess options for effective and efficient land management to contain the increasing population of the country and ensure sustainable production of food and other critical raw materials including biomass for energy production.

These activities will require financial support and effort must be made to access national and international sources for the purpose.

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