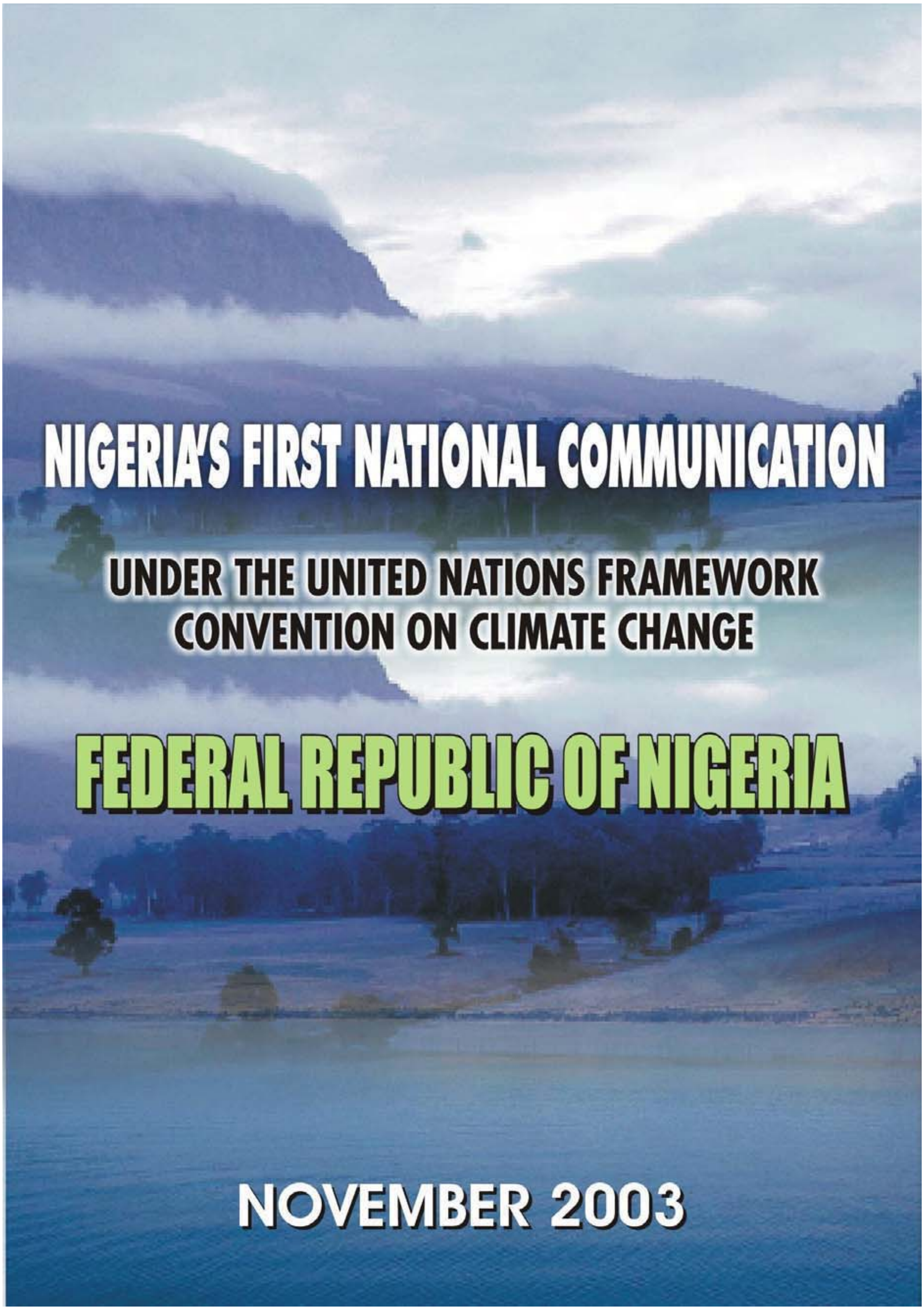
# NIGERIA'S FIRST NATIONAL COMMUNICATION

## UNDER THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

## FEDERAL REPUBLIC OF NIGERIA

NOVEMBER 2003



# NIGERIA'S FIRST NATIONAL COMMUNICATION

# UNDER THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

*The Ministry of Environment of the Federal Republic of Nigeria*

*Abuja 2003*

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| | |
|---|---|
| ACMAD | African Centre of Meteorological Applications for Development |
| ASLR | Accelerated Sea Level Rise |
| CFC | Chlorofluorocarbon |
| COP | Conference of Parties |
| ECN | Energy Commission of Nigeria |
| EPA | Environmental Protection Agency (of the USA) |
| FAO | Food Agriculture Organisation |
| FEPA | Federal Environmental Protection Agency |
| FMEnv. | Federal Ministry of Environment |
| FORMECU | Forestry Resources Management, Evaluation and Coordinating Unit |
| FOS | Federal Office of Statistics |
| FRN | Federal Republic of Nigeria |
| GCM | General Circulation Model |
| GDP | Gross Domestic Product |
| GEF | Global Environment Facility |
| GHG | Greenhouse Gas |
| ICCC | Interministerial Committee on Climate Change |
| IEC | Information, Education, and Communication |
| IGBP | International Geosphere – Biosphere Programme |
| IPCC | Inter-governmental Panel on Climate Change |
| LULUCF | Landuse Landuse Changes and Forestry |
| MARKal | Market Allocation |
| NASRDA | National Space Research and Development Agency |
| NCAZS | National Centre for Arid Zone Studies |
| NCC | Nigerian Coal Corporation |
| NCCC | National Committee on Climate Change |
| NCRS | National Centre for Remote Sensing |
| NEPA | National Electric Power Authority |
| NIMET | Nigerian Meteorological Agency |
| NIOMR | Nigerian Institute for Oceanography and Marine Research |
| NMVOC | Non-methane Volatile Organic Compound |
| NNPC | Nigerian National Petroleum Corporation |
| NNRA | Nigerian Nuclear Regulatory Authority |

| | |
|---|---|
| NWRI | National Water Resources Institute |
| OECD | Organisation for Economic Co-operation and Development |
| SRES | Special Report on Emission Scenarios |
| UNCED | United Nations Conference on Environment and Development |
| UNDP | United Nations Development Programme |
| UNEP | United Nations Environment Programme |
| UNFCCC | United Nations Framework Convention on Climate Change |
| WCP | World Climate Programme |
| WMO | World Meteorological Organisation |

# EXECUTIVE SUMMARY

## NATIONAL CIRCUMSTANCES

Some physical and socio-economic characteristics of Nigeria are presented in Table ES1.

**Table ES1 Physical and Socio-Economic Characteristics of Nigeria**

| **Characteristic** | **1994** |
|---|---|
| Location | West Africa Subregion |
| Total Area | 923,800 $Km^2$ |
| Land Area | 910,770 $Km^2$ |
| Population Estimate from (1991 Census) | 96.8Million |
| Population Growth Rate | 2.83 |
| Adult Literacy (%) | 57.0 |
| Life Expectancy at Birth (Years) | 52.0 |
| Share of Agriculture (%) | 37.19 |
| Share of Industry (%) | 20.07 |
| Petroleum (%) | 12.58 |
| Mining and Quarrying (%) | 0.30 |
| Manufacturing (%) | 7.18 |
| Services (%) | 41.75 |
| GDP Per Capital Income (US$) | 47.70 |
| GDP (in million US$) | 4,616,633,388 |
| GDP Growth Rate (%) | 1.34 |
| Human Development Index | 0.402 |

Nigeria with a total area of 923,800 sq km occupies about 14% of land area in West Africa. The country lies between 4$^{o}$N and 14$^{o}$N, and between 3$^{o}$E and 15$^{o}$E. It is bordered respectively in the north, east, and west by Niger, the Cameroon, and Benin Republic, while the Gulf of Guinea, an arm of the Atlantic Ocean, forms the southern border. Most of Nigeria is covered with Pre- Cambrian rocks, but there are also metamorphic and sedimentary rocks of Eocene times as well as volcanic rocks. In general, three types of geologic structures exist in Nigeria, namely, areas of uplift, basins of sedimentation, and isolated volcanic areas. The areas of uplift are made up of the oldest rocks in Nigeria - the basement complex rocks. The basins of sedimentation are the down-warped areas, which were drowned by the sea at different times and in which sediments eroded from the areas of uplift were laid down.

**RELIEF AND DRAINAGE**

The highest areas are in the east, north, and west, where land is generally over 1,500 metres, 600 metres, and 300 metres, respectively. The low-lying areas, which are generally below 300 metres, lie along the coast and along the main river valleys. The Udi Plateau which lies to the east breaks the monotony of the surface along the coastal lowlands, which are characterized by coastal creeks and lagoons on both sides of the Niger Delta. West of this Delta the coastal areas consist of lagoons and swamps, separated from the open sea by strips of sandy land, which vary in width from 2 to 6 kilometers. The Niger Delta is cut up by numerous water channels through which the River Niger reaches the sea.

The main drainage systems in Nigeria are the Niger - Benue, Chad, and coastal rivers. The main sources of the rivers include the North-Central Plateau, Western Uplands, Eastern Highlands, and the Udi Plateau.

**CLIMATE**

Nigeria is located within the tropics and therefore experiences high temperatures throughout the year. The mean for the country is $27^oC$. Average maximum temperatures vary from $32^oC$ along the coast to $41^oC$ in the far north, while mean minimum figures range from $21^oC$ in the coast to under $13^oC$ in the north. The climate of the country varies from a very wet coastal area with annual rainfall greater than 3,500 mm to the Sahel region in the north western and north eastern parts, with annual rainfall less than 600 mm. Recent studies have revealed declining trends in rainfall. There are generally two seasons in the year: the wet and the dry seasons. The length of the rainy season decreases from 9-12 months in the south to only 3-4 months in the extreme northeast.

**VEGETATION**

Nigeria has six main vegetation zones namely, the mangrove swamps the Fresh water swamps , the rain forest swamps and other coastal vegetation, tropical lowland rainforest, Guinea savanna, Sudan savanna, and the Sahel savanna. Along the coast are salt-water and freshwater swamps and other coastal vegetation. Further inland, the lowland rainforest, Guinea savanna, Sudan savanna, and Sahel savanna follow roughly in that order.

**SOILS**

The soils in Nigeria can broadly be categorized into the northern zone of sandy soils, Guinea savanna zone of lateritic soils, the southern belt of forest soils, and the zone of alluvial soils. They have varying potentials for agriculture.

**ECONOMIC STRUCTURE**

Nigeria's GDP growth rate is 2.7%, down from over 7% in the 1980s and the first half of the 1990s. Agricultural growth averages 2.5%, industries 2.9%, and the service sector 2.4%. Petroleum dominates the economy and contributes over 80 percent of the foreign exchange.

**POPULATION AND SETTLEMENT**

With an estimated population of about 120 million and total area of 923,800 $km^2$, Nigeria's dense population makes it a high potential contributor to global warming. Very high population densities are found in the eastern states, the western cocoa belt, the Lagos metropolitan area, and the Kano and Sokoto regions of the north. In some parts of the eastern States, the population density exceeds 1,000 persons per sq. km. Large areas of the country are, however, sparsely populated. Out of over 250 ethnic groups the most numerous are Yoruba, Igbo, and Hausa/Fulani. Other groups include Tiv, Ibibio, Ijaw, Edo, and

Urhobo.

**ENERGY**
Nigeria is well endowed with energy resources, the main ones being petroleum, natural gas, coal, tar sand, and biomass. The country consumes a very considerable amount of liquefied petroleum gas, 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 country has a massive potential for renewable energy: solar, hydro, biomass, and wind.

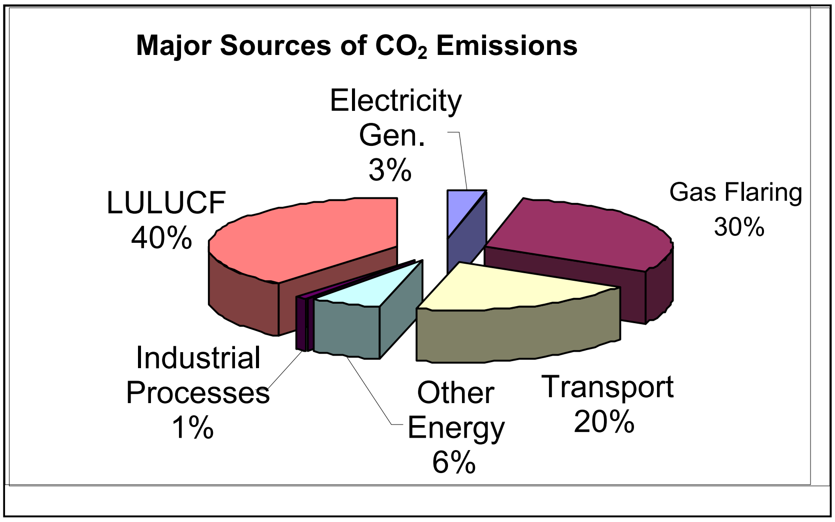
**AGRICULTURE**
Although crude oil is now by far the most important source of national revenue, about 60% of the labour force is still employed in agriculture. More than 90% of agricultural production comes from rural-based, small-scale farmers. While root crops dominate in the south, grains prevail in the north where also the main livestock population exists.

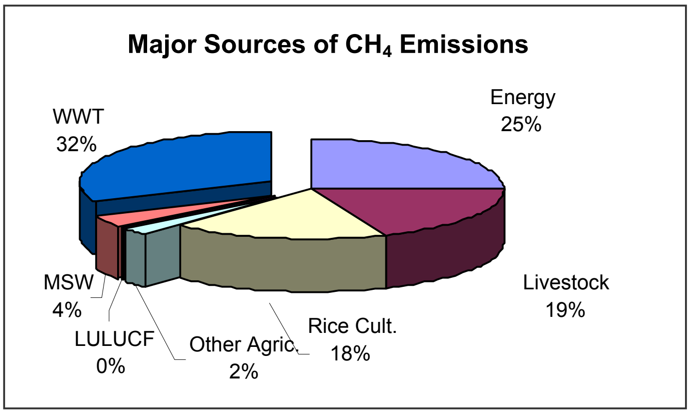
## INVENTORY OF GREENHOUSE GASES

Article 4 of the United Nations Framework Convention on Climate Change (UNFCCC), requires each Party to periodically report the emissions of greenhouse gases (GHGs) including $CO_2$, $CH_4$, $N_2O$ and precursor gases - CO, $NO_X$, and Non-Methane Volatile Organic Compounds (NMVOC) in their first National Communication. This communication presents Nigeria's gross national emissions of GHGs by sources and by sinks.

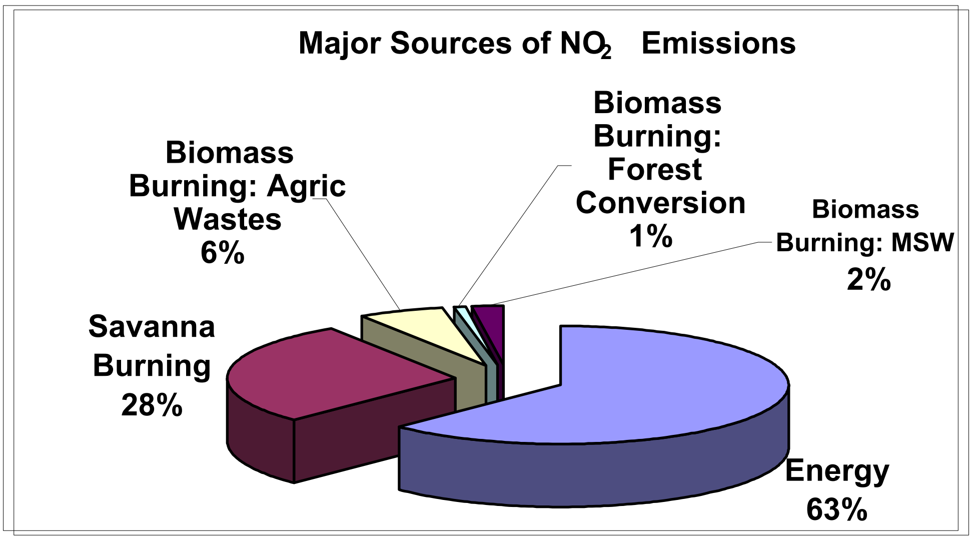
The Intergovernmental Panel on Climate Change (IPCC) has developed a set of common guidelines for national GHG inventories by sources and sinks in relation to national obligations under the UNFCCC. This IPCC common methodology was adopted for this study. Under the IPCC methodology, default IPCC emission factors data were used for most of source emission computation, while activity data were obtained from national sources. These include Department of Petroleum Resources (DPR), Nigerian National Petroleum Corporation (NNPC), Federal Office of Statistics (FOS), Manufacturers Association of Nigeria (MAN), Central Bank of Nigeria (CBN), Departments of Forestry and Livestock in the Federal Ministry of Agriculture, and Waste Management Agencies at national and state levels. Others include the National Population Commission (NPC), Chambers of Commerce and Industry and the National Electric Power Authority (NEPA). These were supported by data from international agencies, especially World Bank, Food and Agriculture Organization (FAO), World Resources Institute (WRI), International Energy Agency (IEA), African Development Bank (ADB) and specialized publications.

The gross carbon emissions from energy, land use change, industry, solvents use, agriculture and waste management in 1994 was 52.5 Tg-$CO_2$-C, while the net uptake, principally from land use change, was 10.4 Tg-$CO_2$-C.



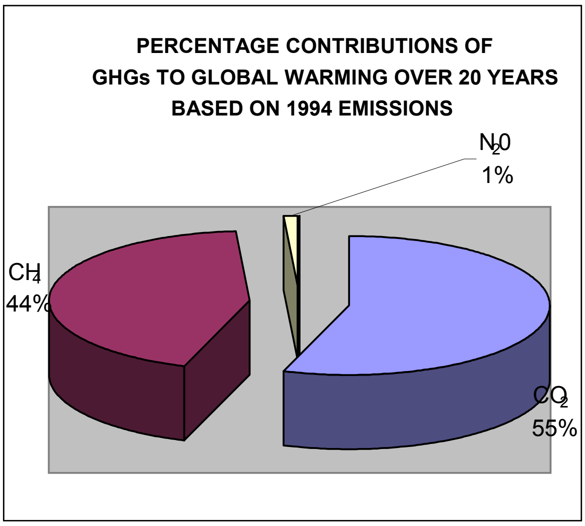



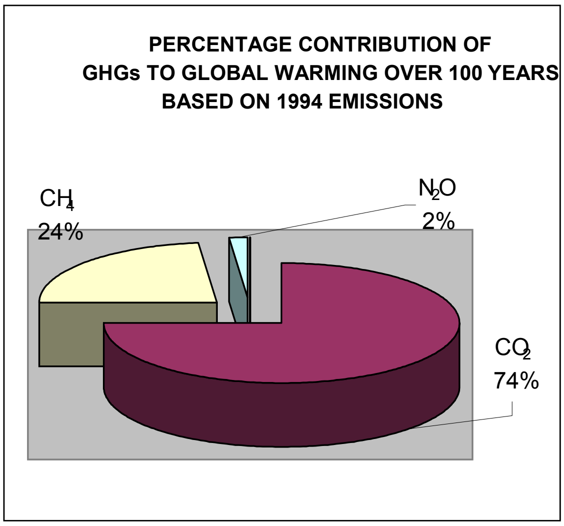

This gives a net carbon emission of 42.1 Tg $CO_2$-C. The summary of national emissions of GHG is: 192 Tg $CO_2$, 17.0 Tg CO, 5.9 Tg $CH_4$, and 2.2 Tg NMVOC. Others include 660 Gg of $NO_X$ and 12 Gg of $N_2O$.



Gas flaring, transportation, and electricity generation are the most significant energy consumption processes leading to GHG emissions. Energy and land use change sectors were the main contributors to $CO_2$ emissions, while energy, agriculture and waste management are the main contributors to $CH_4$ emissions. The energy and land use change sectors are the dominant contributors to $CO_2$ emission, while agriculture, waste management and energy are the main contributors to $CH_4$ emissions. Carbon monoxide emissions and other GHG precursors arise mainly from energy and agriculture and to a lesser extent from waste management and industrial processes.

The assessment of the potential for inducing global warming by the three major GHGs has also been undertaken based on the global warming potential (GWP) for $CO_2$, $CH_4$ and $N_2O$ projected for the next 100 years.



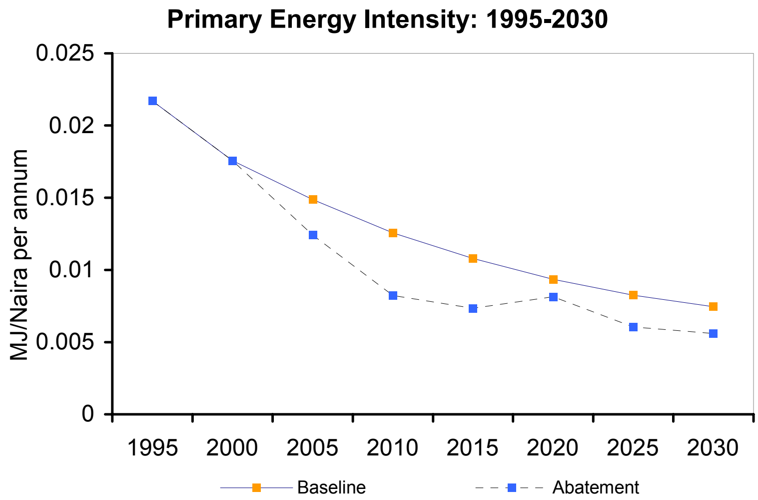




This is an indication of the relative importance of the major GHGs to mitigation analysis. The data quality for the GHG inventory could be significantly improved by implementing new studies on local emission factors estimation and some sub-sectoral activities data collection, which are currently inadequate.

## MITIGATION MEASURES TO ADDRESS CLIMATE CHANGE

The emission of GHG in Nigeria is generally low based on low per capita energy and other resources consumption in the country. These are expected to rise in the future as a result of the high population growth rate, and corresponding increase in per capita energy and other resource consumption. The assessment of options to reduce future GHG emissions is considered an important contribution to the sustainable development of Nigeria. This is being undertaken in respect of the energy, land use change and forestry (LUCF) sectors, which are the main contributors to carbon emissions.

The primary tools used for the study of Nigeria's future energy system and options for mitigation are the MARKet Allocation (MARKAL) model, and the Model for Analysis of Demand for Energy (MADE). Based on these, the expected current and projected primary energy consumption patterns are presented up to 2030.




The identification and ranking of mitigation options for energy, land use change and forestry (LUCF) sectors have been carried out. For the energy sector, results indicate that some of the options can be implemented at a net negative cost to the total energy system cost. Apart from the obvious case of gas-flare reduction in the oil industry, significant $CO_2$ emission reduction could be achieved in the residential, transport and industrial sectors of the energy system. Based on the incremental costs per ton of $CO_2$ removed, the most promising mitigation options in the Nigerian energy system are the introduction of compact fluorescent light (CFL) bulbs at a negative incremental cost of $58/Ton $CO_2$, followed by the introduction of improved kerosene stoves in households, at a cost of $21/Ton of $CO_2$ reduced. Other viable options include fuel-oil to natural gas fuel substitution in the cement industry ($18/Ton), introduction of efficient motors in industry ($15/Ton), and improved electrical appliances ($16/Ton) and wood-stoves ($3/Ton) in the residential sector.

For the land use change and forestry sector, afforestation, agroforestry and forest protection options have been evaluated. Results for the afforestation have the highest potential for carbon sequestration followed by agroforestry and forest protection options. For the afforestation option, the volume of carbon expected to be sequestered is in excess of the estimated net emissions of 427.4 and 580.5 MtC at 1.3% and 2.6% deforestation rates respectively. The average initial cost of establishment is $500/ha or an average unit cost of $13.4/tC. This implies a capital need of $3.8 billion over a period of 40 years (about $94 million/yr). The analysis also shows that the wood product needs of the country would be met over the 40-year period. For the agroforestry option, the estimated volume of carbon expected to be stored over the period is less than that which will be released by 2030.

## CLIMATE CHANGE SCENARIOS IN NIGERIA

In this section, we have attempted to give an outline of the potential climate change in Nigeria in the aftermath of observed current global warming. The outline has been provided with respect to the ecological zones including: Forest, Southern Guinea, Northern Guinea, Sudan and Sahel. While analyses were undertaken for several climatic parameters including cloud cover, precipitation, diurnal temperature range, minimum temperature, maximum temperature, average daily temperature and vapor pressure, only two of them namely precipitation and maximum temperature are discussed. The main findings are as follows:

- The most significant changes are with respect to temperature and temperature related parameters. There has been a tendency to emphasize changes in temperature in the temperate latitudes and to imply that similar changes will not occur in tropical areas. Given some of the emission scenarios discussed in this document, changes in minimum and maximum temperatures of the order of 7$^{o}$C or more could be expected in certain parts of the country. This is likely to create a significantly different world with implications in vulnerability and adaptive capacity. The impacts of such changes will be felt in multiple sectors including: health, water, biodiversity, agriculture and forestry.

- Night time temperatures will in general increase at a higher rate than day time temperatures. This has a potential to alter the themo-period to the detriment of biodiversity. Crops and other plants requiring low temperature conditioning may in the short run survive through autonomous adaptations, but in the long run, may suffer extinction.

- Day time temperatures may in future attain levels unknown to areas outside the hot desert regions. In areas with perennially humid air, this has the potential to produce sultriness usually associated with the oppressive heat.

- There has been an observed trend towards aridity in Sub Saharan West Africa. Our findings are to the effect that this trend will be put on hold or reversed as the century progresses. There are possibilities however, that the additional water need created by higher temperatures may not be met by the increases in rainfall.

- One aspect of the current climate pattern that will be carried forward into the potential climate of the future is zonation. All the parameter values are still likely to increase or decrease with distance from the coastline. Rainfall and humidity will decrease, while temperature will increase with distance from the sea.

- Uncertainties regarding climate change will most likely be in terms of magnitude rather than of direction. The more significant uncertainties pertain to temperature and temperature related parameters in respect of which the expected changes are relatively large. With respect to moisture, the projections are for an increase rather than a decrease. The worst case scenarios are the situations in which the moisture level does not change

## IMPACTS, VULNERABILITY, AND ADAPTATION MEASURES

It is widely assumed that over the past decade in West Africa, temperatures have generally increased by 0.2 to 0.3 degree centigrade. Thus, three sets of boundary conditions for accelerated sea level rise (ASLR) have been used in analysing vulnerability to, impact of, and adaptations to climate change. The three are ASLR of 0.2, 0.5, and 1.0 metre.

### PHYSICAL AND ECOLOGICAL SYSTEMS

Climate change will lead to a shift in the boundaries of major ecological zones, alteration in floristic and faunistic composition, significant reduction in products from the various zones, greater soil erosion and flooding in areas of higher rainfall, heightened drought and desertification in the northern regions, and salt-water intrusion along the coastal belt. The numerous adaptation and control measures required here include construction of check dams, barrages, and diversion channels; use of cover plants, sound agroforestry methods, and sandbagging; population resettlement; realignment of transportation routes; sand-dune stabilization; reduction of vegetation destruction; and vigorous afforestation.

### AGRICULTURE AND LIVESTOCK PRODUCTION

In Nigeria agriculture is the main source of food, is a major source of industrial raw materials and foreign exchange, and employs about 60 percent of the population. It is dominantly rain-fed and is therefore particularly vulnerable to climate change. Similarly, livestock production, which involves more than 12 million cattle, 24 million goats, and 8 million sheep raised principally in the northern states, is heavily dependent on rainfall and is equally vulnerable. Adaptation measures and coping strategies required in the agriculture and livestock production sectors include

- alteration of planting calendar and crop choices
- increased irrigation and number of watering points
- use of terraces, ridges, and minimum tillage
- careful use of agrochemicals and supplementary feeding
- preference of polyculture over monoculture
- reduction of stocking rates or livestock density
- restoration and expansion of grazing areas
- provision of effective extension services.

### FISHERIES

Apart from food supply, fisheries are very important for labour employment. Significant rise in marine and freshwater temperature will impact adversely on fisheries just as salt-water intrusion would seriously damage inland fisheries in rivers, lakes, and aquacultural installations. Necessary adaptation strategies include

- improvements and changes in harvest/ processing/ storage technology
- change in preferred fish species
- expansion of aquaculture.

### WATER RESOURCES

The four principal categories of water resources are precipitation in direct use, river flow plus lake systems, man-made reservoirs, and groundwater resources. Although the country is well-endowed with water, the demand continues to outstrip the supply. In 1996, demand was 6,502 million litres per day with supply being 2,957 MLD. For 2030, the projection is 34,563 MLD and 16,997 MLD, respectively. Enhanced precipitation through climate change naturally benefits the water resource sector while reduced rainfall can spell disaster in terms of insufficient rainfall harvest, low ground water recharge rate, low river/ lake volume and even impaired hydroelectricity generation. Among the mitigation and adaptation options are the following:

- construction of more dams and other reservoirs
- intensification of roof-catch and other rainfall harvesting strategies
- desiltation of reservoirs
- encouraging water recycling and reuse
- protection of watersheds, aquifers, and reservoir sites.

### ENERGY

The most significant impact of climate change on energy will include (a) higher electricity demand for heating, cooling, water pumping, etc., (b) reduced availability of hydroelectricity and fuelwood, and (c) extensive damage to petrochemical industrial installations presently concentrated in the coastal belt. Hence the following strategies must be embraced:

- readiness to relocate power generation and transmission facilities
- sitting new energy facility developments in safer locations
- vigorous and extensive tree planting
- greater development and use of solar energy.

### INDUSTRY AND MINING

Industrial vulnerability to climate change varies with the nature of the industry itself, its raw materials, its products and, as mentioned above, its location. For instance, the numerous industries clustering around Nigeria's seaports are seriously threatened by sea level rise. They must be ready to relocate to safer sites while, on the other hand, the nation's coal, tin, iron ore, limestone and gold mines may only be slightly affected by flooding via heavy precipitation. The latter may require the construction of physical barriers and flood drainage channels.

### TRANSPORT

Adverse climate change will impact heavily on air, land, and water transport but in varying degrees via highway truncation by erosion, waterlogging and submergence of routes and port structures, dust storms, and storms over water bodies. Mitigation measures required will include emplacement of storm surge barriers and channels, realignment of routes, and protection of transport machinery against excessive dust, humidity and heat.

### TOURISM

This is a fast-growing and weather-sensitive activity based mainly on natural reserves, topography, industrial/ transportation construction, water-mediated recreation, and traditional festivals. This base and consequently tourism contribution to GDP are seriously threatened by adverse climatic changes. The problem calls for

- creation of more tourist attractions and facilities
- protection of viable historic sites and relics
- adjustment of tourist visit schedules.

### HEALTH

The health status of Nigerians is poor, life expectancy is under 50 years, annual population growth rate remains above 2.8 percent, and the array of diseases is large. Ill-health and associated conditions stemming from climate change range from heat stroke, cerebro-spinal meningitis, and increase in vector-borne diseases to contamination of freshwater supplies, population dislocations, and damage to healthcare infrastructure. The principal adaptation measures are

- relentless attack on disease vector populations
- improved public sanitation and water supply
- enhanced immunization coverage and general healthcare delivery
- adequate response to disasters
- reduced population growth rate
- sustained public enlightenment on health issues.

## RESEARCH AND SYSTEMATIC OBSERVATION

Nigeria is a large African country highly vulnerable to flood, erosion, drought, desertification, and other hazards directly and indirectly linked to climate. Also the country is associated with international efforts at combating the adverse effects of climate change and at ensuring the availability and adequacy of climatic data. Thus, Nigeria has established various agencies and institutions which are setting up a number of programs as a reflection of the country's concerns. Among the agencies are the National Institute for Freshwater Fisheries Research, National Centre for Arid Zone Studies, National Centre for Climate Change, and Nigerian Meteorological Agency (NIMET), the Universities, Nigerian Institute for Marine Research (NIOMR) and the Hydropower Development Department of the National Electric Power Authority (NEPA).

There is need to establish and strengthen national climate related initiatives and research geared towards

- collection, storage, and easy retrieval of climatic data
- effective and widespread utilization of such data particularly in national planning, policy-making, and institutionalisation of early warning systems
- training of scientists, engineers, and technologists
- greater public awareness of the nature of climate change and of impact mitigation possibilities and coping mechanisms.

## SUSTAINABLE DEVELOPMENT AND INTEGRATED PLANNING

Nigeria's National Policy on the Environment reflects the country's subscription to the concept of sustainable development in which present activities are so conceived, structured, planned, and executed that the future is not jeopardized. At least this is the country's overall developmental objective, as far as the handling of the numerous environmental problems (including adverse climate change) is concerned. These problems, the principal factors responsible for them, and a wide array of mitigation options and adaptation measures have been presented in this Report. However, one absolutely critical factor that needs to be emphasized here is the general inability of the national and regional agencies in charge of the environment to enforce codes, regulations, and laws, especially with respect to urban planning and infrastructural development, mineral prospecting, adherence to industrial standards, and installation of facilities and utilities in ecologically sensitive zones.

Broadly, national strategies that address environmental problems in Nigeria fall under five headings, and these are: legal and institutional policy framework, capacity building and institution strengthening, encouragement of private initiatives particularly from NGOs and communities, collaboration with international organizations, and financial support.

Most Nigerians have only little knowledge about the nature of climate and the implications of climate change. Therefore, it is important that public information and education programmes be designed (a) to promote knowledge of climate change issues and (b) to guide positive practices to limit or adjust to climate change. At the tertiary, secondary, and primary school levels, the curricula can be adjusted to include topics such as

- nature of weather and climate
- role of weather and climate in human affairs
- nature of climate change
- hazards and general effects of climate change
- adaptation and adjustment to climate change.

For the public at large, seminars, workshops, and talks will greatly enhance enlightenment and awareness creation especially when supported with Information, Education Communication (IEC) materials. Those media houses whose newspapers or magazines devote space and time to environmental issues need to be encouraged to focus more on climate change. Finally, Nigerian policy makers should be adequately sensitized on climate change issues.

### PROPOSED PROJECT CONCEPTS IN CLIMATE CHANGE STUDIES

Certain gaps were identified in the course of preparing this document. The gaps need to be filled in order to enhance the quality of the contents of the second national communication. Some project concepts have been identified and briefly developed in this section in order to fill in some of the gaps while preparing the second national communication.

# CHAPTER ONE

# NATIONAL CIRCUMSTANCES

## 1.1 LOCATION, SIZE AND HISTORICAL BACKGROUND

With an estimated population of about120million (2000), the Federal Republic of Nigeria is the most populous country in Africa. Its 923,800 square kilometres occupies about 14% of West Africa. The country lies between 4$^o$N and 14$^o$N and between 3$^o$E and 15$^o$E. It is bordered on the north, east, and west by Niger, the Cameroon, and Benin Republic, respectively. The Atlantic Ocean forms the southern boundary. The total length of the coastline of the country is about 850 km.

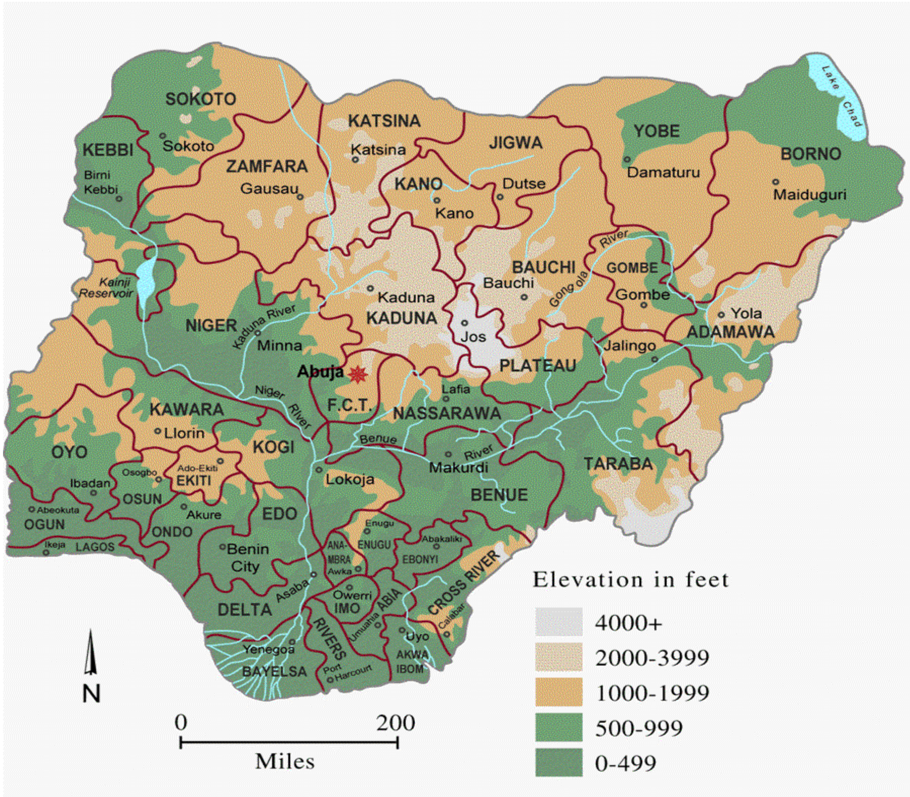



**Figure 1.1: Map of Nigeria Showing Thirty – Six States**

Nigeria is a creation of the colonial period, which started during the late nineteenth century. The history of the country as one political unit, however, dates back to 1914 when the two protectorates of Northern and Southern Nigeria were administered together. The country became independent in 1960, and three years later, adopted a republican constitution but remained a member of the Commonwealth of Nations. Nigeria still has strong economic ties with Britain, although some other countries including Japan, France, Germany, and the United States of America have also emerged as important trading partners. English is the official language. Nigeria is made up of 36 states with a Federal Capital Territory (Fig.1.1.).

## 1.2 PHYSICAL BACKGROUND

### 1.2.1 Geology

Most of Nigeria comprises rocks of Pre-Cambrian age, but there are also rocks of Eocene times, as well as volcanic rocks (Fig. 1.2). The Pre-Cambrian rocks are mostly composed of granites and metamorphosed rocks and are generally found in the higher parts of the country while sandstones of Cretaceous and Eocene times occupy the Benue, Gongola, and Middle Niger Basins.

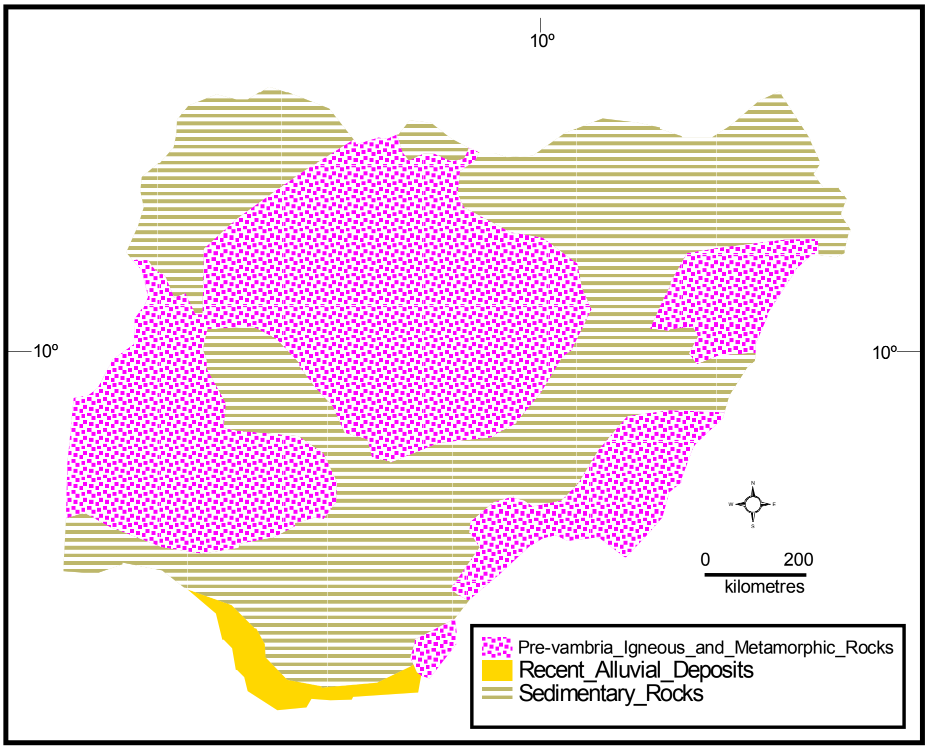



Figure 1.2: Geology of Nigeria

In general, three types of structures can be identified in Nigeria, namely, areas of uplift, basins of sedimentation, and isolated volcanic areas. The areas of uplift are the areas raised en bloc during Pre-Cambrian times. They are the oldest rocks in Nigeria – the

Basement Complex rocks - and are found in four main areas of the northern block, the western block, and two eastern blocks. The rocks are made up of granites, gneiss, and quartzites. The Basement Complex rocks are most widespread, and where they are not found at the surface they underlie relatively younger rocks at great depths.

The basins of sedimentation are the down-warped areas, which were drowned by the sea at different times and in which sediments eroded from the areas of uplift were laid down. These are in the Sokoto Basin, the Chad Basin, the Niger-Benue Trough and the Lower Niger. Basin. The Niger-Benue trough is an elongated basin of sedimentation, which occupies the middle Niger and the Benue, separated from the Sokoto Basin by the Bussa anticline, but joined to the Chad Basin by a narrow corridor west of the Biu Plateau. The Lower Niger Basin is a continuation of the Niger-Benue Trough, and forms a simple syncline.

### 1.2.2 Relief

The highest areas are in the east, north, and west, where land is generally over 1,500 metres, 600 metres, and 300 metres respectively. The low-lying areas, which are generally below 300 metres, lie along the coast and along the valleys of the main rivers. (Fig. 1.3). The Udi Plateau, which lies to the east, however attains a height of over 300 meters and this breaks the monotony of the coastal lowlands, which are also characterized by creeks and lagoons on both sides of the Niger Delta. West of the Niger Delta, the coastal areas consist of lagoons and swamps, separated from the open sea, by a strip of sandy land, which varies in width from 2 to 16 kilometres. The Lagos entrance is the only major outlet through which the lagoons and creeks drain into the sea. The section which lies in the east of the Niger Delta consists of creeks and swamps which stretch from Opobo town through the Cross River estuary to the border with the Cameroon.

The Niger Delta is a low-lying region, cut up by a complicated system of natural channels through which the River Niger finds its way to the sea. It is made up of three distinct sub-regions. They are (a) freshwater zone (b) the mangrove swamps, and (c) the zone of coastal sands and beach ridges. The freshwater zone, which starts from the apex of the delta, just below the town of Aboh, is essentially an extension of the lower Niger floodplains. The numerous water channels in this zone are bordered by natural levees, which provide the sites for most of the settlements and farmlands in the zone. The mangrove swamps, covering about 10,360 square kilometers and located to the south of the freshwater swamps, are sparsely settled. Strips of sandy beaches and ridges, which vary from a few meters to 16 kilometers, separate the mangrove swamps from the open sea. In addition to natural levees, ox-bow lakes are common landforms in the Niger Delta. The high rainfall in the region, coupled with the abundance of surface water and the flat terrain, create a serious drainage problem and makes road construction very difficult.

The coastal plain is a region of gently undulating landscapes developed on young sedimentary rocks. It has an average elevation of less than 90 m above sea level. The portion of the River Niger especially between Jebba and Yelwa is characterized by rapids which impede navigation. Below Jebba, the Niger is free of rapids.

### 1.2.3 Drainage

The main drainage systems in Nigeria are (a) the Niger – Benue, (b) the Chad, and (c) the coastal river systems (Fig. 1.3). The main sources of the rivers include the Jos Plateau, the Western uplands, the Eastern Highlands, and the Udi Plateau. While some of these rivers flow into Lake Chad, others are tributary to the Niger and Benue Rivers

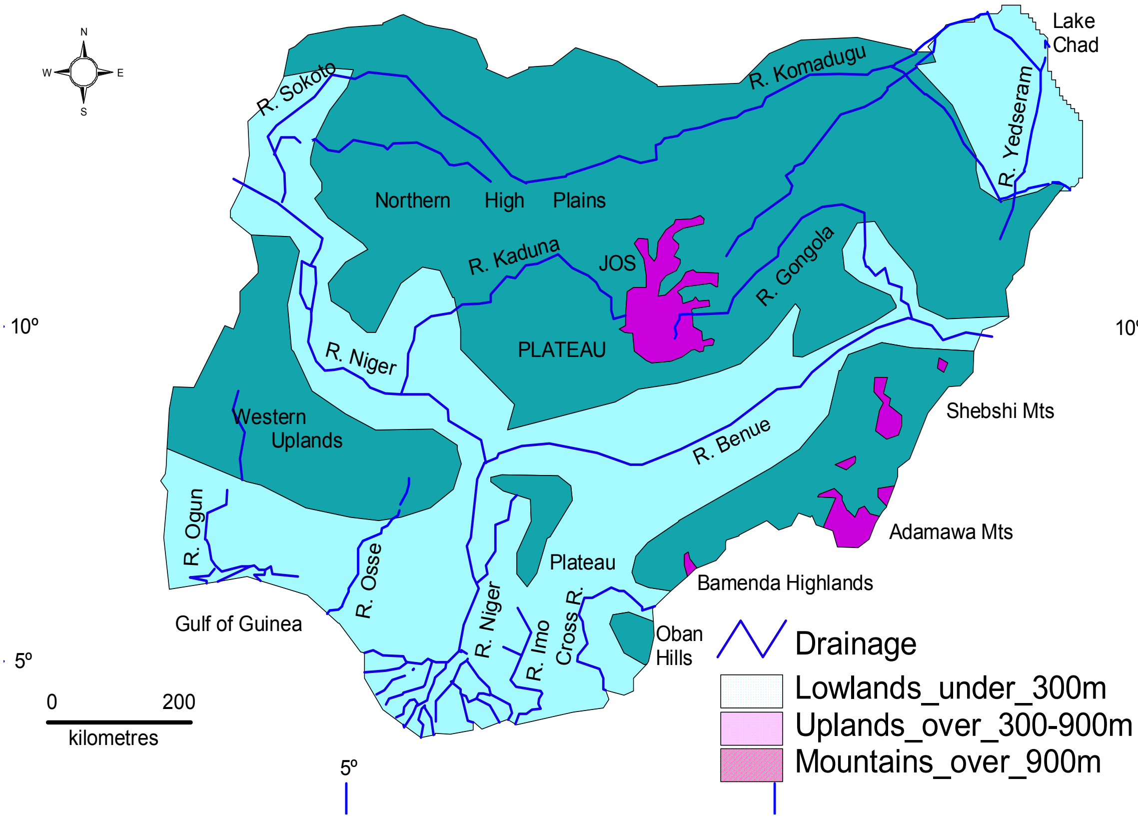



**Figure 1.3. Relief and Drainage Systems in Nigeria**

Some of the rivers which rise from the Western Highlands flow northwards into the Niger and some flow into the Atlantic Ocean. Rivers which rise from the Eastern highlands flow mainly into the Benue River; while some of those that rise from the Udi Plateau, flow into the Niger. Some of the smaller rivers flow into the Cross River. Most of the coastal areas are poorly drained particularly during the rainy season when the rivers and creeks overflow their banks.

The largest river in Nigeria is the Niger, followed by the Benue which joins the Niger at Lokoja. and rises from the Cameroonian Highlands. The Chad, located to the north -east of the country, is the largest natural lake. It is generally shallow but extensive in area, covering about 10,000 to 13,000 square kilometres with marked seasonal fluctuations. It has significantly shrunk from its original size. Lake Kainji on the Niger is man-made, and at 1295 sq km is one of the largest lakes in Africa.

### 1.2.4 Climate

Nigeria is located primarily within the lowland humid tropics and is generally characterized by a high temperature regime almost through the year. In the far south, mean maximum temperature is 32°C while in the north it is 41°C. However, the mean minimum temperature is 21°C in the south and under 13°C in the north which has a much higher annual range. The mean temperature for the country is 27°C, in the absence of altitudinal modifications. Over the last few decades, there has been a general increase in temperature throughout Nigeria.

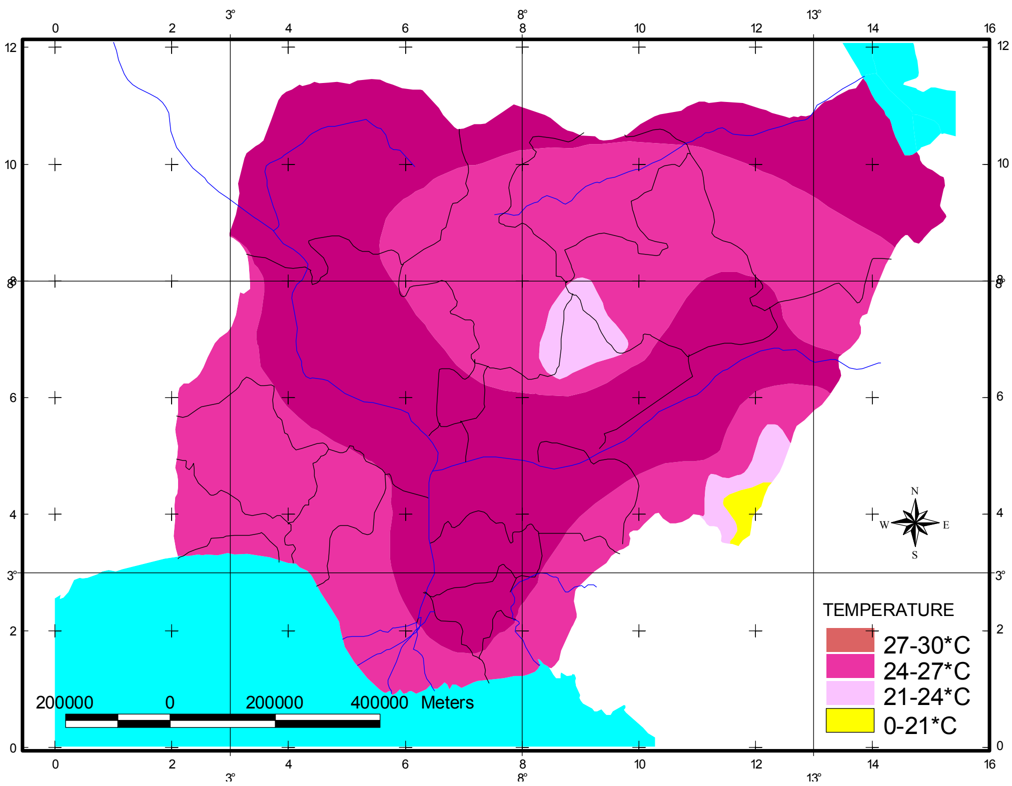



**Figure 1.4. Spatial Variation of Mean Annual Temperature in Nigeria**

The climate of the country varies from a very wet coastal area with annual rainfall greater than 3,500 mm to the Sahel region in the northwest and north-eastern parts, with annual rainfall less than 600 mm. The annual variation of rainfall, particularly in the northern parts, is large. This often results in climatic hazards, especially floods and droughts, which bring in their wake much suffering with devastating effects on food production and the nation's economy. Recent studies have revealed declining trends in rainfall. Often enough parts of Nigeria receive less than 75 percent of their annual rainfall and this is particularly worrisome in the north.

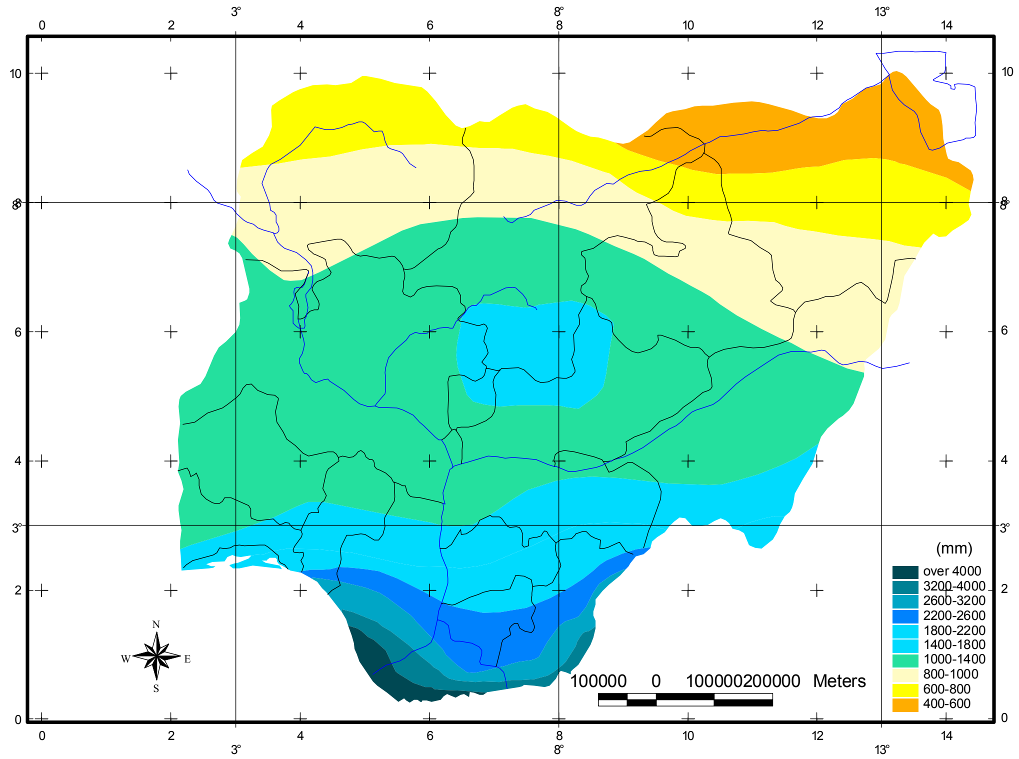



**Figure 1.5: Spatial Variation of Annual Rainfall in Nigeria**

There are generally two seasons in the year, the wet and the dry seasons. The length of the rainy season decreases from 9-12 months in the south to only 2-3 months in the extreme northeast. The climate is also characterized by double rainfall maxima in the south, with the first maximum in June and the second maximum in September. There is thus the "August break" or short dry season in between.

Rainfall is by far the most important element of climate in Nigeria. From a water balance perspective, the country experiences large spatial and temporal variations in rainfall, and less variation in evaporation and evapotranspiration. Consequently, precipitation becomes a very important index for assessing agricultural and water resources potential in the country. In general, most of the coastal areas which receive rainfall throughout the year have more water than required, and often these areas are drained by numerous rivers and creeks. On the other hand, water needs generally exceed water supplies from rainfall for many months of the year in the areas to the north. The quality of domestic water supply in these regions is generally poor. In the middle part of the country, water needs exceed water supply from rainfall for about 3 – 4 months of the year.

### 1.2.5 Vegetation

Nigeria has six main vegetation zones: the Saltwater and Freshwater swamps, tropical lowland rainforests, Guinea savanna, Sudan savanna, and Sahel savanna (Fig. 1.4). Salt and fresh water swamps are along the coast of Nigeria. The salt-water swamps stretch inland for 1-2 km in the Lagos area to over 30 km in the Sapele area. Further inland, beyond the reach of tidal waters, mangroves give way to freshwater plants, the most important of which is the raffia palm. Many species of the tropical lowland forests such as *Mitragyna and Clastopholic spps* grow in the freshwater swamps.

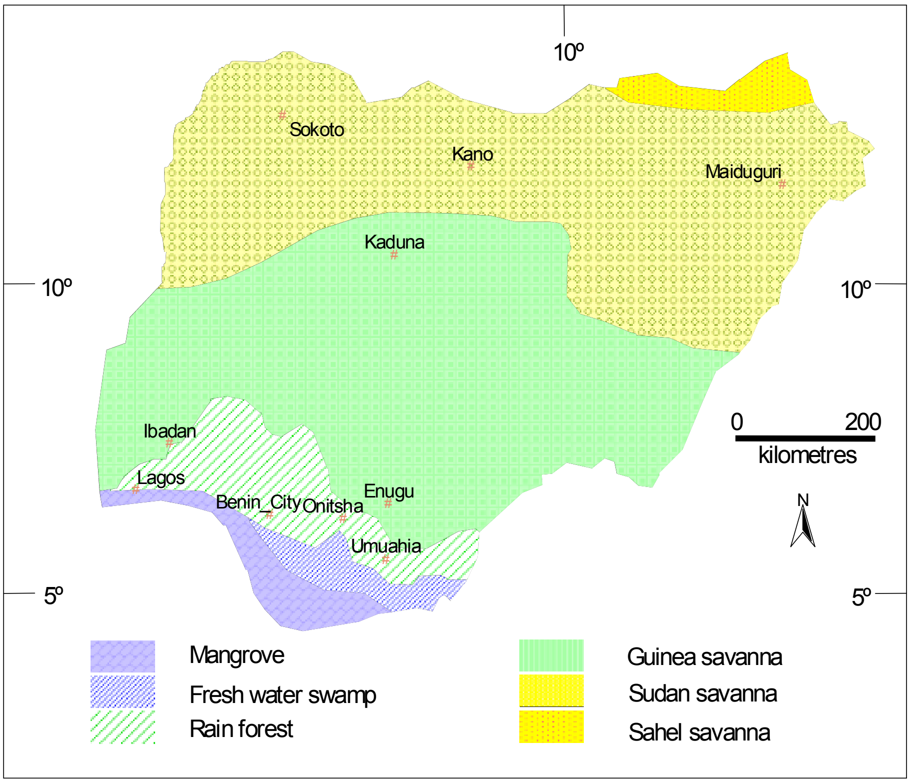



**Figure 1.6: Vegetation of Nigeria**

Along the lagoons, the mangroves give way to the tropical lowland rainforest, a dense evergreen vegetation of tall trees with undergrowth of small trees, shrubs, and herbs. These may become so entangled as to make penetration difficult. The forests are dominated by three layers of tree crowns, with the tallest trees being more than 36 metres. Wherever the forest is relatively untouched, the top canopy becomes so closely interlocked as to prevent most of the rays of the sun from reaching the ground. In such cases, the ground remains damp and almost completely void of undergrowth. The total area of the tropical rainforest in Nigeria is less than 10 percent of the country and continues to be threatened by human activities.

The Guinea savanna is the most extensive vegetation belt in Nigeria. It consists of a mixture of trees and grass, with trees being more numerous in sparsely settled areas. It exists in areas with 1,000 to 1,500 mm of annual rainfall and where the wet season lasts for 6-8 months. Much of the savanna is a by-product of centuries of devastation by man and fire. Along the river banks in the savanna belts are finger-like extensions of the low forests known as gallery forests.

The Sudan savanna belt is found in the northern parts of the country. It stretches from the Sokoto Plains across to the Chad Basin, covering over a quarter of the country's land area. It is found in places with rainfall of about 600-1000 mm and 4 – 6 months of dry season. The vegetation is made up of grasses 1-2 m high and often stunted trees. Some of the most frequent trees in this environment are acacia, dum palm, and the baobab.

The Sahel savanna, the last of the five vegetation zones, occurs in the extreme northwest and northeast where the annual rainfall is less than 600 mm and the length of the dry season exceeds 8 months. The atmosphere is dry except for one or two months in the middle of the brief wet season. The grasses are short and tussocky, 0.5 – 1.0 m high, and are inter-spersed with sand- dunes. The acacia is the dominant tree in the zone, although date palms appear here and there. The swampy shores of Lake Chad support tall reeds growing on seasonally flooded flat land.

The distribution of vegetation has been highly affected by landuse changes during the last 100 years. This has partly been induced by the high population and high rate of urbanization on one hand, and desertification on the other.

### 1.2.6 Soils

Nigerian soils are broadly categorized into four groups. These are (a) the northern zone of sandy soils, (b) the interior zone of lateritic soils, (c) the southern belt of forest soils, and (d) the zone of alluvial soils. The northern zone of sandy soils lies in the Sudan and Sahel savanna belts and is generally formed under the conditions of aridity and wind-deposited sand and silt. In some areas as in Kano, Kaduna and Sokoto States, the soils are fine sandy loam, friable, relatively easy to cultivate, little leached and therefore good for agricultural crops, particularly groundnuts.

The lateritic soils of the interior are generally found in the Guinea savanna and are grey or reddish. They are generally sticky, impervious, and of medium fertility. Clearing of land for cultivation reduces the fertility further. On exposure, they often become hard and are more useful for road paving and building construction than for agriculture. The Guinea savanna also has rich lava soils, for example, in Biu Plateau. These soils have good prospects for agricultural expansion.

The southern belt of forest soils coincides roughly with the high forest zone where the wet season is long and the harmattan season is short. The vegetation plays the double role of supplying humus to the soil and protecting it from erosion. The soil would naturally be fertile but excessive leaching has removed much of the required plant food. The soils are of considerable importance to Nigeria as they yield crops such as cocoa, palm produce, and rubber.

Alluvial soils occur on the floodplains of rivers, in the delta, and along the coast. The zone extends inland from the coast and runs along the valleys of the Niger and the Benue, thus cutting across the vegetation belts. Along the river courses, the soils are sandy, light-hued, and often sterile. In the delta areas, they are clayey or muddy, dark grey in colour, usually waterlogged, and good for rice cultivation. Where they are found on higher drier ground, other crops are also grown on them.

## 1.3 SOCIO-ECONOMIC STRUCTURE

During the past two decades, Nigeria's GDP, already low, grew very slowly, by 2.7% compared with more than 7 to 8% in the 1970s and the first half of the 1980s. The GDP has been characterized by relative sectoral stability showing an annual average of 41% for services, 39% for agriculture, and 21% for industry (see Tables 1.1. and 1.2). The average GDP growth rates indicate that real per capita income fell especially during the 1990s. Furthermore, there was a persistent upward movement of prices, as illustrated by 57.2%, 57.0% and 72.8% rates of inflation for 1993, 1994 and 1995, respectively.

The growth rate of agricultural production has generally been low, between 1.4 and 4.9% with an annual average of 2.5%. At an annual average of 38.8% of total GDP between 1993 and 1997, agriculture continued to represent a major component of GDP, falling slightly below the services sector, which dominates the GDP with an annual average of 41%. Potential for growth remains very high with agriculture providing food, employment, local income, foreign exchange earnings, and essential raw materials for domestic industries.

After consecutive declines of 1.4%, 1.8% and 8.4% from 1993 to 1995, the industrial sector made a positive gain of 2.9 % in 1996. It further expanded by 5.8% contributing 20.2% of total GDP. The petroleum sector averaged 13% of total GDP with an average growth rate of 1.3%. The manufacturing industry constituted a major drawback. The main constraints for the industrial sector stemmed from government policies of excessive regulation especially in the period of exchange control, when many of the industries were established under high protective tariffs and relatively easy access to cheap foreign exchange in the 1970s and early 1980s.

As shown in Table 1.2, the services sector, which consists of utilities, building and construction, transport, communications, wholesale and retail trade, hotels and restaurant, finance and insurance, real estate, housing, producers of government services and of community, social and personal services, account for an increase of about 2.4% over the level of 1996 and account for about 41% of the total GDP.

**Table 1.1: Percentage Distribution of GDP By Sector**

| CATEGORY | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|
| GDP | 100 | 100 | 100 | 100 | 100 |
| Agriculture | 37.78 | 37.19 | 38.24 | 39.01 | 39.17 |
| Industry | 20.71 | 20.07 | 19.57 | 19.83 | 20.22 |
| Petroleum | 13.08 | 12.58 | 12.62 | 13.03 | 13.63 |
| Mining & Quarrying | 0.29 | 0.30 | 0.30 | 0.30 | 0.30 |
| Manufacturing | 7.34 | 7.18 | 6.65 | 6.48 | 6.29 |
| Services | 41.52 | 41.75 | 41.69 | 41.15 | 40.60 |

**Table 1.2: Nigeria's Economic Performance: Annual Growth Rate By Sector (1993-1997)**

| CATEGORY | 1993 | 1994 | 1995 | 2996 | 1997 | Ave. Growth Rate |
|---|---|---|---|---|---|---|
| GDP | 2.68 | 1.34 | 2.15 | 3.37 | 3.77 | 2.66 |
| Agriculture | 1.37 | 2.44 | 3.61 | 4.09 | 4.19 | 3.15 |
| Industry | 1.43 | 1.79 | 0.39 | 4.79 | 5.79 | 1.39 |
| Petroleum | 0.23 | 2.32 | 2.31 | 6.89 | 6.38 | 3.10 |
| Mining & Quarrying | 7.14 | 6.90 | 0.0 | 3.23 | 3.13 | 4.8 |
| Manufacturing | 4.18 | 0.82 | 5.49 | 0.87 | 0.72 | 1.60 |
| Services | 6.05 | 1.90 | 2.01 | 2.04 | 2.38 | 2.88 |

## 1.4 POPULATION AND SETTLEMENT

With a population of about 120 million spread over an area of 923,800 square kilometers, Nigeria is the most populated nation and one of the largest countries in Africa. This high population makes Nigeria a high potential contributor to global warming and, consequently, climate change. The people belongs to many ethnic groups, the most numerous of which include the Yoruba, Igbo and Hausa/Fulani that occupy much of the southwest, southeast, and northern parts of the country, respectively. Among other groups are Tiv, Ibibio, Ijaw, Edo and Urhobo.

High population densities are found in the eastern states, the cocoa belt of the west, the Lagos metropolitan area, and the Kano and Sokoto regions of the north. In parts of the eastern states, the population density exceeds 1,000 people per sq. km. Indeed the east is the most densely populated part of Sub-Saharan Africa south of the Sahara. Medium population densities occur in several areas such as around the Jos Plateau, southern

Tivland and Okene. Large areas of the country are, however, sparsely populated, for example, in parts of the Middle Belt, the Niger Delta region, the Chad Basin, and the Cross River region. Correspondingly, the number and size of settlements reflect the variations in population density. The growth rate of population, its size, structure, density, spatial distribution, urbanization and migration characteristics are critical factors of the environment as well as sustainable development and must be considered in the context of climate change and its impacts.

## 1.5 ENERGY

Nigeria is endowed with energy resources, the major ones being crude oil, natural gas, coal, tar sand, and biomass. 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. Also significant is the fact that at present the bulk (99%) of the natural gas produced is flared while only 1% is consumed in Nigeria. 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 important one in the discussion of greenhouse gas-induced climate change, its consequences, and the need for mitigation and adaptation measures.

Proven crude oil reserves in the country stand at more than 20 billion barrels and may reach 40 billion barrels with additional offshore potentials. Gas reserves are put conservatively at about 2.7 billion cubic metres. The abundance of oil and gas supplies in the country has played a significant role in accounting for Nigeria's heavy reliance on energy. In particular, Nigeria consumed about 19 million metric tones of oil equivalent of commercial energy in 1990, and the level of consumption has been increasing since this period. Also, 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.

The country has a lot of potential for renewable energy. For instance, the annual radiation level in northern Nigeria is about 190 kcal while the level in the south is about 110 kcal. Nigeria is also blessed with massive potential for hydroelectric power generation. 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.

As a source of energy, wood is widely used in Nigeria in both rural and urban areas for cooking and heating. The overall effect is that the country witnesses a high rate of deforestation, about 3.5% annually in 1980–1990. Annual deforestation of the woodlands in northern Nigeria runs to about 92,000 hectares, while the whole country consumes about 50 to 55 million cubic metres of wood annually. According to Food and Agriculture Organization (FAO), the remaining forest area in Nigeria will likely disappear by 2020 if the current rate of forest depletion continues unabated. This means that the major sink for carbon dioxide could soon disappear in the country.

## 1.6 AGRICULTURE

Although crude oil is now by far the most important source of national revenue, about 60% of the labour force is still employed in agriculture. Indeed, the low per capita income partly reflects the continuing reliance of most Nigerians on agriculture. More than 90 percent of agricultural production comes from rural-based, small-scale farmers who produce their own food crops and derive income from several cash crops as well as from the sale of surplus food crops. Mixed cropping on fields, which rarely exceed 2 ha, is characteristic of agriculture in Nigeria. The agricultural sector (crop production, livestock and fisheries) is likely to retain its relative dominance in terms of total labour force for the economy of the country for a long time. This indicates that agricultural activities will remain a significant source of methane emission in the long term.

# CHAPTER TWO

## INVENTORY OF GREENHOUSE GASES

### 2.1 INTRODUCTION

Article 4 of the United Nations Framework Convention on Climate Change (UNFCCC), requires each Party to periodically report the emissions of greenhouse gases (GHGs) including $CO_2$, $CH_4$, $N_2O$ and precursor gases - CO, $NO_X$, and Non-Methane Volatile Organic Compounds (NMVOC) in their first National Communication. This communication presents Nigeria's gross national emissions of GHGs by sources and by sinks.

### 2.2 METHODOLOGY

The estimates of the gross emissions of GHGs from the energy sector, industrial processes, solvents and other products use, agriculture, land use change and forestry, and waste management have been documented by IPCC, the Organization for Economic Co-operation and Development (OECD), and other national agencies. The IPCC procedure has been endorsed as the common framework to report emission inventories of GHG sources and sinks related to the activities of the UNFCCC. The source-emission relations for any GHG are given by the equation:

$$E_i = \sum_{j,k} A_k F_{k,i} \qquad 2.1$$

where E is the emission of pollutant *i* from the consumption/production of a product whose quantity is represented by an activity (A) index and F is the emission factor for pollutant *i* (emissions per unit activity A). The total emission of pollutant *i* for each process is then added over the total number of similar and diverse processes *k* (sectors and sub-sectors), as well as over spatial grids of interest. An emission inventory therefore aims to obtain accurate estimates of the unknowns A and F for each sector and generic sources. The values of A per sector in any country are obtained from all available national data published. Additional data may be obtained from informal sectors through actual field data collection exercises. Similarly IPCC and other international inventory databases have published default emission factors (F) data for all processes in the energy, solvents and other products use, industry, agriculture, land use change and forestry, and waste management. These are to be supplemented by locally measured F values for any process where such emission inventories have been undertaken.

For the energy sector, emissions may be provided through the top-down (TD) method which provides aggregate emissions based on production, imports, exports, stock changes, etc of primary and secondary fuels without details of sectoral fuel use. Under the TD approach, apparent energy consumption is estimated for primary and secondary fuels as follows:

***Primary Fuels:***

$$C_a = P + I - E - IMB - SC \qquad 2.2$$

***Secondary Fuels:***

$$C_a = I - IMB - SC \qquad 2.3$$

where Ca = the apparent energy consumption by fuel type, P = production, I = imports, E = exports, IMB = international marine bunkers, and SC = stock change for both primary and secondary fuels.

The aggregate emission of carbon from all fuels is based on the fuel carbon content, heating values, oxidation fraction and production/consumption data.

$$E_c = C_a \cdot F_c \qquad 2.\ 4$$

where $E_c$ is the aggregate emissions factor in Gg-C, $C_a$ is the apparent energy consumption in PJ and $F_c$ is the carbon emissions factor in tC/TJ.

IPCC provides a more accurate method for national GHG inventory based on the bottom-up (BU) approach for the energy sector, which provides techniques for emission factor estimates for all sub-sector processes based on downstream energy technologies and technology efficiencies. The downstream emissions relevant processes and technologies in the energy sector are segregated into energy and transformations, industrial energy consumption (boilers, etc), transport, small combustion (domestic, commercial/institutional, off-road/forestry/agriculture, etc), and fugitive emissions processes in both the upstream and downstream energy sector. Emissions from the BU approach are based on the application of Equation 2.4 to each downstream energy technology.

The emissions and uptake of carbon and other GHGs from the following non-energy sectors have been undertaken by applying the IPCC BU method to data collected for each of the following sectors:

- Industrial processes
- Solvents and other products use
- Agriculture
  - Livestock production
  - Rice cultivation
  - Savannah burning
  - Field burning of crop wastes
  - Soil emissions related to fertilizer applications
- Land Use Change
  - Forest and other ecosystems growth
  - Biomass harvests
  - Forest conversions (on-site and off-site biomass burning)
  - Abandonment of managed lands
- Waste Management

- Municipal (Domestic and Commercial (D&C)) Solid Wastes
  - Landfills
  - Open dump sites
  - Open burning
  - Incineration
- Waste Water Treatment
  - Municipal (D&C)
  - Industrial

## 2.3 DATA SOURCES

Data for the upstream and downstream energy sectors in Nigeria are obtained from the Department of Petroleum Resources Datasets and the Federal Office of Statistics. The details of the primary and secondary fuels consumption based on the TD approach are presented in Appendix A. The sectoral partitions of energy consumption, which are an input into the BU emissions method are partly documented and partly estimated using established indices. While substantial data exist from Nigerian National Petroleum Corporation (NNPC) and the Department of Petroleum Resources (DPR) technical publications for calculating emissions for power generation, petroleum refining, gas flaring, estimates are made for the following sectors: transport, industrial fuel consumption, and waste generation. For transport, fuel consumption was obtained from total vehicles stock and aggregate, computed from national data on new vehicle registrations based on the method of US EPA. The total consumption of gasoline and diesel per vehicle stock was then calculated. Data on fuel consumption from auto-generation were obtained by projecting data in the Energy Sector Management Assistance Program (ESMAP) of the World Bank's Report to 1994. The production and consumption data in the informal energy sector (comprising fuelwood and charcoal production and consumption) were obtained from the projections of Energy Master plan for Rural Development (EMRD).

The emissions of GHG and precursor gases from industrial processes that are not related to heat and electricity generation in industrial establishments were estimated based on process chemistry. For most processes, default emission factors were obtained from the IPCC Reference Manual, while other stock of emission factors were obtained from locally available estimates as well as from other sources. The main industrial processes considered are $CO_2$ emissions from cement and lime production and $CH_4$ emissions from ammonia production and natural gas processing. Others include $CH_4$ and NMVOC emissions from primary metals production and associated processes, refinery and petrochemical industries, basic and organic chemicals manufacturing, and food/beverage industries. Data for cement production, ammonia production, primary and secondary iron/steel production, primary aluminium production and other industrial products are published by the Federal Office of Statistics (FOS) and the Central Bank of Nigeria. The NNPC provides the data for petroleum refineries and petrochemicals production, natural gas processing, and other oil and gas related activities. These were used together with the estimated emission factors for these processes to obtain the emissions.

There are insufficient data for accurate estimates of emissions from solvents and other products use. This accounts for the low percentage contribution reported for this sub-sector in the gross national emissions of NMVOC. The emissions of NMVOC in Nigeria are currently below 4% in comparison with other countries whose emissions from this sub-sector account for more than 25%. The gross emission from this sector is dominated by paint application, obtained from FOS based on the total local paint production. This is actually lower than the total value of paint application when imports data are added. Data for use of degreasing chemicals, dry cleaning, paper printing and other solvents/products use are not yet available. Among the GHG data are those from data on land use, municipal solid and liquid wastes and agriculture including enteric fermentation and manure management, rice cultivation, savannah burning, field burning of crop residues and agricultural soils.

Municipal solid and liquid wastes (MSW) are generated from various activities in domestic premises and commercial/industrial establishments. MSW generation in Nigeria is estimated from per capita waste generation of 0.49 kg/cap/day (FMHE, 1982) and the urban population, estimated for 1994 to be 16.93 million, based on urban population fraction of 17.5% (FOS, 1997). Estimates of MSW applied in landfills were assumed to be below 5% nationally, while the remaining MSW are assumed to be partially decaying at dumpsites and partially burnt there.

The IPCC guidelines on good practice and uncertainty management provide formats for the documentation of the level of confidence in emission inventory results. Three levels of confidence have been adopted for results presented from this assessment and are shown in Table 2.1.

**Table 2.1: Level of Confidence Associated with 1994 National GHG Inventory in Nigeria**

| Level of Confidence | Code No. | UNCERTAINTY LEVEL PER SECTOR | |
|---|---|---|---|
| | | Energy, Industry | Agriculture, Land Use Change and Waste Management |
| High | 1 | < 20% | < 30% |
| Medium | 2 | 20 – 50% | 30 – 75% |
| Low | 3 | > 50% | > 75% |

## 2.4. GROSS EMISSIONS BY SOURCES AND REMOVAL BY SINKS

An overview of gross carbon emissions by sources and removal by sinks for the year 1994 is presented in Figure 2.1. This indicates gas flaring, transportation, and electricity generation as the most significant energy consumption processes leading to GHG emissions. Similarly, biomass harvests and the conversion of forests to managed lands are the land use and forestry activities leading to gross carbon emissions. Carbon uptake is principally from annual forest growths and the growth of non-forest trees and minimally from the abandonment of managed lands. The gross carbon emissions from energy, land use change, industry, solvents use, agriculture and waste management in 1994 was 52.5 Tg-$CO_2$-C, while the net uptake, principally from land use change, was 10.4 Tg-$CO_2$-C.

This gives a net carbon emission of 42.1 Tg $CO_2$-C. The summary of national emissions (Table 2.2) shows the following gross emissions of GHG: 192 Tg $CO_2$, 17.0 Tg CO, 5.9 Tg $CH_4$, and 2.2 Tg NMVOC. Others include 660 Gg of $NO_X$ and 12 Gg of $N_2O$. The energy and land use change sectors are the dominant contributors to $CO_2$ emission, while agriculture, waste management and energy are the main contributors to $CH_4$ emissions. CO emissions arise mainly from energy (13.1 Tg CO) and agriculture (3.6 Tg CO).

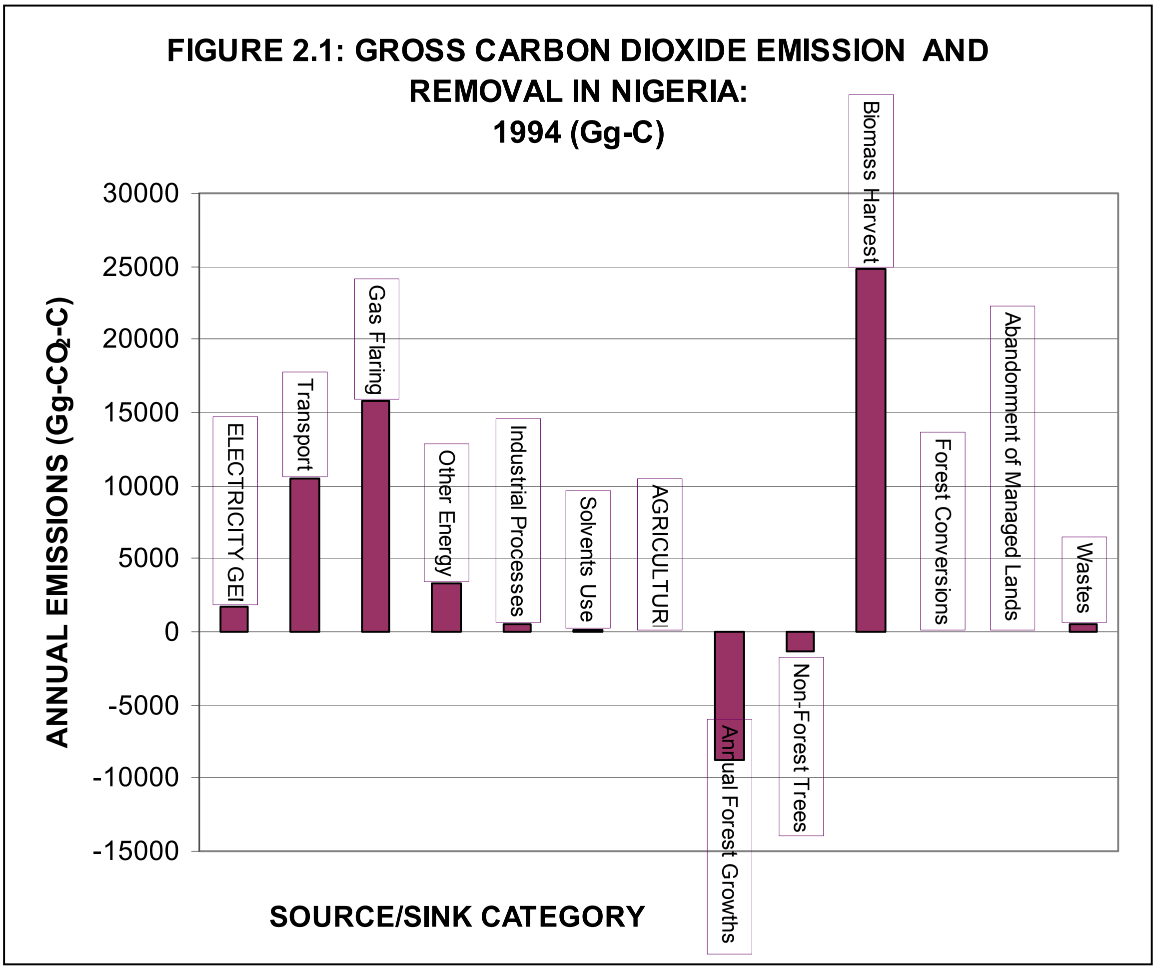


**Table 2.2: Gross National Emissions by Major Sectors and Removal by Sinks in 1994**

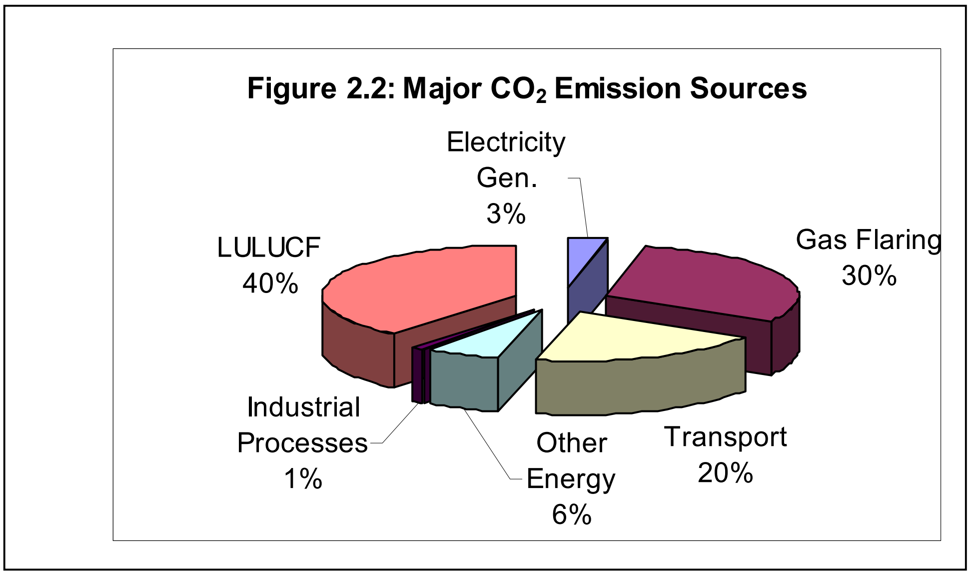
| SOURCE/SINK CATEGORIES | EMISSIONS 1994 (Gg) | | | | | |
|---|---|---|---|---|---|---|
| | $CO_2$ | $CH_4$ | $N_2O$ | CO | $NO_X$ | NMVOC |
| ***1. ENERGY*** | ***115109.45*** | ***1462.96*** | ***7.52*** | ***13124.90*** | ***499.30*** | ***1864.40*** |
| 1.1 Fossil Fuels | 115109.45 | 1018.24 | 4.32 | 9044.52 | 383.43 | 1864.40 |
| 1.2 Biomass Fuels | | 444.72 | 3.21 | 4080.38 | 115.87 | 913.30 |
| ***2. INDUSTRIAL PROCESSES*** | ***1760.88*** | ***0.05*** | ***na*** | | ***0.46*** | ***366.84*** |
| 2.1 Iron/Steel | | 0.05 | na | | | 0.04 |
| 2.2 Inorganic Chemicals | 260.09 | Na | na | | 0.46 | |
| 2.3 Non-Metallic Minerals | 1500.79 | Na | na | | 0.00 | |
| 2.4 Paint | | Na | na | | | 274.97 |
| 2.5 Food/Beverages | | Na | na | | | 3.07 |
| 2.6 Textiles | | Na | na | | | 88.77 |
| ***3. SOLVENTS USE*** | ***260.09*** | ***0.05*** | ***na*** | | ***0.46*** | ***0.04*** |
| 3.1 Paints Application | | 0.05 | | | | 0.04 |
| 3.2 Degreasing/Dry-cleaning | | | | | | |
| 3.3 Paper Printing | 260.09 | | | | 0.46 | |
| ***4. AGRICULTURE*** | | ***2,344.2*** | ***4.10*** | ***3,586.7*** | ***148.00*** | |
| 4.1 Livestock | | 1115.09 | | | | |
| 4.2 Rice Cultivation | | 1085.65 | | | | |
| 4.3 Savannah Burning | | 109.20 | 3.38 | 2866.42 | 122.10 | |
| 4.4 Agricultural Wastes | | 34.30 | 0.72 | 720.29 | 25.94 | |
| 4.5 Soils | | Na | | | | |
| ***5. LAND USE CHANGE & FORESTRY (Net Emissions)*** | ***75,541.7*** | ***18.51*** | ***0.13*** | ***162.0*** | ***4.60*** | |
| 5.1 Annual Forest Growth | -31934.96 | | | | | |
| 5.2 Non-forest Tree Growth | -4785.00 | | | | | |
| 5.3 Biomass Harvests | 91242.79 | | | | | |
| 5.5Forests Conversion to Managed Lands | 21051.34 | 18.51 | 0.13 | 162.00 | 4.60 | |
| 5.6 Abandonment of Managed Lands | -32.45 | | | | | |
| 6. WASTES | 1760.88 | 0.05 | | | 0.46 | 458.68 |
| 6.1 Municipal Solid Wastes | 1760.88 | 0.05 | | | 0.46 | 458.68 |
| 6.2 Waste Water Treatment | Na | na | na | na | na | Na |
| ***NET EMISSIONS*** | ***192484.7*** | ***5930.70*** | ***11.95*** | ***17045.4*** | ***658.28*** | ***2231.51*** |

***Key: na=not available*** ***Solvents Use = Solvents and Other Products Use***

## 2.5. TOTAL GHG EMISSIONS BY SOURCES

### 2.5.1 Carbon Dioxide Emissions

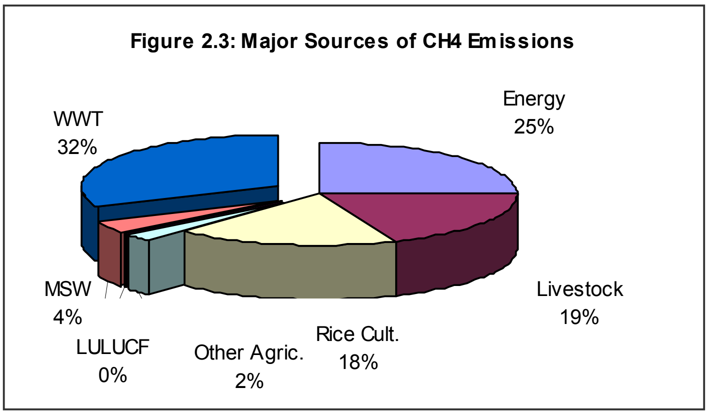
The total $CO_2$ emission in 1994 was 192 Tg $CO_2$. The energy sector contributed 115 Tg $CO_2$, This represents 59.7% of gross national emissions, while land use and land use change and forestry (LULUCF) sector generated 75.5 Tg CO2 representing 39.2% of gross national emissions into the atmosphere.




Less than 1% of gross national $CO_2$ emissions were emitted from the industrial sector. Gas flaring contributed 58.1 million tonnes or 50.4% of gross emissions from the energy sector. The consumption of liquid and gaseous fuels in the sector led to the emissions of 51.3 and 5.4 million tonnes of $CO_2$,respectively.

### 2.5.2 Methane Emissions

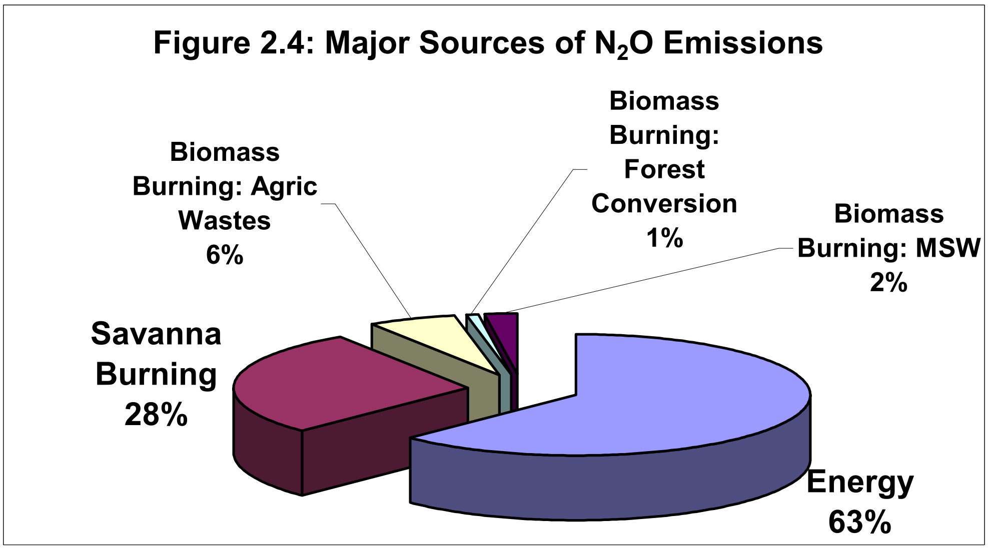
Methane is the second most important GHG after $CO_2$ based on its global warming potential. The total methane emission in 1994 was 5.9 Tg $CH_4$. Out of this, the energy production and consumption sector with a total emission of 1.48 Tg-$CH_4$ contributed 25% of gross national emissions, with agriculture and waste management contributing the rest.



In the agricultural sector, livestock contributed to the emission of 1.1 Tg $CH_4$ representing 19% of gross national emissions, while rice cultivation and other agricultural process contributed 1.08 Tg $CH_4$ and 0.14 Tg $CH_4$ respectively. Municipal solid wastes (MSW) and waste water treatment (WWT) respectively contributed 0.21 and 1.88 Tg $CH_4$ respectively. These respectively represent 4 and 32% of gross national emissions. There were insignificant emissions from industries, solvent and other products use, and land use/land use change and forestry sectors. This indicates that municipal and industrial wastewater treatment is the single most significant source of $CH_4$ emissions.

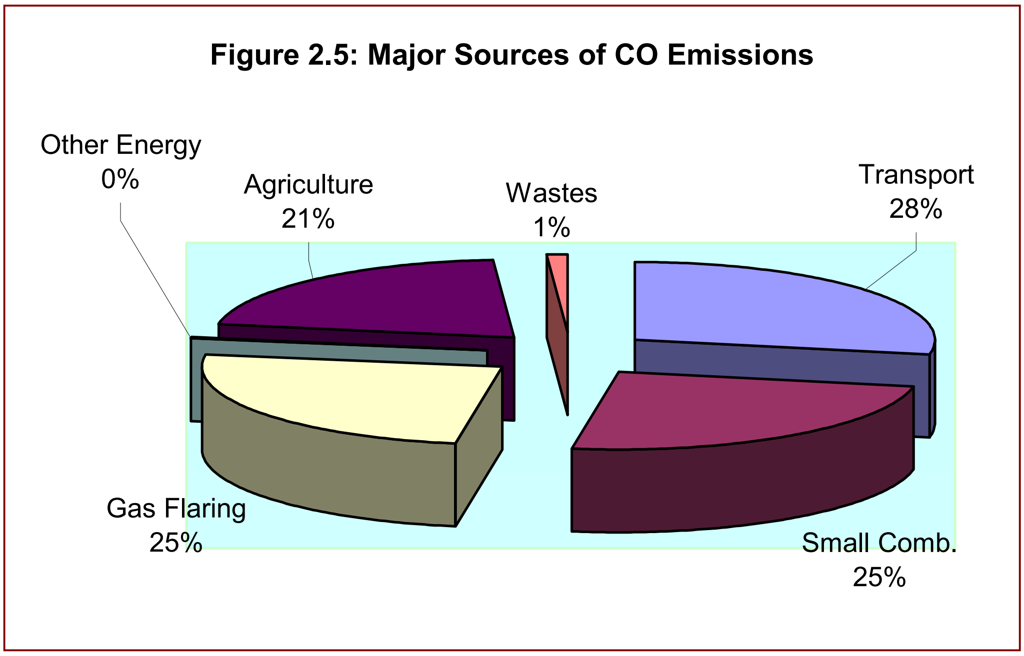
### 2.5.3 Nitrous Oxide Emissions

The gross emission of nitrous oxide in 1994 was 11.95 Gg $N_2O$. The energy sector (principally petroleum refining, small combustion and transport sub-sectors generated 7.47 Gg $N_2O$ representing 63% of gross national emissions for the year. This was closely followed by emissions from savannah burning (28%), field burning of agricultural wastes (6%), burning of municipal solid wastes (2%) and on-site biomass burning from forest conversion (1%).



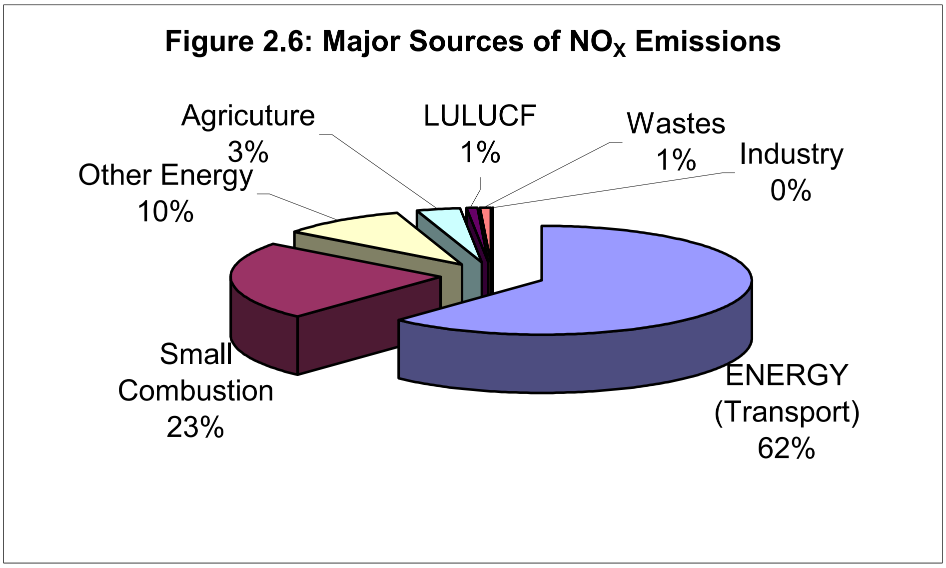

### 2.5.4 Carbon Monoxide Emissions

The total CO emissions for 1994 was 17.05 Tg CO. Out of these, the energy sector generated 13.1 Tg CO with the following major energy sub-group emissions: transport 4.73 Tg CO or 28% of the gross national emissions; small combustion sources and gas flaring each representing about 25% of the gross national CO emissions. The agricultural sector emitted 3.59 Tg CO or 28% of the gross national emissions for 1994, while the other energy sub-sectors, waste management and land use change and forestry emitted 33.2 Gg CO, 171 Gg CO and 162 Gg CO, respectively. Energy sector sources therefore dominated the CO profile, with the various sub-sector activities contributing 78% of the gross national CO emissions.




### 2.5.5 Oxides Of Nitrogen Emissions

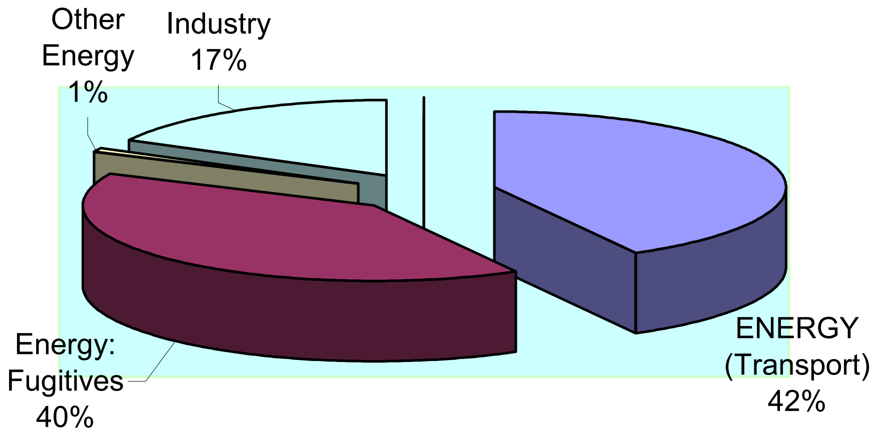
Nitrogen oxides are, like CO mainly emitted from combustion processes, with emissions highly technology dependent. The gross emission for 1994 was 658 Gg $NO_X$. These were derived mainly from energy (502 Gg $NO_X$), and agriculture (148 Gg $NO_X$). Process industries, land use change and forestry, and waste management contribution to $NO_X$ emissions was less than 10 Gg $NO_X$. The profile of process emissions indicates that the transport sector contributed highest to $NO_X$ emission. The sector is responsible for 62% of the total $NO_X$ emission, closely followed by small combustion sub-sector with a contribution of 23%. Other energy sub-sectors contributed 10%, LULUCF and wastes management had 1% each, while agriculture contributed 3%.



## 2.6 NON-METHANE VOLATILE ORGANIC COMPOUNDS EMISSIONS: TOTAL EMISSIONS BY SECTORS

The total national emissions of non-methane volatile organic compounds (NMVOC) in 1994 were 2.2 Tg NMVOC. Out of this, the energy sector contributed 1.86 Tg NMVOC, while industrial processes generated 366 Gg NMVOC. Of the energy sub-sectors, transportation contributed 42% to gross national emissions while fugitive sources (including gas flaring) contributed 40%. The other energy sub-sectors together contributed 17 Gg NMVOC or 1% of gross national emissions.

**Figure 2.7: Major Sources of NMVOC Emissions**




### 2.6.1 Emissions From Energy

From the TD method, the consumption of solid, liquid and gaseous fuels together (approximately about 2500 PJ) with the associated fugitive emissions lead to the total $CO_2$ emissions of 105.5 million tonnes (Mt $CO_2$) or teragrams ($10^6$ grammes, Tg) of $CO_2$ (Table 2.2). Liquid fuels contributed 31% to $CO_2$ emissions, while natural gas contributed 68.96% with solid fuels (coal) contributing less than 0.04%. Based on the consumption of biomass fuels and fugitive processes in the upstream energy sector, the total emissions of non- $CO_2$ GHG and precursor gases were 1708 Gg of $CH_4$, 3.36 Gg of $N_2O$, 4232 Gg of CO, 123 Gg of $NO_X$ and 1334 Gg of NMVOC.

The assessment of total $CO_2$ and non-$CO_2$ emissions for solid, liquid and gaseous fuels based on the TD method is similarly presented in Table 2.3. This indicated a total energy consumption of 2182 PJ, leading to the emissions of 115.1 Tg $CO_2$, 1463 Gg $CH_4$, 7.5 Gg $N_2O$, 13124.9 Gg CO, 499.3 Gg $NO_X$ and 1864.4 Gg NMVOC. Thus, while the $CO_2$ estimates from the TD-method, which represents about 91.7% of the estimate from the BU method may be considered acceptable, there remarkable deviations are observed for the other GHGs. Since, these GHGs are more process and end-use technologies dependent, the BU estimates are usually more acceptable over the TD estimates for these GHGs.

**Table 2.3: Summary of Gross National Emissions: Top-Down Method**

| FUEL TYPE | ENERGY CONSUMP-TION (PJ) | EMISSIONS $CO_2$ (Tg-CO2) | $CH_4$ (Gg) | $N_2O$ (Gg) | CO (Gg) | $NO_X$ (Gg) | NMVOC (Gg) |
|---|---|---|---|---|---|---|---|
| **LIQUID** | 571.43 | 32.72 | | | | | |
| **SOLID** | 0.34 | 0.03 | | | | | |
| **GASEOUS** | 1309.8 | 72.75 | | | | | |
| **BIOMASS** | 672.83 | | 484.44 | 3.36 | 4232.08 | 123.13 | |
| INT-T'L BUNKERS | 13.93 | 1.05 | | | | | |
| FUGITIVES: | | | | | | | |
| Liquid Fuels | | | 19.85 | | | | 23.82 |
| Solid Fuels | | | 0.14 | | | | |
| Gaseous Fuels | | | 1203.72 | | | | 1309.82 |
| **Sub-total:** | | | 1223.71 | | | | |
| ***TOTAL (Excluding Intern. Bunkers)*** | **2540.5** | **104.5** | **1708.15** | **3.36** | **4232.08** | **123.13** | **1333.64** |

**Table 2.4: Summary of Gross National Emissions: Bottom-Up Method**

| FUEL | ENERGY CONSUMPTION. (PJ) | 1994 EMISSIONS (Gg) $CO_2$ | $CH_4$ | $N_2O$ | CO | $NO_X$ | NMVOC |
|---|---|---|---|---|---|---|---|
| LIQUID | 1403.8 | 51335.8 | | 4.1 | 4819.1 | 348.5 | 913.3 |
| SOLID | 0.3 | 48.7 | 0.0 | 0.0 | 0.1 | 0.2 | 0.0 |
| GASEOUS | 100.3 | 5644.9 | 0.0 | 0.2 | 1.3 | 5.8 | 0.0 |
| BIOMASS | 672.8 | 0.0 | 444.7 | 3.2 | 4080.4 | 115.9 | 0.0 |
| FUGITIVES | | | | | | | |
| *SOLID | 0.7 | 0.0 | 136.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *LIQUID | 1.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *GAS | 3.3 | 58080.0 | 882.2 | 0.0 | 4224.0 | 29.0 | 951.1 |
| **TOTAL** | 2182.4 | 115109.4 | 1463.0 | 7.5 | 13124.9 | 499.3 | 1864.4 |

**Table 2.5: Summary of Emissions from the Energy Sector**

| SECTOR | TOTAL ENERGY CONSUMPTION (PJ) | 1994 EMISSIONS (Gg) $CO_2$ | $CH_4$ | $N_20$ | C0 | $NO_X$ | NMVOC |
|---|---|---|---|---|---|---|---|
| Public Electricity | 100.9 | 5686.3 | 0.01 | 0.20 | 1.30 | 5.82 | 0.00 |
| Auto-generation | 9.5 | 706.7 | 0.02 | 0.02 | 3.34 | 9.54 | 0.12 |
| Petroleum Refinery | 765.9 | 6098.9 | 0.61 | 2.91 | 28.34 | 4.14 | 12.10 |
| Industry | 18.3 | 1435.9 | 0.05 | 0.12 | 0.30 | 3.06 | 0.04 |
| Transport | 545.1 | 38473.4 | 12.07 | 0.86 | 4728.99 | 322.47 | 896.19 |
| Small Combustion | 738.5 | 4700.9 | 445.21 | 3.36 | 4139.25 | 127.87 | 4.71 |
| Fugitives | 5.2 | 58080.0 | 1018.23 | 0.00 | 4224.00 | 28.99 | 951.10 |
| **Total** | 2183.4 | 115182.1 | 1476.21 | 7.47 | 13125.53 | 501.89 | 1864.26 |

### 2.6.2 Emissions from Process Industries

The preliminary results of the emissions estimate from process industries indicate that non-metallic minerals (mainly cement and lime) and inorganic chemicals production generated about 1760 Gg $CO_2$. $CH_4$ emissions from ammonia and urea production, and NMVOC emissions from paints production, food/beverage production and textiles. The industrial emissions of CO and $NO_X$ are substantially low in comparison with emissions of $CO_2$.

### 2.6.3 Emissions from Solvents and Other Products Use

It is currently estimated that 0.4 Gg of NMVOC are emitted from paint applications in Nigeria annually based only on local production of paints. The sector therefore accounts for less than 4% of gross NMVOC emissions in Nigeria.

### 2.6.4 Emissions from Agriculture

Current estimates indicate that emissions from a combined livestock population of 509,000 in 1994 led to the emissions of 1115 Gg CH4. Similarly, rice production led to the emissions of 1090 Gg $CH_4$, while savannah burning generated 109 Gg $CH_4$, 3.4 Gg $N_2O$, 2870 Gg CO and 120 Gg $NO_X$. The field burning of 61.2 Mt of agricultural crop wastes also led to the emissions of 34 Gg of $CH_4$, 0.7 Gg $N_20$, 720 Gg CO and 26 Gg of $NO_X$. These and the gross emissions from all identified activities in the agricultural sector presented in Table 2.9. Thus, the sector emitted 2.3 Tg $CH_4$ and 3.6 Tg CO into the atmosphere, while $N_2O$ and $NO_X$ emissions were 4.1 and 148 Gg, respectively.

### 2.6.5 Emissions from Land Use Change and Forestry

The gross estimates of carbon uptake from forest and non-forest trees growth as well as from abandonment of managed lands are 36.75 Tg $CO_2$ (10.02 Tg $CO_2$-C). Similarly, the gross emissions of carbon from biomass harvests and conversion of forests and savannah to agricultural lands is estimated to be 112.23 Tg $CO_2$ (30.61 Tg $CO_2$-C). This gives a net carbon emission of 75.54 Tg $CO_2$ (20.6 Tg $CO_2$-C). Table 1.10 presents details of emission estimates from the land use change sector. This indicates the gross emission of 18.5 Gg $CH_4$, 0.1 Gg $N_2O$, 162 Gg CO and 4.6 Gg $NO_X$ from biomass burning associated with forests conversion to managed lands.

### 2.6.6 Emissions from Wastes

Estimates of wastewater generation from industries are obtained from gross industrial water consumption and $BOD_5$ content of industrial wastewater from different sub-sectors. The results of emission assessment show that WWT accounts for approximately 1.88 Tg $CH_4$, while MSW accounts for 0.2 Tg $CH_4$. The burning of MSW also leads to the emissions of 0.25 Gg $N_2O$, 171 Gg CO and 3.3 Gg $NO_X$.

## 2.7 SPECIFIC EMISSIONS

The potential for per capita sectoral emissions and gross emissions based on emission per unit human population is presented in Table 2.6 based on gross population of 96.7 million for the year 1994. This indicates a gross per capita $CO_2$ emissions in the energy sector to be highest (0.32 t C/cap) compared to gross per capita emission of 0.5 t C/cap.). Per capita non-$CO_2$ GHG and precursor gases are between 2 to 4 orders of magnitude lower than $CO_2$ per capita emissions. These data is low when compared to emissions from the United States and the OECD countries. However, this indicates that Nigeria's gross emissions may approach those of these countries if its population continuous to grow at the current rate of 2.5% per annum since per capita emissions are also likely to increase with increasing trends in the economy.

**Table 2.6: Per Capita Sectoral and Gross Emissions for 1994.**

| | | 1994 | SPECIFIC | EMISSIONS | | |
|---|---|---|---|---|---|---|
| SECTOR | $CO_2$ | $CH_4$ | $N_20$ | C0 | $NO_X$ | NMVOC |
| | (kg C/cap) | (kg C/cap) | (kg N/cap) | (kg C/cap) | (kg N/cap) | (kg NMVOC/cap) |
| ENERGY | 324.65 | 11.44 | 0.05 | 54.26 | 1.58 | 19.27 |
| INDUSTRY | 4.96 | 0.00 | 0.00 | 0.00 | 0.00 | 3.79 |
| SOLV. USE | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| AGRIC | 0.00 | 18.17 | 0.03 | 14.83 | 0.47 | 0.00 |
| LUC | 212.92 | 0.14 | 0.00 | 0.67 | 0.01 | 0.00 |
| WASTES | 0.00 | 16.21 | 0.00 | 0.71 | 0.01 | 0.00 |
| **TOTAL** | 542.54 | 45.97 | 0.08 | 70.46 | 2.07 | 23.06 |

### 2.8 TOTAL $CO_2$ EQUIVALENT EMISSIONS

The assessment of the potential for inducing global warming by the three major GHGs has also been undertaken based on the global warming potential (GWP) for $CO_2$, $CH_4$ and $N_2O$ for 20 and 100 years averaging periods. The results are presented in Table 2.7. This indicates that the gross $CO_2$ equivalent emissions are 564 Tg $CO_2$ equivalent and 341 Tg $CO_2$ equivalent respectively. Over a 20 year averaging, methane seems to have the potential to contribute about 44% of total global warming despite its lower emissions. This indicates that mitigation to reduce methane emissions in the short term is important. However, over the long term period (100 years), $CO_2$ emissions' contribution to global warming is observed to increase from 55% to 74% (see Figure 2.9).

FIGURE 2.8: PERCENTAGE CONTRIBUTIONS OF GHGs TO GLOBAL WARMING OVER 20 YEARS BASED ON 1994 EMISSIONS

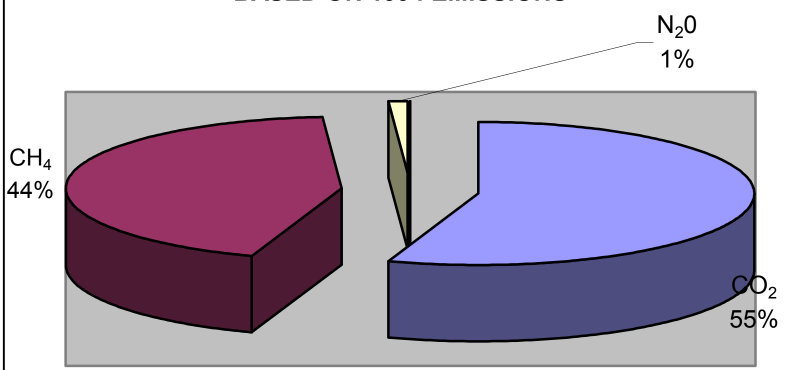


FIGURE 2.9: PERCENTAGE CONTRIBUTION OF GHGs TO GLOBAL WARMING OVER 100 YEARS BASED ON 1994 EMISSIONS

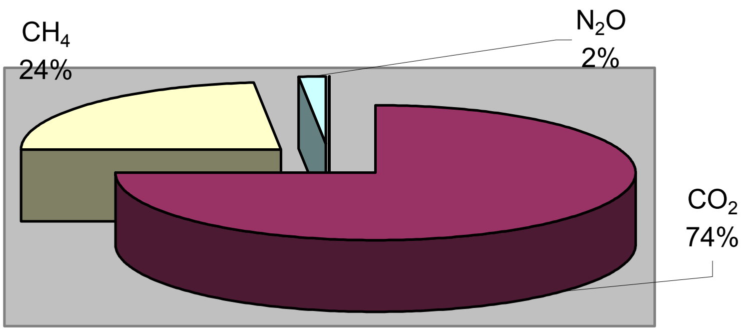



**Table 2.7: Cumulative Effect of GHG Emissions in 1994 to Global Warming in 20- year and 100- years Horizons**

| GHG EMISSION BY SECTOR | 1994 EMISSION (Gg GHG) | GWP 20 Yrs | GWP 100 Yrs | $CO_2$ EQUIVALENT ($Gg-CO_2$) 20 Yrs | $CO_2$ EQUIVALENT ($Gg-CO_2$) 100 Yrs | PERCENTAGE CONTRIBUTION TO WARMING 20 Yrs | PERCENTAGE CONTRIBUTION TO WARMING 100 Yrs |
|---|---|---|---|---|---|---|---|
| $CO_2$ | | | | | | | |
| ENERGY | 115182.1 | 1 | 1 | 115182 | 115182 | 20.43 | 33.72 |
| INDUSTRY | 1760.9 | | | 1761 | 1761 | 0.31 | 0.52 |
| SOLV. USE | 0.0 | | | 0 | 0 | 0.00 | 0.00 |
| AGRIC | 0.0 | | | 0 | 0 | 0.00 | 0.00 |
| LUC | 75541.7 | | | 75542 | 75542 | 13.40 | 22.11 |
| WASTE | 0.0 | | | 0 | 0 | 0.00 | 0.00 |
| SUB-TOTAL | 192484.7 | | | 192485 | 192485 | 34.15 | 56.35 |
| $CH_4$ | | | | | | | |
| ENERGY | 1476.2 | 62 | 24.5 | 91525 | 36167 | 16.24 | 10.59 |
| INDUSTRY | 0.0 | | | 3 | 1 | 0.00 | 0.00 |
| SOLV. USE | 0 | | | 0 | 0 | 0.00 | 0.00 |
| AGRIC | 2344.2 | | | 145342 | 57434 | 25.79 | 16.81 |
| LUC | 18.5 | | | 1148 | 454 | 0.20 | 0.13 |
| WASTES | 2091.7 | | | 129686 | 51247 | 23.01 | 15.00 |
| SUB-TOTAL | 5930.7 | | | 367703 | 145302 | 65.24 | 42.53 |
| $N_2O$ | | | | | | | |
| ENERGY | 7.5 | 290 | 320 | 2167 | 2391 | 0.38 | 0.70 |
| INDUSTRY | 0.0 | | | 0 | 0 | 0.00 | 0.00 |
| SOLV. USE | 0.0 | | | 0 | 0 | 0.00 | 0.00 |
| AGRIC | 4.1 | | | 1188 | 1311 | 0.21 | 0.38 |
| LUC | 0.1 | | | 37 | 41 | 0.01 | 0.01 |
| WASTES | 0.3 | | | 74 | 81 | 0.01 | 0.02 |
| SUB-TOTAL | 11.9 | | | 3465 | 3823 | 0.61 | 1.12 |
| TOTAL | | | | 563653 | 341610 | 100.00 | 100.00 |

## 2.9 CONCLUSION

An overview of gross carbon emissions by sources and removal by sinks for the year 1994 indicates gas flaring, transportation, and electricity generation as the most significant energy consumption processes leading to GHG emissions. Energy and land use change sectors were the main contributors to $CO_2$ emissions, while energy, agriculture and waste management are the main contributors to $CH_4$ emissions. The gross emissions of $CO_2$, $CH_4$ and $N_2O$ are 342 Tg-$CO_2$ equivalent based on 100-year GWP, however the gross and per capita emissions of these gases in country are still low when compared with those of the more industrialized countries. The data quality for the GHG inventory could be significantly improved by implementing new studies on local emission factors estimation and some sub-sectoral activities data collection, which are currently inadequate.

# CHAPTER THREE

## MITIGATION MEASURES TO ADDRESS CLIMATE CHANGE

### 3.1 INTRODUCTION

The emissions of GHG in Nigeria is generally low based on available data. This is expected to rise in the future as a result of the high population growth rate, which is expected to lead to increase in energy consumption. Nigeria is not a member of the Annex I countries and therefore is not committed to any GHG emission reduction under the Kyoto Protocol. In order to assist non-Annex 1 parties to achieve sustainable development and at the same time assist Annex 1 parties to achieve compliance with their emission reduction commitments, Article 12 of the Kyoto Protocol established the Clean Development Mechanism (CDM). In this first national communication, mitigation analyses were carried out in two major source sector categories: energy and land-use change/ forestry sectors. The analyses were done with a view to identifying mitigation measures that could also contribute to sustainable development of the country. The analyses for the two sectors are described in this chapter.

### 3.2 THE ENERGY SECTOR

Energy plays a dominant role in the Nigerian economy. It supports virtually every other sector of the country and its dominance will increase as the population increases and as the industrial sector expands.

The primary modelling tool employed in studying the future of Nigeria's energy system is the **MARK***et* **AL***location* (MARKAL) model. MARKAL is a large-scale linear optimisation model based on the concept of the reference energy system (RES). It is capable of capturing the complex interrelationships of an energy system from primary energy resources to energy service demands. Being a dynamic model, MARKAL can be used to explore mid- to long-term responses to different technological futures, emission constraints and policy scenarios. Given a set of energy demand projections, technologies and emission constraints, MARKAL is able to identify the least-cost path within the RES that best satisfies the overall objectives of the energy-environmental system. A brief description of MARKAL is given in Appendix 3.1.

MARKAL is demand-driven, and useful energy demand must be estimated exogenously for input into the model. Useful energy demand projections have been computed using the **M**odel for **A**nalysis of **D**emand for **E**nergy (MADE), a simulation model. Basically, MADE employs a combination of statistical, econometric and engineering process techniques in calculating useful energy demand projections.

Useful energy demand projections are made for four economic sectors of the energy system – industrial (including agriculture), transportation, residential, and commercial sectors. In all, the sectors are broken down into 30 demand categories with a total of 102 demand technologies. A summary of useful energy projections is given in Table 3.1.

**Table 3.1: Useful Energy Projections**

| Sector | 1995 | 2010 | 2030 |
|---|---|---|---|
| **Residential** | **112.58** | **177.02** | **326.06** |
| • *Cooking* | 78.80 | 119.87 | 209.76 |
| • *Lighting* | 17.27 | 28.44 | 55.85 |
| • *Non-substitutable electricity* | 16.50 | 28.72 | 60.44 |
| **Commercial** | **6.29** | **13.08** | **34.72** |
| • *Cooking* | 0.47 | 0.97 | 2.57 |
| • *Lighting* | 4.58 | 9.51 | 25.25 |
| • *Non-substitutable electricity* | 1.00 | 2.08 | 5.52 |
| • *Street Lighting* | 0.25 | 0.52 | 1.38 |
| **Industrial** | **81.00** | **114.57** | **134.14** |
| • *Feed-stock* | 14.78 | 30.38 | 30.38 |
| • *Process heat* | 53.97 | 70.13 | 86.88 |
| • *Motive power* | 5.61 | 6.44 | 7.73 |
| • *Lighting* | 1.13 | 1.30 | 1.56 |
| • *Non-substitutable electricity* | 5.51 | 6.32 | 7.59 |
| **Transport** | | | |
| • *Passenger Transport (Billion pass-km/a)* | 514.27 | 1090.73 | 2960.85 |
| • *Freight Transport ion (Billion-Ton-km/a)* | 38.86 | 80.78 | 214.34 |
| • *Air Transport* | 23.48 | 48.81 | 129.51 |
| • *Water Transport* | 2.31 | 4.09 | 9.76 |

*N.B. Unless otherwise indicated, all units are in petajoules*

### 3.2.1 Greenhouse Gas Mitigation in the Energy Sector

Two possible scenarios for the energy sector are presented in this section. These are the baseline scenario and the greenhouse gas abatement scenario. The baseline scenario follows the concept of the most likely development path in the energy system, whereby inefficiencies in the current system are not necessarily carried into the future. In addition to existing social and economic infrastructures, all firm or proposed projects and policies are incorporated into the baseline scenario. The abatement scenario is obtained by the introduction of a number of mitigation options into the baseline scenario. These include:

(a) Efficiency improvement options in the residential, industrial and commercial sectors;

(b) Increased use of renewable resources, consisting of the introduction of small-scale hydro plants and solar-electric options;

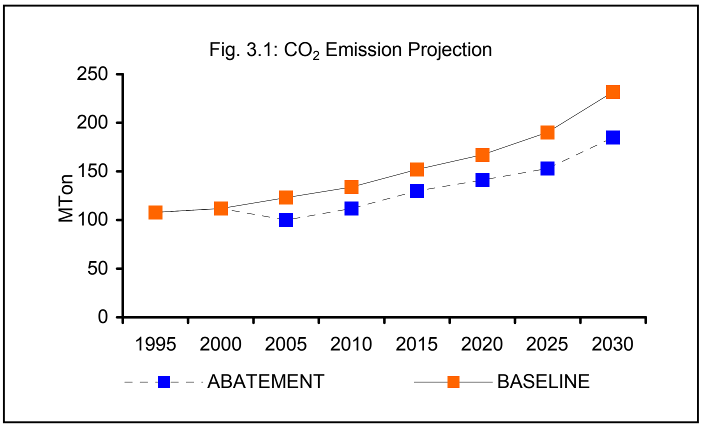
(c) Supply-side options, especially rehabilitation of some existing oil refineries and power plants, and the introduction of newer technologies;

(d) Options for increased use of natural gas.

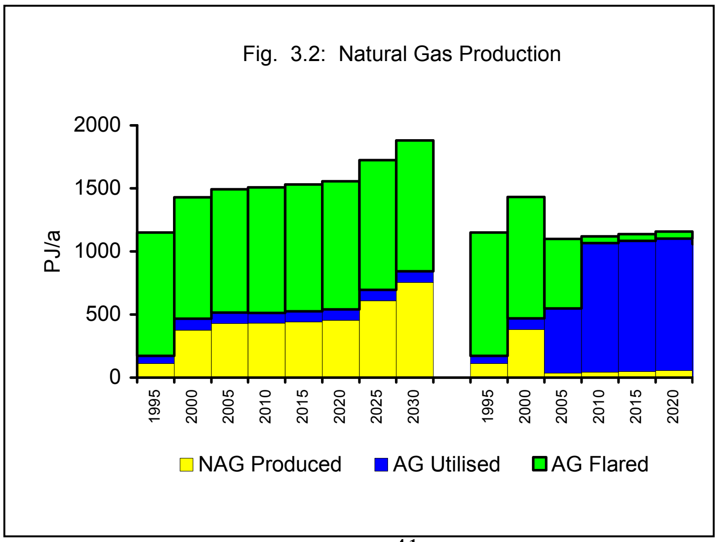
The increased gas-use options focus on finding domestic economic uses for the associated natural gas that is currently being flared in the oil fields. The options considered in this category include liquefied petroleum gas and methanol extraction plants, substitution of fuel-oil for natural gas in the industry for process heat generation and the introduction of compressed natural gas vehicles in the transport sector. There has been various attempts by the government to reduce gas flaring in the past, including introduction of penalties for the amount of gas flared by the producing companies. These have had only little effects. Recently, however, the major oil producing companies have set targets for the elimination of gas flaring (Chevron, Elf and Shell: 2008; Texaco: 2005/6; Agip and Mobil: 2004). Therefore, the abatement scenario assumes that adequate legislation will be introduced to compel the oil companies to eliminate gas flaring by year 2010.

#### 3.2.1.1 GHG Emissions Projections

For this analysis, only the emissions of carbon dioxide from the energy sector are considered. In assessing $CO_2$ emissions, the IPCC Reference Approach was used in emissions accounting. In this case, only the carbon in fuels supplied to the economy was accounted for, irrespective of the technologies consuming the fuels or whatever transformations they went through before. In addition the IPCC default $CO_2$ emission factors were adopted.




Total $CO_2$ emissions in the energy sector amounted to 108 Tg $CO_2$ in 1995, and this is expected to rise to 232 Tg $CO_2$ by year 2030 in the baseline scenario, at an average annual growth rate of 2.2%. Also shown in Figure 3.1 is the $CO_2$ situation under an abatement scenario. Cumulative reduction from baseline is 887 Tg $CO_2$, of which the *no-regrets* abatement options contribute only 76 Tg $CO_2$ or 8% of total reduction; gas-flare reduction in the oil industry is responsible for the rest. Under these circumstances, the projected natural gas requirement of the economy for the two scenarios is shown in Figure 3.2.



What is illustrated in Figure 3.2 is merely a displacement of non-associated gas (NAG) by the associated gas (AG) which would have been flared, although this displacement adds an extra cost to the energy system cost.

### 3.2.1.2 Energy Supply

Total primary energy consumption of Nigeria was 1270 PJ in 1995, projected to 1360PJ in year 2000, 1718 PJ in 2010, 2800PJ in 2020, and 3140PJ in 2030 in the baseline scenario. As shown in Fig. 3.3, of the total requirements in 1995 oil accounted for 47%, natural gas 14%, solid fuels 32%, while hydropower accounted for only 7%. By year 2030 however, the energy-mix would change to 52% oil, 25% natural gas, 16% solid fuels, while the contribution of hydropower remains at 7% hydro. Although the percentage contribution of hydro remains the same at about 7%, its absolute contribution to the energy supply has increased considerably.

Fig. 3.3: Primary Energy Consumption

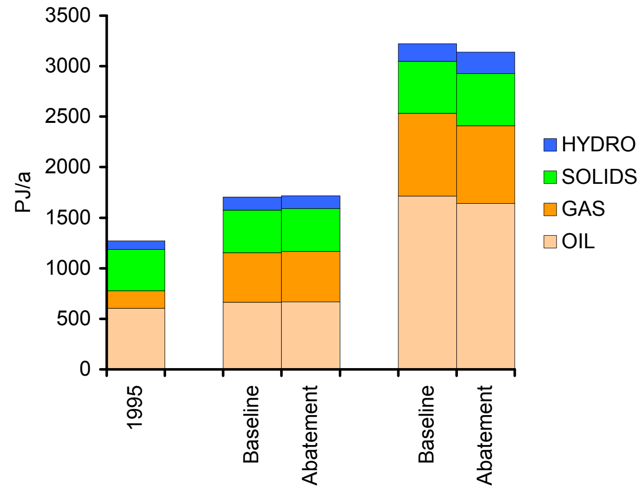
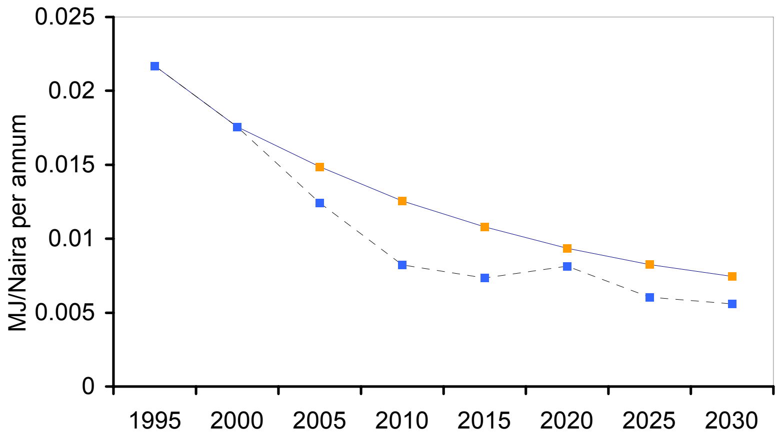


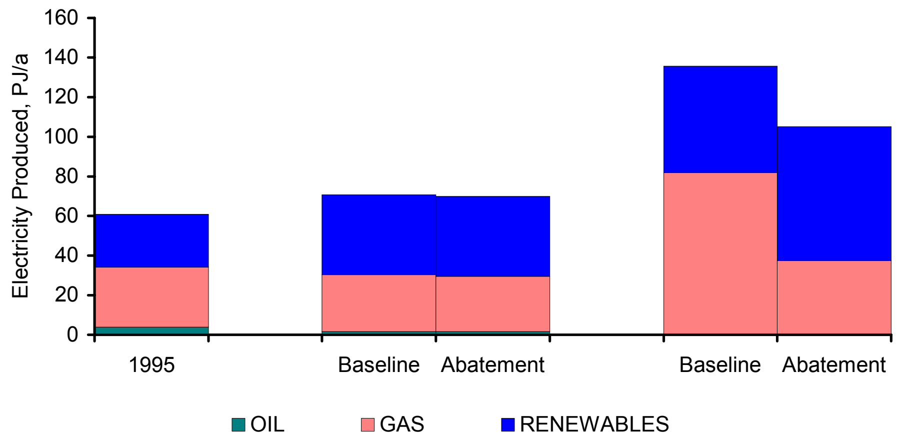

Fig: 3.4: Primary Energy Intensity: 1995-2030



The primary energy intensity in terms of the amount of primary energy consumed per GDP is indicative of the energy required to sustain the projected economic and structural developments. This is shown in Fig.3.4 for the period 1995-2030. From it is shown that primary energy intensity decreases with time over the period under investigation, an indication that the GDP is growing faster than primary energy consumption.

*Electricity Production*: Electricity generation in Nigeria is mainly from gas and hydropower. A small amount of diesel and fuel oil is still used in some generating stations, while gasoline and diesel are used for private generation. In 1995, total electricity production was 61 PJ. This is projected to about 136 PJ in 2030.A reduction of about 20% from the projected 2030 production estimates are observed under the abatement scenario. Hydroelectricity has a lot of potentials in Nigeria's energy mix. For instance, in the abatement case, the share of the projected hydroelectric generation rises from 44% in 1995 to 64% in 2030.

Fig. 3.5: Electricity Production by Fuel Type

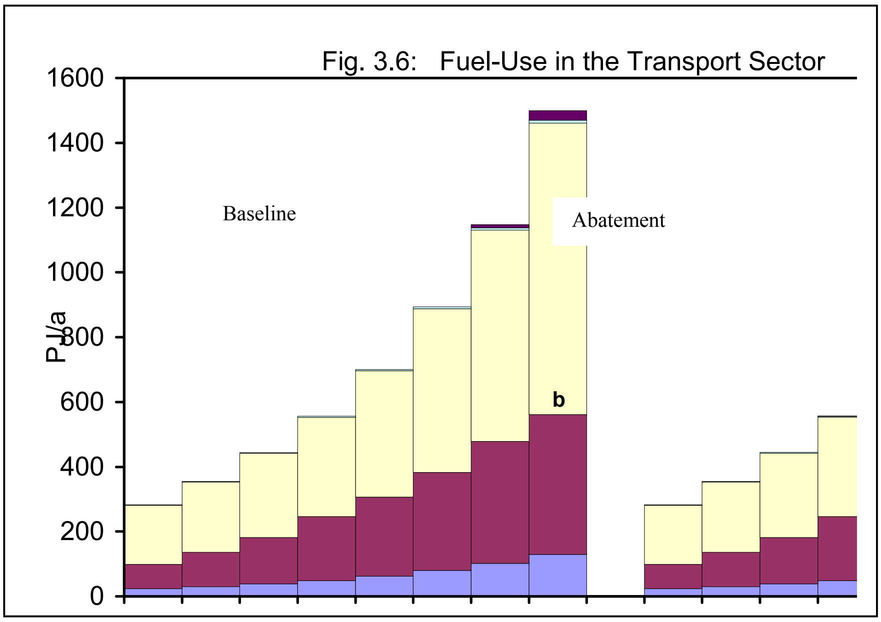



### 3.2.1.3 End-Use Energy Demand

*Residential and Commercial Sub-Sector*: The main requirements for energy in the residential sector are for cooking, lighting and non-substitutable electricity. The prominent fuel for cooking is fuelwood in the rural and urban areas, and kerosene and LPG mainly in the urban areas. In 1995, out of the total of 494 PJ of energy requirements in this subsector, fuelwood consumption amounted for about 78%. Total energy demand is projected to increase to 660 PJ in 2010, and 1030 PJ in 2030 at an average rate of 2% per annum. Demand for electricity (29 PJ in 1995) is expected to drop from the baseline projection of 96PJ in 2030 to about 75 PJ in the abatement scenario. This is mainly due to the penetration of compact fluorescent bulbs into the Nigerian market.

*Industrial and Agricultural Sub-Sector*: Energy requirement in the agricultural sector is minimal due to the low mechanisation in Nigeria. Fuel requirement is mainly diesel for irrigation and tractor motive power. Energy demand in the industrial sector is broken down to electricity, oil products (principally diesel and fuel oil), solid fuel consisting of coal, coke and charcoal, and gas. The fuel contributions in 1995 in the baseline scenario are oil products (37%), natural gas (49%) and electricity (11%). The remaining share of 3% is taken up by coal, coke and charcoal.

<u>*Transport Sub-Sector*</u>: Diesel and gasoline are the most important fuels used in the transport sector. It is not expected that LNG will take over from these two fuels in the near future. Gasoline and LNG vehicles rather than dedicated LNG vehicles are expected to be introduced into the road transport sector in during the new century and most of these will take the form of retrofitting existing vehicle fleet. As shown in Figure 3.6, the displacement of gasoline LNG is more pronounced under $CO_2$ abatement.




### 3.2.3 Assessment of Mitigation Options

Some of the results of mitigation assessment are shown in Table 3.2. Ranking of the options have been based on the incremental cost per unit of $CO_2$ reduced. From the result it is clear that some of the options can be implemented at a net negative cost to the total energy system cost. Apart from the obvious case of gas-flare reduction in the oil industry, significant $CO_2$ emission reduction could be achieved in the residential, transport and industrial sectors of the energy system. Furthermore, as shown in Table 3.2, based on the incremental costs per ton of $CO_2$ removed, the most promising mitigation options in the Nigerian energy system are the introduction of compact fluorescent light (CFL) bulbs at a negative incremental cost of \$58/Ton $CO_2$, followed by the introduction of improved kerosene stoves in households, at a cost of \$21/Ton of $CO_2$ reduced. Other viable options include fuel-oil to natural gas fuel substitution in the cement industry (\$18/Ton), introduction of efficient motors in the industry (\$15/Ton), and improved electrical appliances (\$16/Ton) and wood-stoves (\$3/Ton) in the residential sector.

**Table 3.2: Ranking of Abatement Options**

| Mitigation Option | Incremental Cost ( US$m) | $CO_2$ Reduction Capacity (Mton) | $/Ton |
|---|---|---|---|
| CFL lighting | -299 | 5.155 | -58.00 |
| Improved kerosene stove | -131 | 6.122 | -21.40 |
| Displacement of fuel-oil by gas in cement industry | -138 | 7.49 | -18.42 |
| Improved elec. appliances in the residential sector | -161 | 9.566 | -16.83 |
| Efficient motors in industry | -171 | 10.738 | -15.92 |
| Small-scale hydro (< 10 MW) | -427 | 41.313 | -10.34 |
| Kainji Hydro Power Plant (retrofit) | -351 | 50.01 | -7.02 |
| Improved woodstove in residential sector | -72 | 18.369 | -3.92 |
| Large-scale hydro | -686 | 197.353 | -3.48 |
| Central solar | -24 | 18.735 | -1.28 |
| Improved refrigerators | 154 | 15.793 | 9.75 |
| Residential solar PV | 74 | 5.883 | 12.58 |
| Gas flare reduction | 45534 | 919.201 | 49.54 |
| Efficient gasoline cars | 17478 | 247.05 | 70.75 |
| Improved air conditioners | 218 | 1.54 | 141.56 |
| Efficient diesel trucks | 9060 | 60.096 | 150.76 |
| Improved electrical appliances, industrial and commercial sectors | 2485 | 14.431 | 172.20 |

## 3.3 FORESTRY AND LAND-USE SECTOR

COPATH and COMAP models were used in assessing mitigation options in the forestry and land-use sector. While COPATH estimates the amount of carbon stored, released and sequestered in different forest formations in a country, COMAP evaluates the costs and benefits of mitigation options. The end-use based approach which is tied to the wood product requirement of the country was adopted. In order to determine the extent to which mitigation policies could be pursued, the demand, supply and balances for the major wood products in use in the country were estimated for the base year and projected to year 2030. .

### 3.3.1 Mitigation Options

Of the several forest management options for mitigating carbon emissions, afforestation, agroforestry and forest protection were screened for detailed evaluation and ranking. Sustainable rotation approach was used for afforestation and agroforestry options, while a combination of 'plant and store' approach with selective harvesting was used for forest protection. Some of the main features of the options assessed are discussed below.

*Afforestation:* This is forestry in which selected tree species are planted. Two of the most commonly adopted tree species are *Gmelina arborea* and *Tectona grand*is

*Agroforestry*: Agroforestry is a collective name for land-use systems and practices in which woody perennials are deliberately integrated with crops and/or animals on the same land. Common forms of agroforestry in the country are *Taungya* system, non-timber tree farms, and inter-cropping of leguminous trees with food crops.

*Forest Protection*: This is a forestry management strategy that emphasises protection of the forest.

### 3.3.2 Scenario Assumptions

*Baseline scenario*: The baseline scenario depicts a business-as-usual situation where deforestation is assumed to be going on without restriction. The scenario also assumes that the demand for wood products will continue to increase in relation to population growth .

*Mitigation scenario*: In the mitigation scenario, deliberate steps are assumed to be taken to reduce deforestation while demand for wood products is increasing. Parameters considered in the mitigation procedures include deforestation rates, land use characteristics and basic biological productivity data such as vegetation and soil carbon contents, biomass density and yield of different wood species.

*Data Reliability/Uncertainties*: Data were assembled from various sources including the Forestry Departments, Forestry Management and Environmental Coordinating Unit (FORMECU), other national agencies (e.g. Central Bank of Nigeria and FOS), international agencies (e.g. Food and Agriculture Organization), IPCC documents and from related literature. In cases of gaps, IPCC default values were used.

### 3.3.3 Carbon Flow Pattern

Table 3.3 shows the estimated carbon stock in the five forest formations considered for the assessment. The total carbon stored in the forest formation is estimated to be 2.84 GtC. Of this figure, the Moist Deciduous Forest contributed the most. In terms of carbon stock per hectare, the Tropical Rainforest has the highest value of 197.35 tC/ha, while Dry Deciduous forest has the least of 125.32 tC/ha.

Table 3.3: Carbon Stock by Forest Formations in Nigeria in 1990

| Forest Formation | Tropical Rain | Moist Deciduous | Dry Deciduous | Very Dry | Hill and Montane |
|---|---|---|---|---|---|
| Land Area Covered (Total = 15634.3 kha) | 1197.0 | 12011.0 | 1380.0 | 803.0 | 243.3 |
| Carbon Stock (Total = 2840 MtC) | 236.224 | 2,269.985 | 184.909 | 100.634 | 44.958 |

The breakdown of carbon emission and uptake in 1990 based on land use characteristics is shown in Table 3.4. Agriculture is the highest contributor to emission and uptake of carbon in the land use and forestry sector, being responsible for 63% and 70% respectively. This is perhaps not surprising since agriculture is the most important use to which rural land is put in Nigeria.

Table 3.4: Total Carbon Released and Uptake by Land-Use type in 1990

| Landuse | Carbon Released (MtC) | Carbon Uptake (MtC) |
|---|---|---|
| Agriculture | 6.247 | 0.319 |
| Pasture | 1.113 | 0.055 |
| Harvesting | 2.066 | 0.079 |
| Others | 0.516 | 0.001 |
| Total | 9.942 | 0.454 |

### 3.3.4 Projected Carbon Emission

The baseline scenario shows that at the current deforestation rate of 1.3%, emissions are expected to increase from 9.5 MtC/year in 1990 to about 15.5 MtC/year in 2030. At a deforestation rate of 2.6%, emission is expected to increase to about 26.5 Mt/C-year 2030.

### 3.3.5 Wood Demand and Land Availability

Under baseline scenario, there is increasing demand for wood products corresponding to population growth rate. With the exception of pulpwood supply, which is expected to be adequate until 2000, there is shortfall in the supply of other wood products. For instance, the annual demand for fuelwood is expected to rise from 73.9 million $m^3$ in 1990 to 99.0 million $m^3$. in 2030. Supply on the other side will decrease from 82.0 million m. in 1990 to 63.0 million cu m in 2030. There are wide variations from State to State and from one ecological zone to the other. For example, the wood supply in the forest zone has a small shortfall while there is a high negative balance of supply in the savannah zones. Thus, under the mitigation scenario it is considered that fuelwood plantations would be better located within the ecological zones where a boost in supply is highly needed.

About 4.5 million hectares of fuelwood plantation would have to be established in order to meet the shortfall in fuelwood supply. It is assumed that the land requirement, which is about 0.2 million ha for 2000, 1.7 million ha in 2010, and 7.5 million ha in 2030, would come from outside of the existing forest estates through increased production from government forestry projects and private investment in forestry.

## 3.4. EFFICIENCY OF MITIGATION OPTIONS

*Afforestation*: The results of the analysis (Table 3.5) show that by the year 2030 the total carbon sequestered in the planted forest of about 7.5 million ha would be 638 MtC at an annual incremental rate of 16.0 MtC. The volume of carbon expected to be sequestered using this option is well in excess of the estimated net emissions of 427.4 and 580.5 MtC at 1.3% and 2.6% deforestation rates respectively. The average initial cost of establishment is $500/ha or an average unit cost of $13.4/tC. This implies a capital need of $3.8 billion over a period of 40 years (about $94 million/yr). The analysis also shows that the wood product needs of the country would be met over the 40-yr period. The costing has taken into consideration the cost of land, land preparation, pegging and planting of seedlings and opportunity cost of land (put at about 40% of the initial cost) at a discount rate of 12% (World Bank lending rate for Nigeria). The product prices were based on local prices provided by the Forestry department.

Table 3.5 Establishment Costs and Carbon Stored per Hectare for Plantations based on Afforestation Option.

| S/N | Plantation | Land Area req. '000 ha | Rotation Period (yrs) | Initial cost $/ha. | Unit Cost $/tC | Mean carbon Pool tC/ha | Carbon Pool tC/ha | Total Carbon Stored (MtC) |
|---|---|---|---|---|---|---|---|---|
| 1 | Fuelwood (*Azadirachta*) | 4,489.5 | 7 | 506 | 20 | 33.1 | 93.1 | 116.1 |
| 2 | Poles (*Tectona*) | 757.2 | 15 | 496 | 6.0 | 107.3 | 187.3 | 67.6 |
| 3 | Pulpwood (*Gmelina)* | 58.1 | 8 | 478 | 12.0 | 57.2 | 172.2 | 2.3 |
| 4 | Sawnlogs (*Tectona)* | 1,956.4 | 30 | 496 | 2.51 | 216.0 | 331.0 | 387.4 |
| 5 | Veneer (*Entandrophragma)* | 244.5 | 40 | 457 | 1.74 | 284.6 | 399.6 | 64.3 |
| | TOTAL | 7505.7 | N/A | 500.57* | 13.37* | 97.64* | 175.21* | 637.7 |

Cost figures are quoted at 12% discount rate. * weighted average values N/A = Not Applicable

*Agroforestry*: Table 3.6 shows the estimates for the agroforestry option. A total of 311 MtC is projected to be sequestered by the year 2030 at an annual incremental rate of 7.77 MtC. The average initial cost of establishment is $320, while the unit cost of carbon is $17.17. Thus the total capital requirement for the 40-year period is $2.4 billion, or $60.1 million/year. The estimated volume of carbon expected to be stored over the period is less than that which will be released by 2030. This implies that this option alone is incapable of absorbing the released carbon and meeting the wood needs of the country.

Table 3.6: Establishment Costs and Carbon Stored per Hectare for Agroforestry Options

| S/N | Agroforestry formation | Land Area Red. '000 ha | Rotation Period (yrs) | Initial Cost $/ha. | Unit Cost $/tC | Mean Carbon Pool tC/ha | Carbon Pool tC/ha | Total Carbon Stored (MtC) |
|---|---|---|---|---|---|---|---|---|
| 1 | Fuelwood (*G. sepium* +) | 4,489.5 | 7 | 321 | 25 | 19.17 | 79.17 | 57.33 |
| 2 | Poles (*Tectona* +) | 757.2 | 15 | 338 | 11 | 48.00 | 128.00 | 22.72 |
| 3 | Pulpwood (*G. arborea*) | 58.1 | 8 | 311 | 33 | 27.41 | 142.41 | 0.55 |
| 4 | Sawnlogs (*E. cylindricum*) | 1,956.4 | 30 | 311 | 3 | 109.36 | 224.36 | 178.74 |
| 5 | Veneer (T. superba +) | 244.5 | 40 | 325 | 2 | 229.28 | 344.28 | 51.65 |
| | TOTAL | 7505.7 | N/A | 320.16* | 17.17* | 52.50* | 131.07* | 310.99 |

Cost figures are quoted at 12% discount rate. * Weighted Average + Zea mays

*Forest Protection*: The initial cost of establishing protected forest units is estimated at $79/ha, or at a unit cost of $0.73/tC. This cost is due mainly to the opportunity cost of land and maintenance costs. Thus the capital requirement for the 40-year period is $758.4 million or $18.96 million/year. By the year 2030, a total of about 1036 MtC will be stored in the protected forests at annual incremental rate of 25.9MtC/year. This is almost two times the amount that needs to be sequestered in absorbing the atmospheric carbon in the country.

## 3.4 CONCLUSION

The identification and ranking of mitigation options for energy, land use change and forestry (LUCF) sectors have been carried out. For the energy sector, results indicate that some of the options can be implemented at a net negative cost to the total energy system cost. Apart from the obvious case of gas-flare reduction in the oil industry, significant $CO_2$ emission reduction could be achieved in the residential, transport and industrial sectors of the energy system. Based on the incremental costs per ton of $CO_2$ removed, the most promising mitigation options in the Nigerian energy system are the introduction of compact fluorescent light (CFL) bulbs at a negative incremental cost of \$58/Ton $CO_2$, followed by the introduction of improved kerosene stoves in households, at a cost of \$21/Ton of $CO_2$ reduced. Other viable options include fuel-oil to natural gas fuel substitution in the cement industry (\$18/Ton), introduction of efficient motors in industry (\$15/Ton), and improved electrical appliances (\$16/Ton) and wood-stoves (\$3/Ton) in the residential sector.

For the land use change and forestry sector, afforestation, agroforestry and forest protection options have been evaluated. Results for the afforestation have the highest potential for carbon sequestration followed by agroforestry and forest protection options. For the afforestation option, the volume of carbon expected to be sequestered is in excess of the estimated net emissions of 427.4 and 580.5 MtC at 1.3% and 2.6% deforestation rates respectively. The average initial cost of establishment is \$500/ha or an average unit cost of \$13.4/tC. This implies a capital need of \$3.8 billion over a period of 40 years (about \$94 million/yr). The analysis also shows that the wood product needs of the country would be met over the 40-year period. For the agroforestry option, the estimated volume of carbon expected to be stored over the period is less than that which will be released by 2030.

# CHAPTER FOUR

## CLIMATE CHANGE SCENARIO IN NIGERIA: 1961-2100

### 4.1 INTRODUCTION

The main question in this chapter pertains to the changes expected in the climate of Nigeria over the next 100 years. According to the UNFCCC (United Nations Framework Convention on Climate Change), '*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. The IPCC (Intergovernmental Panel on Climate Change) has evolved its own usage of the term *climate change* as any change in climate over time whether due to natural variability or as a result of human activity. Attribution of climate change to natural forcing and human activities has been addressed by Working Group I of The IPCC in *Climate Change 2001.* The Working Group I Report concludes that globally averaged surface air temperature is projected to warm 1.4 to 5.8$^{o}$C by the year 2100 relative to 1990, and globally averaged sea level is projected to rise 0.09 to 0.88m by the year 2100.

Climate change within Nigeria during the next 100 years will depend primarily on the global changes in climate. In turn, expected global changes in climate will depend on increases in the concentrations of the greenhouse gases including carbon dioxide, methane and nitrous oxide. Increasing concentrations of greenhouse gases in the atmosphere enhances the potential of the atmosphere to conserve heat and therefore bring about global warming. Whatever increases in the concentrations of the major greenhouse gases realized within the coming century and beyond will be a function of the emissions of these gases and will depend in the main on increases in the consumption of fossil fuels, the rate of deforestation and increases in the size of the land turned over to paddy rice cultivation. In other words, expected global climate change will depend basically on global population increases, global energy consumption, and global changes in the land use pattern. Such changes, it has been discovered, cannot be predicted or forecast, because they are governed by large scale uncertainties in political, demographic, socio-economic, technological and energy sectors. For example while some forecasts of global human population at the end of the 21$^{st}$ century are as high as 17 billion, others are as low as 7 billion or less. As the basic driving force in the demand for energy and food, such wide disparities in the population forecasts are likely to pose very real nightmares to forecasters of GHG emissions and by implication to extended climate forecasters given the potential impacts of climate change.

### 4.2 IPCC EMISSION SCENARIOS AND GLOBAL CLIMATE CHANGE

While efforts to mitigate climate change through negotiations are progressing, suggestions for greater investments in adaptations, with its philosophy of learning to live with climate change, are being heeded. To be able to formulate policies on adaptation strategies, it is necessary to measure and assess the impacts of climate change on the affected human, biological and physical systems. There is also the need to measure and assess their adaptive capacities and vulnerability to climate change as well as the adaptation measures being proffered. Thus, the need for an insight into the probable climate of the next fifty or one hundred years is now more urgent than it has ever been. Climate change could have both positive and negative impacts. The impacts could be measured in terms of effects on crop growth, availability of soil water, soil fertility, soil erosion, incidents of pests and diseases, and sea level rise.

Scenarios are in essence images of the future, or alternate futures. However they are neither predictions nor forecasts and should not be regarded as such. The basic purpose of scenarios is to explore possible pathways of greenhouse gas emissions in the absence of new policies to reduce them. At the instance of IPCC, two series of scenarios have been developed. These include the IS92 and the SRES (Special Report on Emission Scenarios) formulated respectively in 1992 and 1998. There are six elements among the IS92 scenarios including IS92 a-f and four main groups in SRES, including: A1, A2, B1 and B2. The IS92 scenarios take into account the London Amendments to the Montreal Protocol; the revised population forecasts of the World Bank and the United Nations; the report of the Energy and Industry sub group of the IPCC (IPCC-EIS, 1990); the political and economic changes in the former Soviet Union, Eastern Europe and the Middle East; and the current data on tropical deforestation and sources and sinks of greenhouse gases. For instance, the assumptions for IS92a, IS92b and IS92e include a world population of 11.3 billion in 2100, while IS92c and IS92d assume a population of 6.4 billion and IS92f assumes a world population of 17.6 billion by 2100. Respectively, CO2 concentrations in the atmosphere under IS92 a-f would have attained levels depicted in Table 4.1 by the year 2100.

**Table 4.1: Scenarios and $CO_2$ Concentration**

| Scenarios | CO2 concentration by2100 |
|---|---|
| IS92 a | 690 ppm |
| IS92 b | 680 ppm |
| IS92 c | 475 ppm |
| IS92 d | 490 ppm |
| IS92 e | 960 ppm |
| IS92 f | 620 ppm |
| SRES A1 | 675 ppm |
| SRES A2 | 830 ppm |
| SRES B1 | 550 ppm |
| SRES B2 | 600 ppm |
| Increase of 1.0%/annum in CO2 conc. | 855 ppm |
| Increase of 0.5%/annum in CO2 conc. | 560 ppm |

Each member of the SRES family departs from its own distinct story line. The A1 storyline describes a future world of very rapid economic growth, global population that peaks mid century and declines thereafter, and the rapid introduction of new and more efficient technologies. The major underlying themes of the story line are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The story line has three sub groups of scenarios departing from it. These include the fossil fuel intensive scenario, (A1F1), the non-fossil energy dominated source (A1T) and a third characterized by a balance among all sources.

The A2 storyline describes a very heterogeneous world, the underlying theme of which is self reliance and the preservation of local identities. It projects a continuously increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological change is more fragmented and slower than in other storylines.

The B1 storyline and scenario family also describes a convergent world, like the A1 group, describes a global population that peaks mid century and declines thereafter. However, unlike the A1 family, the storyline describes a world with changes in economic structures towards a service and information economy, with reductions 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. The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to social, economic and environmental sustainability. It is a world with continually increasing global population, though at a rate lower than in A2, with an intermediate level of economic development, with less rapid and more diverse technological change than in B1 and A1 storylines. While the world described by this scenario is also oriented towards environmental protection and social equity, it nevertheless focuses on local and regional rather than global levels.

Based on IPCC SRES'S A1F1, A2, B1 and B2 GHG emission scenarios, the state of the art HadCM3 models had been used to update climate change projections into the 21st century (Hadley Centre, 2000). The indications are that between now and the end of the century, there will be a warming of over 4°C for the A1F1 scenario, about 3.5°C for the A2 scenario and 2.5°C for the B2 scenario. For the same period, a warming of just under 2°C is projected for the B1 scenario. The projections also indicate that the warming would vary by region, and would be accompanied by increases and/or decreases in precipitation. In addition, there would be changes in the variability of climate, and changes in the frequency and intensity of some extreme climate events. Surface warming is projected for most of the globe with the largest increase of more than 10°C in the A1F1 simulation at high northern latitudes. There will also be greater contrasts in temperature between land and sea surfaces because land surfaces would have warmed 80% faster than sea surfaces. With global warming, mean precipitation is expected to increase.

The predicted regional changes in precipitation are highest in the tropics in the AIFI, A2 and B2 SRES scenarios. It is expected that southern Europe, southern Africa, Australia, Central America, and the northern region of South America will experience a sizeable reduction in the amount of rainfall. The greatest increases in overland precipitation are expected to occur over south-east Asia, Central Africa, eastern South America and at high northern latitudes. It is however to be noted that the confidence to be reposed in the precipitation projections is much less than those reposed in the temperature projections.

## 4.3 PROJECTIONS FOR NIGERIA BASED ON 1% ANNUAL INCREASE IN $CO_2$ CONCENTRATION

### 4.3.1 Methodology

The data used in this study are the products of experiments conducted at the Hadley Center, United Kingdom using the second version of the UK Meteorological Office's unified Model (HADCM2). This is a 19 layer high resolution atmospheric GCM coupled to a 20 layer ocean model. The horizontal resolution of the atmosphere-ocean model is $2.5^o$ latitude by $3.75^o$ longitude. According to IPCC (1995), the experiment consisted of four separate simulations using the HADCM2 model with identical forcing but with different initial conditions, a so-called ensemble experiments, the historic forcing for each simulation being introduced at 150 year interval in the long control integration. The scenario forcing was introduced in 1990 and consisted several sets of assumptions, among which were: a 1 % per annum and a 0.5 % per annum increase in equivalent CO2 concentration through to 2100. The resolution of $2.5^o$ latitude by $3.75^o$ longitude is a relatively fine one. This makes the Hadley products a better choice over the products of the other models available at IPCC'S Data Distribution Centre. Apart from this, it is a warm start simulation. This simply implies that the greenhouse gases integrations simulated the changes in forcing of the climate system since early industrial period; that is since 1860. The data used for both scenarios adopted represent the averages from the four simulations.

The scenarios on which the available data were based simply assume a rate of increase in the concentration of $CO_2$ in the atmosphere. One of such scenarios assumes a rate of 1.0 percent per annum increase in the concentration of $CO_2$ in the atmosphere. An increase of 1.0 percent per annum will result in a concentration level of over 855 parts per million by the year 2100. It represents a worst case scenario with the potential for a most rapid change in climate. In this regards it falls into the same class of scenarios as IS92a and SRES A2, (Table 4.1). By using this as a policy scenario, we are more or less trying to attend to the most change that could occur in the climate of the country. An increase of 0.5 percent per annum will result in a concentration of 560 ppm by the year 2100. It represents an average case falling into a group including IS92b, and SRES A1. In concluding the current exercise the results of the experiments conducted with such a scenario could be examined as reference scenario to provide us with a measure of the uncertainties attending to the issue of climate change projections.

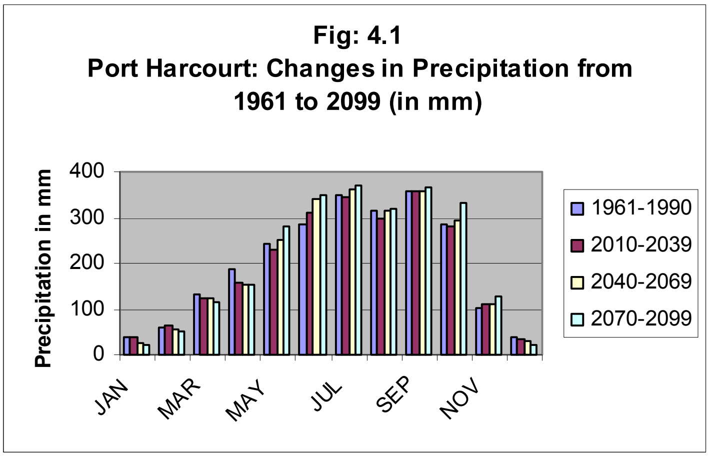
For the projections in the following sections of the chapter, four time slices are used. These include: 1961-90; 2010-2039; 2040-2069 and 2070-2099. The 1961-90 data are observed data and are the baseline from which projections are made to the other time slices. Downloaded from the IPCC Data Distribution Center, they are presented on a resolution of $0.5^o$ latitude x $0.5^o$ longitude; each cell thus has an area of about 50 km x 50 km. Within Nigeria, with an area of about 900,000 square km, there are as many as 360 such cells. Thus the resolution is finer than the pattern of distribution of the 28 Nigeria standard meteorological stations to which the data are ascribed for further analysis. Each of the meteorological stations is ascribed the data of the $0.5^0$ latitude x $0.5^0$ longitude cell in which it is located. The data in respect of the other time slices are on a resolution of 2.5 x $3.75^o$ latitude and longitude and are in the form of changes relative to the observed 1961-90 data. To project the climate of the meteorological stations to the $21^{st}$ century time slices, the changes relative to the observed data for the larger cells in which the stations are located are used.

Seven climate parameters are used in the projections including: cloud cover, diurnal temperature range, precipitation, minimum temperature, maximum temperature, mean temperature and vapor pressure. However, only two parameters namely precipitation and mean monthly temperature have been discussed in the analysis of climate change scenario for Nigeria. The scenario covers the well known broad ecological zones aligned east to west and following one another from the coast of the Gulf of Guinea to the Sahara Desert in the north. These are: the Forest Zone, Southern Guinea Savanna, Northern Guinea Savanna, Sudan Savanna, and Sahel Savanna.

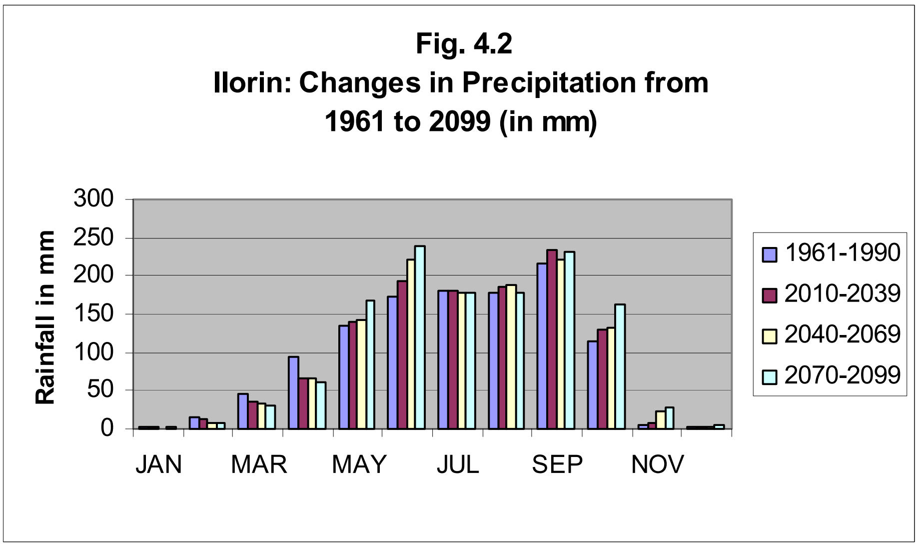
### 4.3.2 Precipitation

Rainfall occurs in Nigeria along disturbance lines in places overlaid by the warm and humid maritime air mass originating over the Atlantic Ocean in the south. Because of this, the southern parts of the country receive more rain than the northern parts. Southern coastal areas are permanently overlaid by the humid air mass. Early in the year, the air mass begins to invade interior locations and more parts of the country fall into an expanding rainfall belt. By the middle of September, the air mass begins a rapid recession back to its coastal, most southerly positions. Thus while coastal locations are perennially humid and receive substantial rainfall throughout the year, interior locations experience various lengths of rainless season. The length of the rainy season therefore decreases with distance from the coastline.

*Forest Zone:* Rainfall in the forest zone of Nigeria follows the typical Tropical Rain Forest pattern. There is rainfall during each month. However, there is a relatively dry part of the year from December to February when monthly rainfall is low. Usually in the Forest Zone of Nigeria, there is a 'Little Dry Season' which occurs from the middle of July to the end of August. There is no indication from the projections that this pattern will change during the coming century. The projections however indicate an increase in rainfall during the rainy season months and a decrease during the dry season months. Thus there is the probability of the dry season becoming drier while the rainy season becomes wetter. The example of Port Harcourt depicted in Figure 4.1 clearly demonstrates this. While the rainfall of each of the dry season months of December, January, and February is projected to decline respectively by 18 mm, 15 mm and 10 mm, the respective rainfall of June, July and October will increase by 65 mm, 20mm and 47 mm. It should be noted that the 'Little Dry Season' is not well represented in the Port Harcourt example.

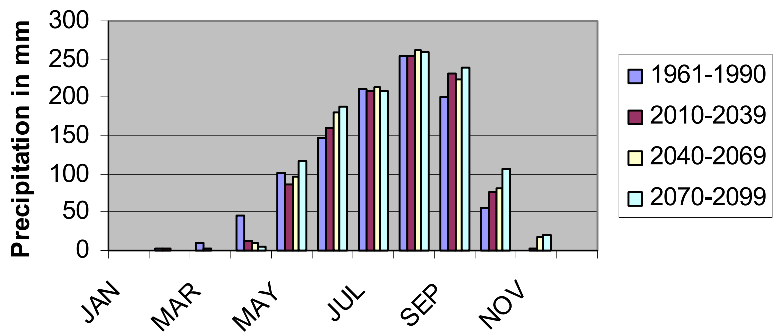



*Southern Guinea Savanna Zone:* In the Southern Guinea Savanna Zone, rain could be expected during any month of the year. However in most years, November, December, January and February are rainless. This pattern characterizes the baseline period and is projected to continue into the 21st century. There is a high degree of certainty that the rainy season commences either early or late April. The case of Ilorin depicted in Figure 4.2 demonstrates the projections of rainfall during the 21st century. A decrease in rainfall is projected for the first four months of the year. This means that these normally dry years will become drier as the century rolls on. Substantial increases are projected for May, June, October and November. There is no discernible trend in the projections for July August, September and December. For example, the projections for July are for rainfall varying between 177mm and 180 mm.



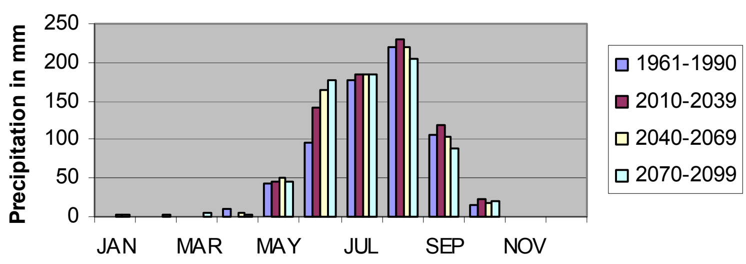

*Northern Guinea Savanna*: In the Northern Guinea Savanna Zone, November, December, January, February and March are usually rainless. In very dry years, the rainless period may start in October and terminate in April. The heavy downpours begin in May and terminate early in October. Peak rainfall is received in August. While the onset of the rainy season is gradual, its cessation is often quite abrupt. The projections in Figure 4.3 indicate the maintenance of the same pattern observed today. However, there will be a trend towards wetter conditions during the onset and the cessation months. Thus the trend will be significant with respect to June, September and October resulting in a rainy season longer by about one month.

**Fig. 4.3**
**Kaduna: Changes in Precipitation from 1961 to 2099 (in mm)**

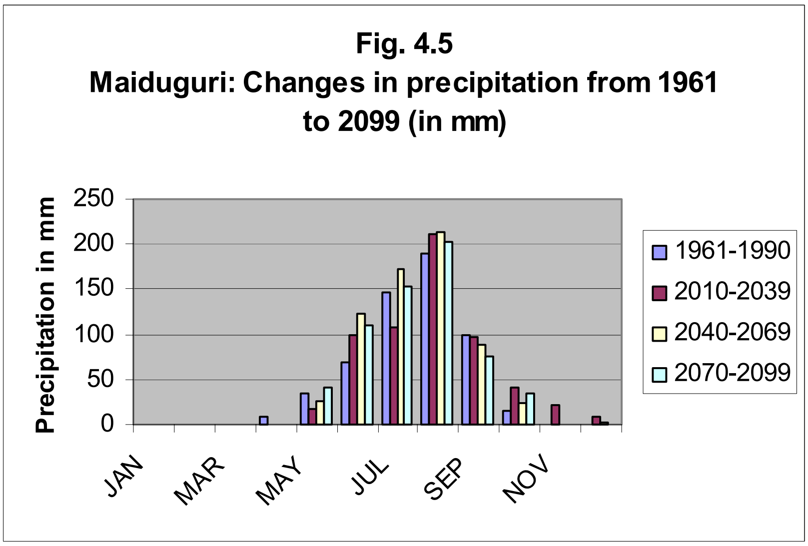



*Sudan Zone*: Baseline period conditions indicate an effective rainy season only four months long. Six of the dry season months are rainless. Although the onset of the season is in May in most years, the fields are not sufficiently wet for cropping until June. As depicted in Figure 4.4, peak rainfall comes in August, and the season terminates at the end of September. The projections for the rest of the 21st century in Kano indicate significant increases in June. The rainfall of July, August and September are projected to remain as they were for the baseline period from 1961 to 1990.

**Fig. 4.4**
**Kano: Changes in precipitation from 1961 to 2099 (in mm)**

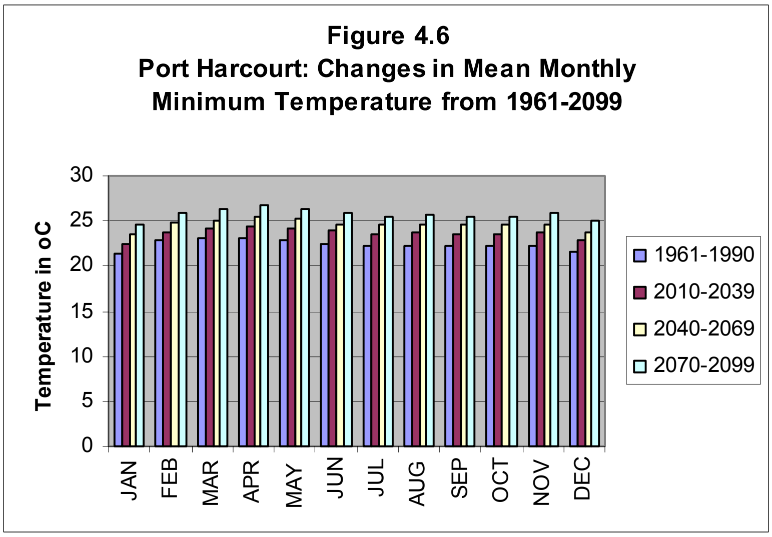



*Sahel Zone:* Contemporary and baseline climate indicates a rainy season four months long. The dry season is eight months long and largely rainless. Although the onset of the season is in May, June in some years may not receive as much rain as to make planting feasible. Rain falls in sufficient amounts only in July and August. Projections of rainfall for Maiduguri during the 21st Century are depicted in Figure 4.5. These indicate an increase in rainfall for June, July and August up to 2069 followed by a decrease during the final thirty years of the century. The significant increases in the rainfall of June will tend to bring that month more effectively into the planting season




### 4.3.3 Mean Monthly Minimum Temperature

*Forest Zone:* In the tropics, the lowest temperature during each day, which is usually described as minimum temperature is experienced during the night. Mean minimum temperature as an element in the Forest Zone climate is lowest in January with about 21 $^0$C and highest in March or April at about 23 $^0$C. There is thus a correspondence between the period of low angle of incidence of the sun and the period of low minimum temperature. However the period of high altitude sun does not correspond to the period of high minimum temperature. According to climate change projections, this general pattern will be maintained as the climate changes during the 21st Century. However there are indications in the projections, as it is going to happen world wide, that as the century progresses, the night will become significantly warmer. For example in the Port Harcourt example presented in Figure 4.6, January minimum temperature is projected to rise from 21.4 $^0$C



to 24.61 $^0$C towards the end of the century. In the same vein April minimum temperature is projected to rise from 23.1 $^0$C to 26.73 $^0$C.

*Southern Guinea Zone:* In general, the nights are usually cool and pleasant, with temperatures in the range of 18$^o$C to 25$^o$C. As is the case in the Forest Zone, the month with the lowest mean minimum temperature is January while the month with the highest mean minimum temperature is April. However January's mean minimum temperature is lower in the Guinea Zone while April's mean minimum temperature is higher than in the Forest Zone. This implies that seasonal contrasts are higher in the Southern Guinea Zone than in the Forest Zone. At Ilorin, the January mean minimum temperature is 19.3$^o$C, while the April mean minimum is 23.9$^o$C. Projections for the 21$^{st}$ Century shown in Figure 4.7 indicates a general increase in minimum temperature for all the months. The increases are consistent in terms of direction and steady with regards to magnitude. They vary from as high as over 5$^o$C for January to less than 3.5$^o$C for August. With these increases, the nights are still expected to remain cool and pleasant with temperatures in the range of 20$^o$C to 28$^o$C.

**Figure 4.7**
**Ilorin: Changes in Mean Monthly Minimum Temperature from 1961-2099**

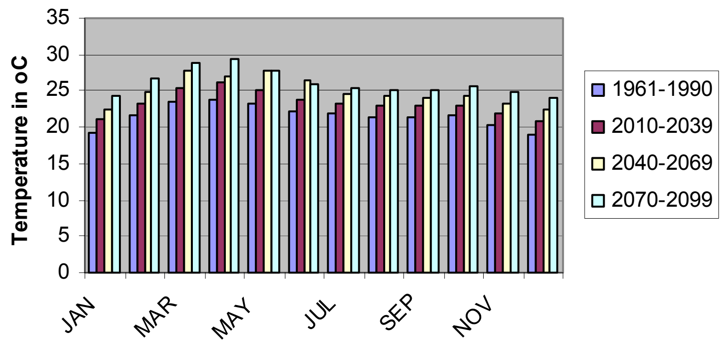
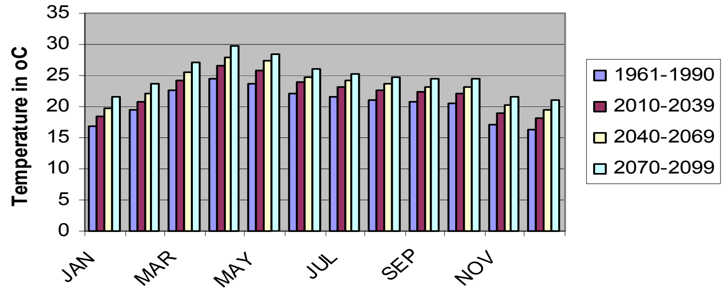



**Figure 4.8**
**Kaduna: Changes in Mean Monthly Minimum Temperture from 1961-2099**

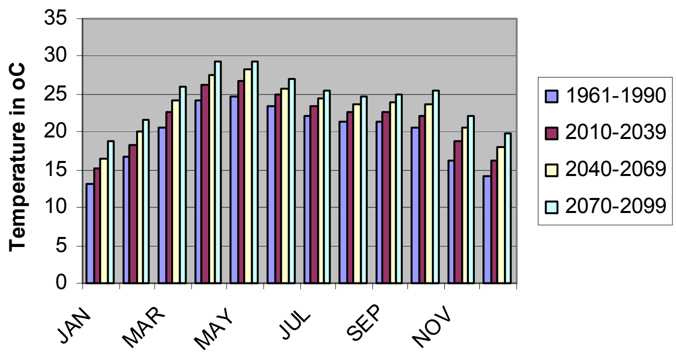



*Northern Guinea Zone:* For most of the year, mean minimum temperatures are lower in the Northern Guinea Zone than in the

Southern Guinea Zone. However for April and May, it is the Northern Zone that records higher minimum temperatures. This notwithstanding, the nights are still cool and pleasant with temperature in the range of 15$^{o}$C to 25$^{o}$C. There are occasions in November, December, January and February when the nights are chilly. As is the case in the Forest and Southern Guinea Zones, the lowest night time temperatures are experienced in January while the highest are recorded in April. Climate Change projections for the century are for steady and consistent increases in mean minimum temperatures. In the case of Kaduna indicated in Figure 4.8, increases of up to 5$^{o}$C are projected. Such increases suggest that the nights could become less pleasant. Frequent occurrence of minimum temperatures of over 30$^{o}$C could make the nights uncomfortable.

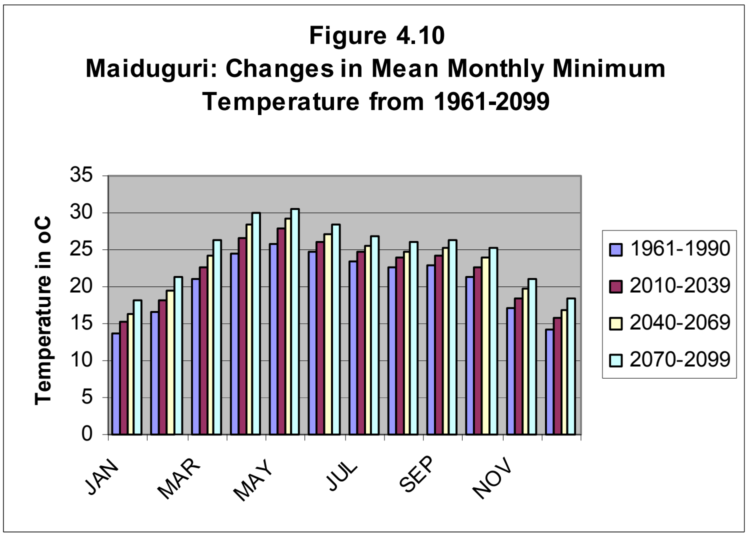
*Sudan Zone:* In the Sudan Zone, January still remains the month with the lowest mean monthly minimum temperature. The highest mean minimum is recorded for May instead of April in the Guinea Zones. On the basis of the disparity between seasonal values of mean minimum temperatures, one could recognize a season with cool nights extending from March to October and another season with cold nights extending from November to February. The season of cold nights correspond to the season of occurrence of dry continental air mass advected from Asia and Europe which is at this time in the winter hemisphere. The dry Harmattan winds from the Sahara Desert contribute to the discomfort with a chilling factor related to its gustiness and its capacity for evaporative cooling. During such nights, people who normally sleep in open spaces within courtyards crowd into small rooms within the houses. Such crowding usually results in rapid spread of contagious diseases such as Cerebrospinal Meningitis. Projections of minimum temperatures into the 21$^{st}$ century indicate steady and consistent increases. Increases of from 4$^{o}$C to 5$^{o}$C are projected for all the months up to the end of the century (Figure 4.9). This implies that the seasonal patterns in which the lowest temperatures are experienced in January and the highest temperatures are recorded in April will be maintained. However the really cold nights will be replaced by cool and pleasant nights. Some of the nights in May could become uncomfortable because of high temperatures coupled with high humidity of the air.

**Figure 4.9**
**Kano: Changes in Mean Monthly Minimum Temperature from 1961-2099**



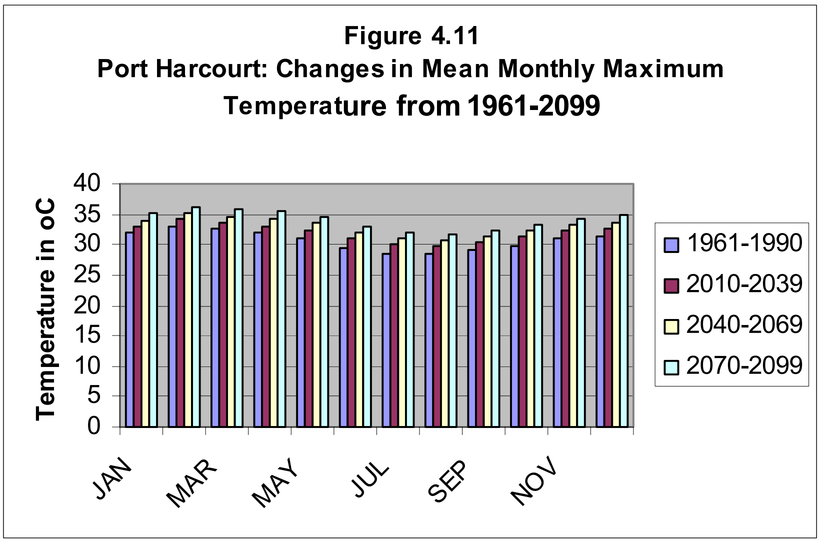

*Sahel Zone:* With regard to mean minimum temperatures, there is but little difference between the Sudan and the Sahel ecological zones. By less than a fraction of a degree in most months, mean minimum temperatures are higher in the Sahel than in the Sudan every month of the year. The seasonal distribution is more or less the same. The lowest minimum temperatures are expected in January, while the highest occur in May. In

Maiduguri, mean minimum temperatures range from 13.8$^{o}$C in January to 25.9$^{o}$C in May. The nights of November to February are cold while the nights of the other months are by comparison cool. For Maiduguri as shown in Figure 4.10, increases of between 4 $^{o}$C and 5 $^{o}$C are projected for all the months. The nights will still be cool for most of the year. Nights during the three months preceding the onset of the rains will be relatively hot and also uncomfortable because of the associated high humidity.



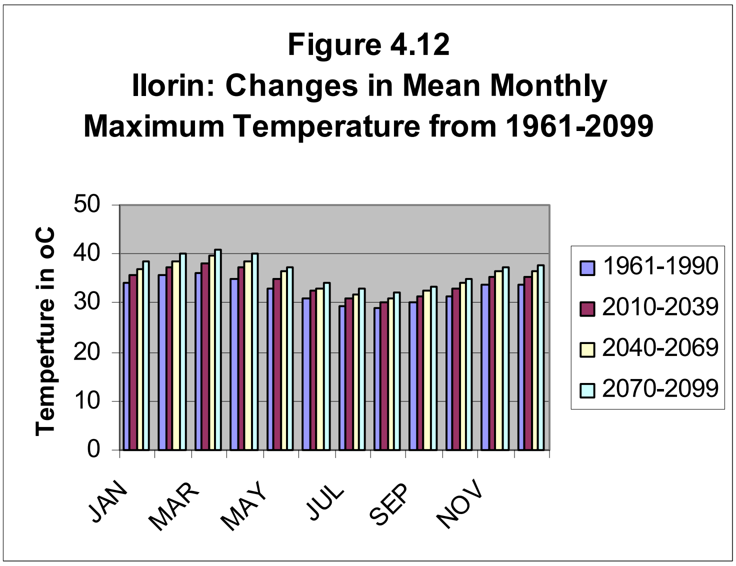

### 4.3.4 Mean Monthly Maximum Temperature

*Forest Zone:* Maximum temperatures in the tropics are usually recorded during day time. One would hence expect maximum temperatures to be high during the summer months with high angle of incidence of sunlight and relatively longer days. However in the Forest Zone of Nigeria, the highest maximum temperatures are recorded during winter and spring, while the lowest maximum temperatures are recorded during the summer months of June, July and August In the Port Harcourt example depicted in Figure 4.11, the highest maximum temperatures are recorded during the winter month of February, while the lowest maximum temperatures are recorded during the summer month of August. As it is well known, temperature in the Forest Zone of Nigeria is determined by what proportion of



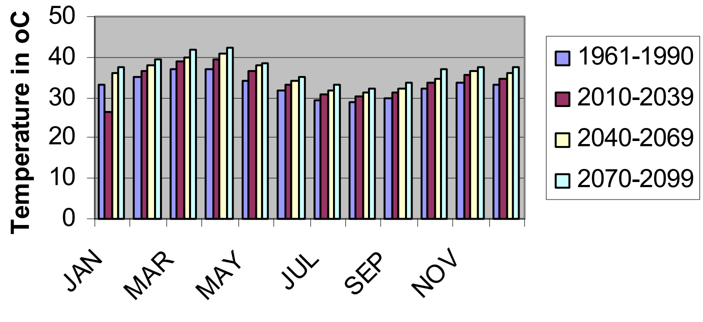
incident solar radiation penetrates through the atmosphere to be converted to heat at the earth's surface. Thus it is the rainy season months with their thick cloud cover that record the lowest maximum temperatures while the dry season months, despite the low angle of the sun, record the highest maximum temperatures. This pattern of inter annual maximum temperature distribution will be maintained during the century. The highest temperatures will continue to be recorded in February while the lowest maximum temperatures are recorded in August. The difference in Maximum temperatures between the two months will remain at about $4^{o}$C. However, our projections indicate that as the century progresses, the forest zone in Nigeria will become warmer as day time temperatures rise by about 3 to $4^{o}$C.

*Southern Guinea Zone:* It appears that the same factors that determine the temporal pattern of Mean Maximum Temperatures in the Forest zone are also the most active in the Southern Guinea Zone. Thick clouds and heavy rainfall downpours depress maximum temperature levels at the height of summer. These leave the winter and spring temperatures to become the highest. Mean monthly maximum temperatures are over $30^{o}$C from October to May and less than $30^{o}$C from June to September. At the present these high day time temperatures are the bases of the proverbial sultriness of tropical weather and the source of an unmitigated physiological stress. These high day-time temperatures are also limiting on the performance of some of the crops (for example, rice) in tropical environments. Projections for the $21^{st}$ Century of the climate of Ilorin in the zone are shown in Figure 4.12. Day time temperatures are projected to increase as the expected climate change unfolds. The magnitude of the increase will be of the order of $4^{o}$C to $5^{o}$C. Towards the end of this century, mean day time temperature will be higher than the normal human body temperature. How to get rid of such excessive heat will become a problem. Living with such high levels of heat could result in increased morbidity and mortality due to heat related ailments.



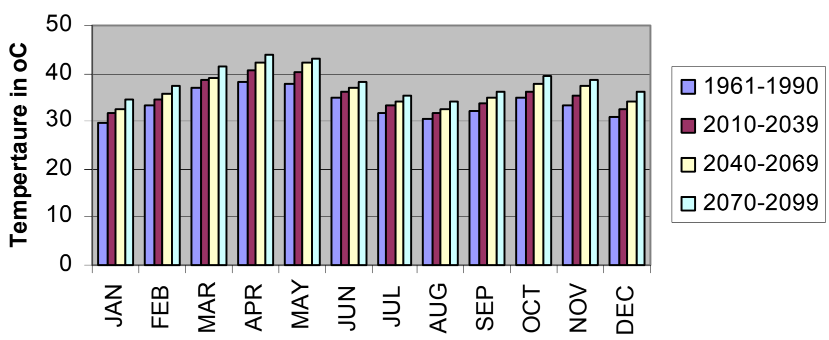

*Northern Guinea Zone:* There is very little difference between the two Guinean zones in the seasonal pattern of mean monthly maximum temperatures. As is the case in the Southern Guinea Zone, very high maximum temperatures characterize the period from January to May, while comparatively low maximum temperatures characterize the period from July to September. A comparison of the 1961-90 observed measurements for Kaduna, the representative climatic station for the northern zone, and those for Ilorin, representing the southern zone, demonstrates the similarities in magnitude. Lower figures were recorded for Kaduna in respect of January, February, September and December (Figure 4.13). The same figures were recorded for July and September, while for the other months higher values were recorded for the more northerly station. Projections based on the scenario adopted for this exercise indicates steady and consistent increases up to the end of the century. The highest increase of more than 5°C is projected for April. For December, January, February, March, May and June increases of between 3 and 4°C are projected. For the other months, the increases projected are less than 4°C. The hottest part of the year according to these projections will be December to May when maximum temperatures above human body temperature will be experienced on a regular basis. Heat stress may be ameliorated by the dry Harmattan winds which are prevalent during this season. Increased humidity is likely to raise sensitive temperature beyond tolerable limits during the period from June to September. Heat related health problems are hence more likely to increase as the century unfolds.

**Figure 4.13**
**Kaduna: Changes in Mean Monthly Maximum Temperature from 1961-2099**




*Sudan Zone:* The observed mean monthly temperatures for 1961 to 1990 show that day time temperatures in the Sudan Zone are lowest in January and highest in April. Mean monthly maximum temperatures vary between 29.8°C in January and 38.3°C in April. The differences between the Sudan Zone and Northern Guinea Zone are similar to the differences between the two Guinea zones. Lower temperatures are recorded for the more northerly zone from November to February while higher temperatures are recorded for the period from April to October. This pattern is explained by the differences in the factors influencing the

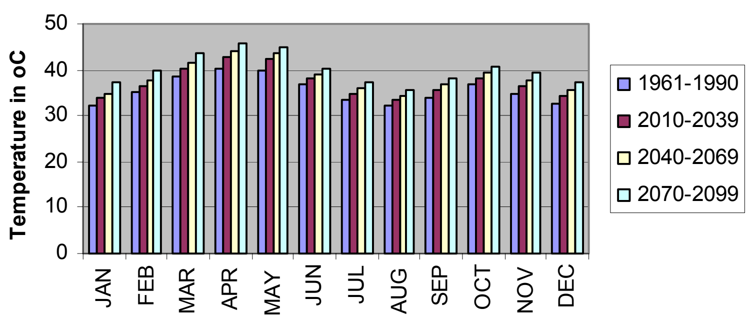
**Figure 4.14**
**Kano: Changes in Mean Monthly Maximum Temperature from 1961-2099**



temperature during the dry and the wet seasons. Wet season temperatures are depressed by a higher rate of evaporative cooling and the reduction in the amount of solar radiation reaching the surface as a result of the thicker cloud cover. Both of these factors are more active in the more southerly locations. On the other hand because of a lower angle of incident of sunlight, reception of solar radiation during the period from November to February is low and consequently temperatures are on the lower side. These factors have the potential to make the temperatures of the more northerly locations lower. Projections based on the selected scenario indicate an increase in mean monthly temperatures of 3 to 5°C. As depicted in Figure 4.14, these increases will raise mean monthly maximum temperatures to a range from 34 to 43°C. There is hence the possibility of an increase in heat related health problems by the 2070 to 2099 time slice.

*Sahel Zone:* During the baseline period from 1961 to 1990, mean monthly maximum temperatures were higher for each month of the year, in the Sahel zone than in the Sudan Zone. The difference in maximum temperature between the two zones average about 2°C. At Maiduguri, the lowest mean monthly maximum temperature is 32.2°C, recorded for January and August, while the highest is 40.4°C, recorded for April. Here again two temperature depressing factors are active. The relatively low temperature for January is a result of the low angle of the incident radiation while that of August is caused by minimum penetration of sunlight as a result of thick clouds. Projections of mean monthly maximum temperature based on the selected scenario are depicted in Figure 4.15. Increases over the hundred year period vary from about 3.5°C to over 5°C. The increases are steady in that they are uniform over time. They are consistent in the sense that they consist of changes in one direction. For the time slice extending from 2070 to 2099, mean monthly maximum temperatures are expected to be perennially higher than human body temperature. For April, the difference between human body temperature and the men maximum would be as high as 8°C. Some of the heat could be mitigated by high rates of evaporative cooling when the dry continental air mass is prevalent. This notwithstanding, high day time temperatures are likely to constitute a major health hazard.

**Figure 4.15**
**Maiduguri: Changes in Mean Monthly Maximum Temperature from 1961to 2099**



## 4.4 UNCERTAINTIES

According to IPCC, key uncertainties still linger on the quantification and the detail of future projections of climate change. Notwithstanding its foundation on the laws of the physical sciences, climate change is anything but an exact science. For one thing, its main tools consisting of the General Circulation Models lack the precision characteristic of the tools of physical science investigations. For another, the main inputs of the models are products of human activities in the energy, transportation, agricultural and forestry sectors. What these inputs will be in quantity and quality are especially difficult to anticipate. Considerable progress has been made in our understanding of the climate system in recent years. These are listed and described in the Synthesis Report of the Third Assessment Report (IPCC, 2001b). Some of the most recent conclusions are established facts or robust findings, while others are regarded as speculative (IPCC, 2001a, Chapter 1). Between the two extremes are conclusions that are established but incomplete and conclusions that are still subject to competing explanations. Thus whatever climate change projections that are available at the moment are subject to uncertainties. First, there are the uncertainties associated with the emission scenarios, including the most recent SRES scenarios. Second, there are those uncertainties inherent in the modeling of climate change, in particular those that concern the understanding of key feedback processes in the climate system especially those involving clouds, water vapor and aerosols. Third, key uncertainties also affect the detail of regional climate change and its impacts because of the limited capabilities of the regional models, and the global models driving them, and inconsistencies in results between different models especially in some areas and in precipitation.

In anticipation of these uncertainties, UNFCCC did provide in its Article 3.3, guidance to the effect that “where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to anticipate, prevent, or minimize the causes of climate change and mitigate its adverse effects” (United Nations, 1992). Our philosophy in mapping out the climate of the 21$^{st}$ Century in the earlier paragraphs is to hope for the best while preparing for the ‘worst’. The ‘worst’ case scenarios are those associated with high emissions of CO2. Our recommendation is that the vulnerability assessment and adaptation strategies should be based on this worst case scenario. The main question at this point is: “What if CO2 emission levels turn out to be much less than anticipated, and CO2 concentration does not rise to over 800 ppm as forecast?” There may be no regrets with regards to those adaptation options that are designed to improve the general resilience of the vital sectors. However, there may be options adopted in anticipation of a high emission scenario that turn out to be unnecessary. It is in view of these that consideration is being given to some of the other plausible scenarios in order to create a broader spectrum of climate change.

### 4.4.1 Uncertainties due to varying GCM Outputs

Projections based on the experiments using the various models invariably give different results. The inability to assign a measure of reliability to any of the GCM experiments creates uncertainty as to what the reality of climate change in the future could be. It is therefore necessary to examine the outline of climate change presented earlier in the.

**Fig. 4.16: Projected Precipitation for Ibadan from Base Year to 2070-2099 using Different Models (1% Increase in CO2)**

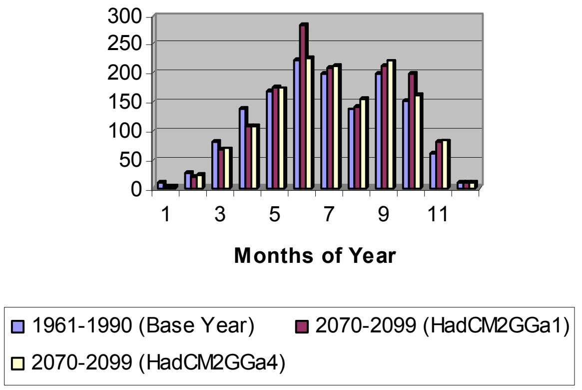
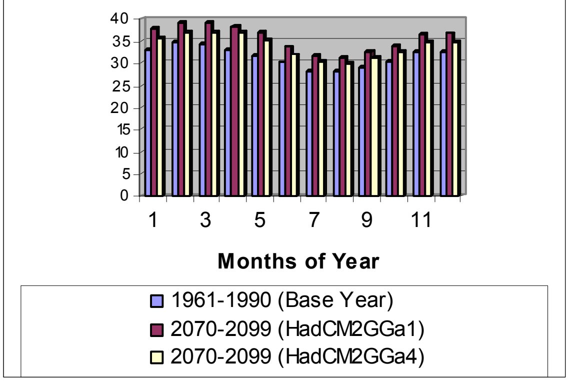



**Fig. 4.17: Projected Temperature for Ibadan from Base Year to 2070-2099 using Different Models (1% Increase in CO2)**




context of what the projections could have been, had we adopted one or two of the other GCM experiments. To demonstrate some of the uncertainties in the climate projections we shall compare the projections based on HadCM2GGa1 Member 1 experiments, with projections based on HadCM2GGa4. Figures 4.16 and 4.17 depict projections of precipitation and temperature of Ibadan, south western Nigeria from the baseline period, 1961 to 1990 to the 2070 to 2099 time slice using HadCM2GGa1 and HadCM2GGa4

For both experiments there is a decrease in mean monthly precipitation. The two experiments give an indication of a dry season becoming drier and a wet season becoming wetter as the century unfolds. June remains the peak rainfall month. However, it is with regards to June rainfall that there is substantial difference with Member 1 projections about 60 mm higher than Member 4 projections.

It appears that the main disparities between model projections are with regard to temperature and temperature-related parameters. Using HadCM2GGa1, the increase in mean maximum temperature amounts to about 5$^{o}$C, compared with about 3$^{o}$C while using HadCM2GGa4 for the projections. This is a very important difference. It means that with HadCM2GGa4 projections, there will be a development towards less contrast between day and night temperatures, while with HadCM2GGa1 the level of current contrasts will be maintained. Moreover, it also means that HadCM2GGa1 promises a more sultry and less comfortable daytime weather in the aftermath of climate change during the 21$^{st}$ Century. Observed 1961 – 1990 mean monthly temperature varies between 25$^{o}$C in August and 29$^{o}$C in March. Projections with HadCM2GGa1 indicate an increase of from

4 to 5$^{o}$C compared to an increase of 3 to 4$^{o}$C when HadCM2GGa4 is used for the projections.

In conclusion, it could be observed that there are differences between the projections based respectively on HadCM2GGa1 and HadCM2GG4. This lack of agreement between the two experiments on what the climate shall be during the period from 2070 to 2099 is a demonstration of uncertainty regarding the anticipated climate change. The differences are observed with respect to two of climatic parameters as depicted in the Figures.

### 4.4.2 Uncertainties due to varying $CO_2$ Concentration Scenarios

Given the fact that global warming, which is the fundamental element in anthropogenic climate change, is largely determined by the concentrations of the greenhouse gases in the atmosphere, it is hardly surprising that a large proportion of climate change uncertainties is a reflection of the uncertainties inherent in the socio-economic scenarios underlying the greenhouse gas emission scenarios. In this section of the chapter, we shall demonstrate the differences in future climate projections based respectively on 1% and 0.5% increases in equivalent CO2 per annum.

Figures 4.13 and 4.14 give a picture of projected rainfall and temperature in Ibadan, south western Nigeria for the baseline period, 1961 to 1990 to the 2070 to 2099 time slice using the averages of HadCM2GGa1-4 and based on a scenario of 1% and 0.5% annual increase in CO2 equivalent concentrations.

Projections of mean monthly rainfall based on the two scenarios have yielded a mixed bag of outputs. In general there is a decrease in rainfall during the first four months of the year. The scenarios are not clearly separated on the basis of whether the reductions in rainfall are higher with one or lower with the other. There is an increase in rainfall indicated by the projections based on the '1% scenario' for the months of May, June, September, October and November. Projections based on the '0.5% scenario' indicate increases only with respect to June, July, August and September. The results of the projections hence can not be clearly separated on the basis of the scenarios adopted.

Projections based on either of the two scenarios indicate very clear and consistent increases in mean minimum temperature between the baseline period and the target time slice. These increases carry with them the characteristic seasonal distribution in which relatively low minimum temperatures are recorded in January and August and relatively higher minimum temperatures are recorded in March, April and May. During the baseline period, mean minimum temperatures vary between 21.6$^{o}$C in January and 23.9$^{o}$C in March. Projections of minimum temperatures based on the '0.5%' scenario indicate a target period mean monthly temperature varying between 24.73$^{o}$C in January and 26.43$^{o}$C in May.

Just as global warming is classified among the robust findings of the IPCC in its Third Assessment Report, so could one describe warming trend in Ibadan as a certainty whatever may be the scenario. Figure 4.19 seems to support this view with respect to mean maximum temperature. While an increase of about 3$^{o}$C is projected on the basis of the ‘0.5%’ scenario, projections based on ‘1%’ scenario indicate increases of at least 5°C in the mean monthly maximum temperature between the baseline period and the 2070 – 2099 time slice. These increases are associated with the characteristic seasonal changes in which lower temperatures are recorded in August and higher temperatures recorded in February, March and April.

Fig. 4.18: Projected Precipitation for Ibadan from Base Year to 2070-2099

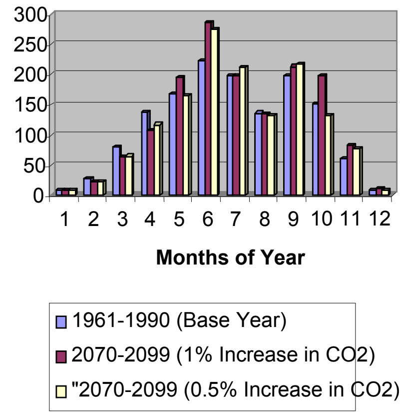
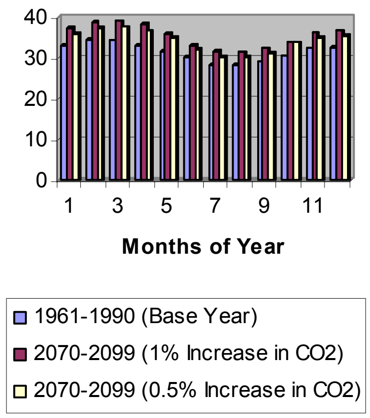



Fig. 4.19: Projected Temperature for Ibadan from Base Year to 2070-2099




The clear distinctions between the day time temperatures to be expected, given each of the scenarios, are sufficient evidences of the uncertainties which are the issue here. Are we to expect an environment in which heat related health problems are more frequent as the case could be with the ‘1%’ scenario or an environment with more tolerable day time temperatures? The implications of these distinctions go beyond human health since uncertainties are also created in other sectors including energy, water, food and agriculture. The mean monthly temperatures are the averages of the mean minimum and mean maximum temperatures. It is therefore not surprising that there is a marked contrast between the projections based on the two scenarios. Mean temperatures projected with the ‘1%’ scenario are about 2°C higher than those projected with the ‘0.5%’ scenario.

### 4.4.3 Projections from Special Report on Emission Scenario (SRES)

SRES scenarios were developed on commission by the IPCC. Data from experiments based on SRES scenarios are contained in MAGICC – SCENGEN Version 2.1. They have been adopted for climate change projections in IPCC’S Third Assessment Report. However SRES data were yet to be lodged at the IPCC’S Data Distribution Center when we were collecting data for this study. The usefulness of the data from MAGICC-SCENGEN is limited by their coarse spatial resolution of 5 x 5° longitude and latitude. In other words each data point represents a cell of about 500 km x 500 km. Only one of these cells lies entirely within the territorial limits of Nigeria. Six other cells include a share of Nigeria’s land area. Also, only three climate parameters: rainfall, cloud cover and mean temperature are included.

To demonstrate an aspect of uncertainty due to change from one emission scenario to another, we have adopted SRES A2 and SRES B1 and used them separately to project mean annual rainfall from the baseline period to six other time slices in the 21$^{st}$ Century. SRES A2 is a high emission scenario while SRES B1 is a low emission scenario. We also used a GIS procedure to interpolate and downscale from the data points to cells of less that 1 km squared in area. The results are summarized in Tables 4.2 and 4.3.

Projections with either of the two scenarios as depicted in the two tables indicate steady and consistent increases in annual rainfall. The magnitude of the projected increases is highest in the south, near the coast and declines with distance from the sea. In general, SRES A2 projections result in rainfall increases much higher than those of SRES B1 projections. With respect to the SRES A2 scenario, annual rainfall is projected to increase from 730 mm in the year 2000 to 839 mm in the year 2100 at Birni Kebbi in the Sudan Zone. In Port Harcourt within the Forest Zone, corresponding increases are from 2373 mm in the year 2000 to 2628mm in the year 2100. On the other hand, with respect to the SRES B1 scenario, annual rainfall at Birni Kebbi is projected to increase from 730 mm in the year 2000 to 803 mm in the year 2100, while in Port Harcourt, the corresponding increase is from 2372 to 2518.

**Table 4.2: Mean Annual Rainfall Projections based on SRES A2 Scenario (mm)**

| Data points | Nearest Settlement /State | Mid Thirty-Year Time Slice | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2000 | 2020 | 2040 | 2060 | 2080 | 2100 |
| A | Birni, Kebbi | 730.00 | 730.00 | 766.50 | 803.00 | 803.00 | 839.50 |
| B | Gusau, Zamfara | 693.50 | 730.00 | 730.00 | 766.50 | 803.50 | 839.50 |
| C | Damaturu, Yobe | 511.00 | 511.00 | 547.50 | 547.50 | 584.00 | 584.00 |
| E | Meko, Ogun | 1241.00 | 1241.00 | 1277.50 | 1277.50 | 1277.50 | 1314.00 |
| F | Ankpa, Benue | 1606.50 | 1642.50 | 1679.00 | 1715.50 | 1715.50 | 1752.00 |
| G | Gasaka, Adamawa | 1423.50 | 1460.00 | 1496.50 | 1533.00 | 1569.50 | 1606.00 |
| H | Port Harcourt, Rivers | 2372.50 | 2409.00 | 2445.50 | 2518.50 | 2555.00 | 2628.00 |

In general, areas with the higher rainfall expand faster under an SRES A2 scenario than under an SRES B1 scenario. The main conclusion here is that significantly different climate patterns will occur given each of the alternate emission scenarios. This is the essence of the uncertainties concerning climate change in Nigeria.

**Table 4.3: Mean Annual Rainfall Projections based on SRES B1 Scenario (mm)**

| Data points | Nearest Settlement | Mid Thirty-Year Time Slice | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2000 | 2020 | 2040 | 2060 | 2080 | 2100 |
| A | Birni, Kebbi | 730.00 | 730.00 | 730.00 | 766.50 | 766.50 | 803.00 |
| B | Gusau, Zamfara | 693.50 | 693.50 | 730.00 | 730.00 | 766.50 | 766.50 |
| C | Damaturu, Yobe | 511.00 | 511.00 | 511.00 | 547.50 | 547.50 | 547.50 |
| E | Meko, Ogun | 1241.00 | 1241.00 | 1241.00 | 1277.50 | 1277.50 | 1277.50 |
| F | Ankpa, Benue | 1606.00 | 1642.50 | 1642.50 | 1679.00 | 1679.00 | 1715.50 |
| G | Gasaka, Adamawa | 1423.50 | 1423.50 | 1460.00 | 1496.50 | 1496.50 | 1533.00 |
| H | Port Harcourt, Rivers | 2372.50 | 2409.00 | 2445.50 | 2482.00 | 2482.00 | 2518.50 |

## 4.5 CONCLUSIONS

In this section, we have attempted to give an outline of the potential climate change in Nigeria in the aftermath of observed current global warming. The outline has been provided with respect to the ecological zones including: Forest, Southern Guinea, Northern Guinea, Sudan and Sahel. While analyses were undertaken for several climatic parameters including cloud cover, precipitation, diurnal temperature range, minimum temperature, maximum temperature, average daily temperature and vapor pressure, only two of them namely precipitation and temperature are discussed. The main findings are as follows:

- The most significant changes are with respect to temperature and temperature related parameters. There has been a tendency to emphasize changes in temperature in the temperate latitudes and to imply that similar changes will not occur in tropical areas. Given some of the emission scenarios discussed in this chapter, changes in minimum and maximum temperatures of the order of 7 $^{o}$C or more could be expected in certain parts of the country. This is likely to create a significantly different world with implications in vulnerability and adaptive capacity. The impacts of such changes will be felt in multiple sectors including: health, water, biodiversity, agriculture and forestry.
- Night time temperatures will in general increase at a higher rate than day time temperatures. This has a potential to alter the thermo-period to the detriment of biodiversity. Crops and other plants requiring low temperature conditioning may in the short run survive through autonomous adaptations, but in the long run may might suffer extinction. In addition, higher respiratory losses due to higher night temperatures could depress plant production.
- Day time temperatures may in future attain levels unknown to areas outside the hot desert regions. In areas with perennially humid air, this has the potential to produce sultriness and the oppressive heat usually associated.
- There has been an observed trend towards aridity in Sub Saharan West Africa. Our findings are to the effect that this trend will be put on hold or reversed as the century progresses. There are possibilities however, that the additional water need created by higher temperatures may not be met by the increases in rainfall.
- One aspect of the current climate pattern that will be carried forward into the potential climate of the future is zonation. All the parameter values are still likely to increase or decrease with distance from the coastline. Rainfall and humidity will decrease, while temperature will increase with distance from the sea..
- Uncertainties regarding climate change will most likely be in terms of magnitude rather than of direction. The more significant uncertainties pertain to temperature and temperature related parameters in respect of which the expected changes are relatively large. With respect to moisture, the projections are for an increase rather than a decrease. The worst case scenarios are the situations in which the moisture level does not change

# CHAPTER FIVE

# IMPACTS, VULNERABILITY ASSESSMENT AND ADAPTATION MEASURES

## 5.1 INTRODUCTION

An assessment of a country's vulnerability in the context of *Climate Change* is an evaluation and analysis of the extent and severity of potential impacts of climate changes on the physical environment, main sectors of the national economy, human health and other socio-economic activities. The main national resources within the physical environment that have been identified to have high potential of susceptibility to climate change include (i) natural ecosystems, (ii) agricultural ecosystem, (iii) water resources, and (iv) coastal resources. Other key socio-economic sectors that are most likely to be impacted by climate change are health and well-being, land-use change and forestry and energy. In general, vulnerability assessment would allow for the identification of the types of problems that a country could face in the event of marked climate changes.

Adaptation on the other hand is concerned with adjustment in ecological, social or economic systems in response to actual or expected climatic stimuli, or their effects, that moderates harm or exploits beneficial opportunities. Thus, adaptation measures refer to all those responses to climate change that may be used to reduce vulnerability. In this regard, an assessment of a country's adaptation is an identification and evaluation of possible options or changes in policies, practices and technologies, as well as actions designed to adapt to or take advantage of new opportunities that may arise as a result of climate change. These measures can be evaluated in terms of criteria such as availability, benefits, costs, effectiveness, efficiency and feasibility.

The overall objective is not only to identify the range of climate change related problems facing Nigeria as a nation and the required adaptation measures but also highlight areas of possible assistance in order to overcome the problems and facilitate adaptation options.

## 5.2 METHODOLOGY

In assessing the vulnerability of the country to climate change, a qualitative approach was adopted. This was in view of available limited data and information that could be used to develop country-specific climate scenarios. Thus, the methodology adopted in this relies heavily on secondary data consisting mainly of existing records and documentation in various forms including socio-economic statistics, photographs, satellite imageries, geologic and oceanographic data, biological and fisheries data and others relevant to the study. The general approach was to use mostly the results of studies available in literature noting the various approaches and methodologies, including models, as provided in 1996 IPCC Guidelines. In particular, the study utilizes the analogue scenario with expert judgment, using available studies and information on Nigeria. The various data were analyzed and the results interpreted and resolved into necessary and useful statistical data and information. From the qualitative description of information available in literature, the socio-economic values at change were grouped into four categories, namely, low (L), medium (M), high (H) and critical (C).

Where precision data are available, the factors of extreme events related to storm surges, river discharges, and possibly climatic conditions have been considered in assessing the vulnerability of the study area. Also, where data are available, the factors of tectonic uplift and subsidence have been taken into account. The report is also based on assumptions of potential increase in temperature accepted by the IPCC in its 1995 Second Assessment Report particularly since these assumptions are generally representative of situations in West Africa where a general trend of 0.2-0.3$^{o}$C rise in temperature has been noted. In addition, the study uses three distinct sets of boundary conditions for accelerated sea level rise (ASLR). These assumptions include (a) 0.2m which represents a low estimate; (b) 0.5 m which represents a medium estimate; and (c) 1.0 m which represents a high estimate of changes in SLR.

Three scales of study were used. These levels are particularly important because of the need to have information and examine the problems on relatively macro, meso, micro scales. The three levels include (a) the whole country as a corporate unit (b) each of the ecological regions as individual entities and (c) selected most vulnerable areas in the country (e.g the Niger Delta, the Lagos region, the Calabar region, the Ondo region and the Sudan-Sahel zone).

In the following analyses, qualitative impact assessment has been made in the various sectors of significance in Nigeria.

## 5.3 IMPACTS

Over the past few decades, Nigeria, like many other parts of the world have been beset by a lot of climatic anomalies with serious consequences on the society. These anomalies and their consequences have been of great concern to the Nigerian people and have created considerable awareness and demonstrated the sensitivity of human welfare and a nation's socio-economic planning and development to climatic events. Consequences of extreme climatic events due to global warming have been so dramatic that there has been considerable and disturbing concern among the various governments and peoples of the country. In particular, with the variations and changes in weather and climate since the late 1960s, and early 1970s, a lot of impacts have been manifested on various environmental processes and human activities in various parts of the country. Evidence abound that global mean surface air temperature has increased by about 0.3$^{o}$C to 0.6$^{o}$C since the late 19$^{th}$ century. Recent years, particularly since 1950s have been among the warmest since 1860 while evidence of warming at the regional levels has been found in many parts of the world. Also significant is the rise in sea level by between 10 and 25 cm over the past 100 years, and according to the IPCC, much of the rise may be related to the increase in global mean temperature.

In general, climate change and sea level rise would no doubt compound the serious problems of sustainability of the environment and management of resources, as well as the currently serious problems in population and consumption patterns and characteristics in the country. In particular, climate change and sea level rise will threaten the coastal zones and the low lying islands, which are already constantly plagued with floods and erosion, while in many cases, the impacts would be most severely felt in regions such as the Sudan and the Sahel areas, which are already under serious water stress. There would be serious consequences on agriculture and livestock production and management, water resources and water resources management, health, ecosystems, forests and forestry, fisheries, and other economic activities. The potential impacts of climate change on some of these sectors in Nigeria are discussed next in view of the common agreement that the characteristics of past climatic variability and changes could continue in future and, therefore, continue to have implications for national development.

### 5.3.1 Climate and Climate Systems

Based on the IPCC projection, the humid tropical zone of southern Nigeria which is already too hot and too wet, is expected to be characterized by increase in both precipitation (especially at the peak of the rainy season) and temperature. Already, temperature increases of about $0.2^{o}C$ - $0.3^{o}C$ per decade have been observed in the various ecological zones of the country, while drought persistence has characterized the Sudan-Sahel regions, particularly since the late 1960s. For the tropically humid zones of Nigeria, precipitation increases of about 2-3% for each degree of global warming may be expected. Thus, it is reasonable to expect that the precipitation would probably increase by approximately 5 - 20% in the very humid areas of the forest regions and southern savanna areas. The increase in temperature in these areas would also possibly increase evaporation, reducing the effectiveness of the increase in precipitation.

According to IPCC projections, rainfall in the very humid regions of southern Nigeria is expected to increase. This may be accompanied by increase in cloudiness and rainfall intensity, particularly during severe storms. It could also result in shifts in geographical patterns of precipitation and changes in the sustainability of the environment and management of resources. However, since the increase in temperature could increase evaporation and potential evapotranspiration, there would be tendency towards "droughts" in parts of these humid areas of the country. In fact, recent studies have shown that precipitation decrease in the humid regions of West Africa, including southern Nigeria, since the beginning of the century is about 10-25% or about 2-5% per decade. If this trend persists, rainfall in the humid regions of southern Nigeria may be about 50% to 80% of the 1900 values by 2100. With increase in ocean temperatures, however, there could be increase in the frequency of storms in the coastal zone of the country.

In contrast to the humid areas of southern Nigeria, the savanna areas of northern Nigeria would probably have less rainfall, which, coupled with the temperature increases, would reduce soil moisture availability. Recent studies have indicated that the Sudan-Sahel zone of Nigeria has suffered decrease in rainfall in the range of about 30-40% or about 3%-4% per decade since the beginning of the nineteenth century. Already, these savanna and semi-arid areas suffer from seasonal and inter annual climatic variabilities, and there have been droughts and effective desertification processes, particularly, since the 1960s. This situation may be worsened by the expected decrease in rainfall with greater drought probabilities and more rainfall variabilities and unreliabilities.

### 5.3.2 Ecology and Ecosystems

The severity of climate change impacts on the ecosystems depends, to a large extent, on the status of the flora and fauna. While details are still lacking, it is expected that the effects of any significant change in climate would shift the boundaries of major ecological zones of the country as well as have tremendous impact on the wildlife they support. In particular, the forest ecology and the ecosystems that are already under significant human pressure would be adversely affected. Significant climate change and sea level rise would result in loss of biodiversity, rapid deterioration in land cover and depletion of water availability through destruction of catchments and aquifers. Although specifics of the changes are yet to be properly analyzed, there would be changes in forest and land cover, species distribution, composition and migration patterns and biome distribution for the worse. Persistent flooding and water logging due to accelerated sea level rise or extreme weather events could render forest regeneration more difficult. Many of the organisms in the forest ecosystem of Nigeria are already near their tolerance limits, and some are not able to adapt further under a change in the ecological conditions.

The savanna biome of northern Nigeria would be very vulnerable to any climate-change-related dramatic reduction in rainfall in the region. This could result wide spread degradation of habitats. In addition, in some of these cases, changes in the ecological conditions being less favourable to the existing ecosystems could result in new ecosystems responding, by gradually invading the neighbouring areas where the climate is more favourable. Thus, climate change and sea level rise could affect the boundaries of the ecosystems and the mix of the species that compose them, such that the distribution of new patterns of plant and animal communities would be a reflection of how the different ecosystems have been able to adapt to the expected climates.

### 5.3.3 Soil Erosion and Flooding

As a consequence of climate change, some areas will start receiving heavier and steadier rainfall and such areas will inevitably begin to experience increased rainfall-induced erosion. As a corollary, in the arid northern parts of Nigeria, higher temperatures will contribute to dry conditions which underlie accelerated wind erosion. These are extremely serious situations given that soil erosion is already of catastrophic proportions in Nigeria whether viewed as gullying or sheet erosion while floods annually ravage many parts of the country during the rainy season. For example, it is estimated that in Abia, Anambra and Imo States located in the south-eastern part of Nigeria, there are no fewer than 600 gully erosion sites.

As a result of widespread reduction of vegetation cover, all parts of the country are vulnerable to soil erosion resulting from climate change either in terms of removal of soil by wind and rain or deposition of same in low-lying and down-wind locations. However, some parts of the country such as in the south-eastern areas are much more vulnerable to rain-induced erosion while the northern-most parts are similarly vulnerable to wind-induced soil erosion.

### 5.3.4 Agriculture

#### *5.3.4.1 Crop Production*

In Nigeria, agriculture is the main source of food and the main employer of labour, employing about 60-70% of the population. Cereals (notably millet and sorghum), groundnuts and beans dominate crop production in the northern part of the country, while the dominant crops in the south are cassava, yam, palm produce, cocoa and rubber. It is a significant sector of the economy and also the source of a lot of raw materials used in the processing industries, as well as a source of foreign exchange earning for the country. Thus, the agriculture sector needs to be assessed for its vulnerability, especially since it is heavily dependent on characteristics of rainfall - a situation that makes the country particularly vulnerable to climate change.

The impacts of climate change on agriculture are assessed using the following assumptions:

Change in seasons

- increased level of $CO_2$ on the physiology of crop plants and weeds;
- changes in climate parameters, particularly temperature and rainfall, on plants and animals; and
- sea level rise on agricultural land.

Change in season would lead to alteration in planting dates, length of growing period and the eventual productivity.

A significant effect of climate change due to increased levels of $CO_2$ would be reflected in the production of both $C_3$ *crops* (such as cassava, yam, cowpeas, wheat, soybeans, rice and potatoes), and $C_4$ *crops* (such as millet, sorghum, sugar cane, and maize). In general, higher increases in productivity can be expected with the $C_3$ *crops* compared with $C_4$ *crops*. Thus, the $C_4$ *crops*, which are more common in Nigeria, would be generally adversely affected as many of them are already functioning near-optimal conditions at today's relatively lower $CO_2$ levels. *$C_3$ weeds* will grow more rapidly and hence compete more severely with a number of *$C_4$ crops*. Similarly, expected changes in crop development and phenology can cause shortening or lengthening of crop cycle that could lead to decreases or increases in productivity. Structural changes, especially in the carbohydrate status of plants can also occur. This may affect the nutritional value, taste and storage quality of some fruits and vegetables. Increases in $CO_2$ can also lower crop water requirements by reducing transpiration per unit leaf area.

Climate change in Nigeria will be accompanied by greater variability in rainfall and temperature. Temperature increases will have detrimental effects on agriculture because of an increase in the number of extremely hot days, a reduction in rainfall and soil moisture, and an acceleration of crop development that would lead to premature ripening and lower yields in crops such as cereals. In particular, increased temperatures, which would increase evaporation, would reduce the effectiveness of any increase in precipitation and cause crop yield to be lowered. Increased rainfall variability would result in more frequent floods and droughts and larger runs of wet and dry years to give rise to frequent changes in agroclimatic characteristics and increased variability in yields of crops in the different ecological zones. Heavier than normal rainfall in the southern part of the country would lead to destruction of crops in the field, greater post-harvest losses, loss of arable land and increased growth of weed. Significant reduction of rainfall in the Sudan-Sahel belt would make the region drier with consequent reduction in crop productivity. Decreased rainfall in the region would also reduce the primary productivity of the grassland areas in which livestock production is currently important. It would also have significant effects on the ecosystems; new ecoclimatic environment for livestock would emerge, possibly shifting towards the coast in many parts of the country.

Indirect effects of climate change on agriculture include the effects on pests and diseases and the impacts of these on agricultural production, the impacts on health, and the impacts on agro-related socio-economic activities. Various pests, including the tobacco cutworm, rice stink bug, rice weevil, and soybean pod borer would probably expand their distribution areas in the event of climate change.

Also, an increase in the frequency of extreme events such as prolonged drought or intense flooding could create conditions that could be conducive to diseases or pest outbreaks, and severely disrupt the predator-prey relationships that normally restrict the proliferation of pests. Warmer and more humid conditions would enhance the growth of bacteria and mould on many types of stored food, and this would increase food spoilage and create some specific toxicological health hazards.

The sea level rise would lead to submergence of the lowlands along the coast, and much of the land currently used for agriculture would be lost leading to socio-economic and socio-cultural problems. There would be mass migration out of submerged agricultural areas and substantial losses of income, as well as great financial stress and unemployment would result.

In the final analysis, the various impacts of climate change on crop and livestock could have tremendous impact on income, employment, food production and even exports. There would also be significant impacts on the characteristics of labour, employment and population processes and their characteristics.

#### *5.3.4.2 Livestock Production*

The Sudan-Sahel zone of Nigeria is home to a large number of livestock The country's livestock population is estimated for 1994 as 12 million cattle, 8 million sheep and 24 million goats. The rangeland and livestock ecosystems in the country are complex, with myriad interactions among the biotic and abiotic components of the systems as well as the economic and social components. Consequently, as already mentioned for crop agriculture, climate change will have both direct and indirect impacts at different spatial and temporal scales. Examples of these impacts include changes in forage yield, changes in livestock productivity, changes in ecological processes, alterations in farm level profitability, and changes in farm incomes. In general, the livestock production systems would be vulnerable to climate change in respect of (i) anticipated decrease in rainfall in the Sudan-Sahelian zone and consequent reduction in the available pastureland, (ii) declining availability of surface water resources for animals, and (iii) possible increase in salinity at watering points due to increase temperature and evaporation in the face of reduced rainfall. To the extent that climate change leads to decrease in livestock production, it will impair the availability of animal protein including meat, egg and milk and animal products such as hides and skins. It will also adversely affect employment in the livestock sector. Possible types of climate change driven impacts that are likely to occur in the Nigerian pasturelands and the livestock sector are given in Table 5.1.

**Table 5.1: Likely Impacts on the Pasture Land and Livestock**

| | |
|---|---|
| Ecological impacts | Alteration in carbon storage capacity of the ecosystem; alterations in greenhouse gas emissions; disturbances in ecosystem functions (e. g. alteration in biogeochemical cycling, incidence of wild fires etc.); changes in soil quality and productivity; changes in biodiversity and changes in habitat suitability for wildfire. |
| Livestock impacts | Changes in forage resources; shifts in range land vegetation structure or boundaries; changes in forage quality and quantity; reduction in harvest forage; changes in length of growing season; reduced feed intake and changes in livestock productivity such as milk production, growth rates and weight gain, reproduction; and changes in water quality and quantity, shift in types of herbivores. |
| Socio-economic impacts | Changes in food production and security (locally and nationally; changes to incomes derived from livestock production, wildlife, and other range land outputs; changes in land use; changes in recreational use of range lands and alteration in scenic quality. |

#### *5.3.4.3 Fisheries*

Fishery resources are of particular significance in Nigeria as they provide a considerable amount of dietary protein in the country and the sector also serves as a major source of employment and labour for a large proportion of Nigerians. While trawling takes place off-shore in the Gulf of Guinea, artisanal fishery occurs along the coast, creeks and lagoons, rivers and lakes. Aquaculture is practised in many widely distributed locations across the country but are particularly important in the southern part. Subtle changes in key environmental variables such as temperature, salinity, wind speed and direction, ocean currents strength of upwelling due to climate change could sharply alter the abundance, distribution, and availability of fish population in the country.

Both inland (e.g. around lake Chad) and ocean fisheries are very sensitive in varying degrees to climate fluctuations. In particular, increased ocean temperatures may affect upwelling along the Gulf of Guinea which could make the ocean waters become unsuitable for fisheries, causing a reduction in and possible collapse of fishing activities. An expected rise in temperature would cause a change in the characteristics of the oceans waters and consequently adversely affect fish habitat in the coastal zone of Nigeria. In addition, wetland loss and increased salinity would reduce estuarine fishing. On the other hand, increase in the depth of the present coastal waters could lead to increased deep sea fishing and ocean fisheries closer to the shore. Any significant reduction in the fish catch would upset both the economy and the culture of Nigeria.

### 5.3.5 Water Resources

Climate change would result in increased variability in precipitation, predictably resulting in floods in humid areas of southern Nigeria and decrease in precipitation resulting in droughts in the savanna and semi-arid areas in the north. Thus, the characteristics of the component of the hydro-climatological systems of the different ecological zones would be altered, with their consequences on the availability of water resources. In particular, higher temperatures will increase the rate of evaporation from land and water surfaces and evapotranspiration from plants. Especially, in the Sudan-Sahel region, which are very sensitive to small changes in temperatures and rainfall, the impacts on water resources, may be greatest because temperature changes will affect the amount of runoff that becomes groundwater - the main source of water supply in many parts of the regions. Global warming would thus increase the risks of drought and desertification processes in these areas. On the other hand, most of the water resources along the coast would become polluted by intrusion of salt water, and water resources management would place greater emphasis on desalinization. These conditions would also lead to changes in management strategies in order to balance water supply and demand through conservation efforts.

Currently, there are three categories of sources for water supply in Nigeria: direct rainfall harvesting, surface (rivers and lakes including human-made reservoirs, e.g. Kainji lake behind Kainji dam on river Niger) and underground water. Rainfall harvesting is used mainly in the rural areas and covers more than 50% of the water consumption in these localities. The estimated national annual water demand in 1996 was 6,502 million litres per day (mld) which far outstripped the supply of 2,957 mld. The water supply-demand projections for the country in the period 1996 – 2030 is given in Table 5.2.

**Table 5.2 Water Supply and Demand Projections for Nigeria (1996 – 2030 MLD)**

| Year | Population (million) | | | Water Supply (mld) | | | Water Demand (mld) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Urban | Rural | Total | Urban | Rural | Total | Urban | Rural | Total |
| 1996 | 50.7 | 39.6 | 90.5 | 2593.5 | 363 | 2956.7 | 4905.6 | 1596.0 | 6501.9 |
| 2000 | 62.8 | 44.7 | 107.5 | 3212.2 | 407.7 | 3619.9 | 6074.1 | 1792.5 | 726.6 |
| 2005 | 82.1 | 51.6 | 133.7 | 4199.4 | 470.6 | 4670 | 7947.3 | 2069.2 | 10076.5 |
| 2010 | 107.3 | 59.5 | 166.8 | 5488.4 | 542.6 | 6031.1 | 10386.6 | 2386.0 | 12775.7 |
| 2015 | 140.3 | 68.5 | 208.6 | 7166.1 | 624.7 | 7730.8 | 13561.7 | 2746.9 | 16308.6 |
| 2020 | 183.5 | 78.9 | 262.4 | 9386 | 719.6 | 10105 | 17762.8 | 3163.9 | 209276.7 |
| 2025 | 240 | 90.9 | 330.9 | 12776 | 829 | 13605 | 23232 | 3645.1 | 26707.1 |
| 2030 | 313.6 | 104.9 | 418.5 | 16040.6 | 956.7 | 16997 | 30356.5 | 4206.5 | 34563.0 |

**Note: (a) Base year (1996) Urban water supply: 51.15 litres/person/day**
**(b) Base year (1996) Urban water demand: 98.6 litres/person/day**
**(c) Base year (1996) Rural water supply: 51.15 litres/person/day**
**(d) Base year (1996) Rural water demand: 51.15 litres/person/day**

Climate change, particularly if it is reflected in reduced rainfall in many parts of Nigeria, would further compound the inability of the country to meet people's demand for water. The country may increase its dependence on underground water sources. But decreased rainfall would lead to lower water tables and this could increase the water stress and problems of environmental sustainability and future water resources management.

Also significant is the fact that climate change will affect water use in all socio-economic sectors and consequently demand for water. These include agricultural, industrial, energy, municipal and reservoir losses. Water use for agriculture includes irrigation and livestock water, which as already noted will be adversely affected by climate change. For industrial purposes, reduction of flow in rivers due to climate change may put increased pressure on wastewater treatment processes, leading to increased water re-cycling and a decline in industrial water use. Water use for energy production takes two forms: hydroelectric and thermoelectric. But of particular significance is the fact that reduced river flow will reduce hydropower reservoir storage and thus reduce potential energy production. Warmer temperatures will increase evaporation from reservoir as already noted. Already, there is increased concern that marked fluctuations in the level of the waters in Kainji dam due to observed changes in climate is disrupting electricity generation from the hydro power station.

### 5.3.6 Socio-Economic and Socio-Cultural Sectors

#### *5.3.6.1 Energy*

Nigeria receives an annual average solar radiation of about 3.5 $Kwh/m^2/day$ in the southern coastal areas and about 7 $Kwh/m^2/day$ in the semi-arid zone in the north. Wind energy is available in the range of an average speed of about 2 m/s near the coast to 4 m/s in the north.

Climate change will have significant effects on the energy sector in Nigeria. In particular, rising temperatures, changes in the amount of precipitation and variation in humidity, wind patterns and the number of sunny days per year, could affect both consumption and production of energy. These impacts would be profound, although the nature and magnitude of the impacts may not be easy to predict.

In general, both energy supply and demand would be affected by climate change and sea level rise. Obviously increased temperatures would result in increased energy demand for air conditioning, refrigeration and other household uses. Water pumping requirements may increase significantly in response to increased water need for irrigation and residential, commercial, and municipal water use to off set temperature increases.

Climate change would also have significant impacts on solar energy and wind, the two significant sources of energy that still remain untapped in Nigeria. Of more immediate concern are the possible impacts on the supply of, and demand for the hydroelectric power and fuelwood, which are the most widely used sources of energy in Nigeria. Expected reduced rainfall, particularly in the northern part of the country would adversely affect the supply of hydroelectric power which is sensitive to river flow, as already pointed for the Kainji hydroelectric power station on River Niger. Reduced hydroelectric power production would also impose economic hardships. The impacts on supply of fuel wood could also be important. For example, with a decrease in rainfall, some sources of the fuelwood would be eliminated. Also, more frequent thunderstorms and erosion could cause more damage to forests. The situation would be worsened by the growing energy demand due to increase in population.

With a rising sea level and the increase landward penetration of salt water, coastal tree species, except the salt tolerant ones could be destroyed, and thus, the forests as sources of wood could decrease. If climate change results in migration of people to particular areas, there could be increase in demand for fuel wood in these areas and this could aggravate environmental problems commonly associated with deforestation in these areas. Also significant is the fact that all types of energy production facilities located along the coastal areas of Nigeria, such as power plants and oil and gas production facilities could be subject to damage from the sea level rise. Virtually all energy production facilities, including electric transmission lines, thermal power plants, wind and oil and gas production facilities are subject to damage by extreme weather which could increase in intensity and frequency under climate change. For example, temperature fluctuations could affect the operations of switches, transformers and other equipment. In warmer weather, lines tend to expand and sag, and become susceptible to more damage from strong winds. If climate change results in population shifts, some existing production facilities may lose utility, causing a reduction in production or closure, if demand they were designed to serve is reduced. This could result in financial losses for the country and increased costs to remaining customers.

#### *5.3.6.2 Mining*

Mining represents a major socio-economic sector in Nigeria. In the Niger Delta alone, total investment in oil mining amount to over US $13 billion, most of which is under threat from climate-change related sea level rise. Considerable losses will thus be incurred in terms of investments and developments of the Niger Delta, particularly with respect to Government revenue in oil and oil-based industries such as oil refineries in coastal cities (e.g. Port Harcourt and Warri) and damage to many infrastructure and social amenities.

#### *5.3.6.3 Industry*

In general, some industrial products (e.g. foods and drinks) are weather dependent and their production are vulnerable to extreme weather conditions. For example, severe storms are detrimental to many industries including offshore oil, and gas drilling and fisheries that dominate the coastal zone of Nigeria. Some industries are also dependent on availability of local resources, which may be affected by changes in the climate. Variations in the production costs of crops domestic animals, fish, wood, water and mineral resources due to climate change and sea level rise, would affect, for instance, industries processing agricultural products, hydroelectricity generation and aluminum industry. Changed biological diversity, which may result from climate change, could also hamper the development of agricultural and pharmaceutical products. The loss of coastal zones, mangroves forests and wetlands, would affect fisheries and many other economic activities based on the species in these habitats. Such vulnerability could result in forced relocation, loss of revenue and inability to continue operations.

#### *5.3.6.4 Population and Settlement*

Climate Change would also directly or indirectly affect population and human settlements in Nigeria. In general, about 15% of the country's population is presently affected by sea level changes. Global warming-related extreme events such as floods (resulting landslides in some areas) strong winds, droughts and tidal waves could cause massive relocation of people. They could contribute to increased population movement via (a) declining agricultural productivity (b) managed and unmanaged retreat from land which is vulnerable to sea level rise and (c) temporary displacement. Declining agricultural productivity that has been a major trigger for population movement in the country could be worsened, especially in the semi-arid and arid zones of northern Nigeria.

#### *5.3.6.5 Health*

The human health impacts of climate change in Nigeria would occur in various ways, and because of the poor health status of many citizens, the impacts could be devastating. The impacts could either be direct or indirect. A summary of some anticipated general direct and ecosystem mediated health effects of global climate change in Nigeria is given in Table 5.3. Some of the direct impacts of climate change on health in Nigeria would include deaths, stroke, illness and injury due to increased exposure to heat waves and effects upon respiratory systems. Indirect effects of climate change and sea level rise include altered spread and transmission of vector-borne diseases (including malaria etc.) and altered transmission of contagious diseases (including cholera, influenza etc).

**Table 5.3: Summary of Anticipated Direct and Ecosystem-mediated Health Effects of Global Climate Change in Nigeria**

| Environmental alteration | Direct effects | Ecosystem-mediated health |
|---|---|---|
| High temperatures and precipitation patterns | Increased heat-related mortality and morbidity. Increase in photochemical and possibly other forms of pollution, with resulting increase in respiratory illness. Increased frequency of floods, storms and natural disasters. | Changes in distribution and seasonal transmission of vector-borne diseases. Increase in toxical bloom and possibly in transmission of water borne diseases. Decreased agricultural production and food shortages. |
| Seal level rise | Loss of habitable land. Contaminated freshwater supplies, damage to public health infrastructure. | Decreased fish stocks due to loss of coastal wetlands. |

Climate change could be anticipated to affect the patterns of various allergic disorders in the country (for example, hay fewer and asthma) via its impact on the production of allergens. Altered pollen production would principally reflect shifts in the natural and agriculturally managed distribution of many plant species. Also, studies have shown that asthma increases in the wet season in many parts of Nigeria. Thus increased wetness anticipated for the southern part of Nigeria could trigger increased rate of asthmatic attack.

Because many of the biological organisms and processes linked to the spread of infectious diseases are especially influenced by fluctuation in climate variables, notably, temperature, precipitation, humidity and wind, the impacts of climate change would be expected to cause widespread shift in the pattern of a number of infectious diseases and in food borne intoxication. Climate change would also alter the life cycle dynamics of vector and infectious parasites, further influencing transmission potential. In addition, distribution of disease agents that are neither transmitted by vectors, nor otherwise dependent on animal hosts, will probably also be affected by climate change. The relevant diseases include the faecal-oral infections, many food borne diseases, and infections spread directly from person to person.

Climate change would also have indirect effects on vector abundance and vector populations. For example, some vector species would be displaced by others following shifts in climatic zones. As the vectorial capacities of the original and displacing species may differ considerably, the effect of species replacement on diseases transmission will depend on the particular species involved. For example, Anopheles species, and in some cases the malaria they transmit, will disappear from previous thickly forested areas of southern Nigeria following the loss of the forests upon which they depend. Also, changes in agricultural practices associated with climate change may affect vector abundance. Introduction or expansion of irrigation in areas affected by drought or decreased precipitation, would increase the number of breeding sites for mosquitoes, and also increase snail population and the risk of schistosomiasis. Sea level rise and increased coastal flooding may result in greater quantities of brackish water, which would favour vector species such as *anopheles subpictus,* since these prefer brackish water for breeding.

#### *5.3.6.6 Tourism*

Tourism, one of Nigeria's fastest growing industries, is based on wildlife, nature reserves, coastal resorts, and an abundant water supply for recreation. Many tourist attractions are located along the coastal zone of the country. Thus, any significant sea level rise due to global warming and climate change would impact on these tourist attractions that range from modern architectural basis through traditional relics to recreational grounds like beaches. Many beaches (e.g. the Victoria Island beach) in Nigeria will be lost. River deltas and maritime wetlands are also potentially endangered, while the existence of coastal settlements, including large cities, is threatened. With the destruction of a lot of these features, most of the socio-cultural features (e.g., the first Christian Church in Nigeria, located in Badagry, near Lagos) will be threatened. Those tourist attracting traditional festivals (eg. Argungu festival on river Argungu in Kebbi State) may decline to the extent that climate change induces shrinkage of such rivers. The anticipated loss of wildlife following the destruction of wildlife sanctuaries and reserves due to reduced vegetation as a result of climate change would discourage tourism. Overall, the base of tourism and, consequently, tourism contribution to GDP, are can be seriously threatened by adverse climate change.

##### *5.3.6.7 Transport*

Nigeria's transport systems will not escape the effects of global warming and climate change. For example, higher sea level rise may require costly changes to other ports and coastal roads and railways as the current means of communications along the coast may be covered by the intruding sea water or washed away by erosion. Changes in lake and river levels would also affect inland navigation. More frequent storms would affect shipping and other forms of transport. Also increased temperatures will exacerbate the problems of road and railways, as for example, the roads will become very hot for vehicle tires. Increased temperatures may also expose these vehicles to increased hazards of road accidents. Also, increased hot weather could cause increased rail length and consequently potential hazards of rail transportation. Any change in prevailing winds and increased dust haze would affect the safety and efficiency of take-off of flights. Airports near the ocean may also be vulnerable to sea level rise. If sea level should rise, for instance, drainage would be needed at the international airports of Lagos and Port Harcourt and other coastal airports.

### 5.3.7 Coastal Resources

The coastline of Nigeria is already undergoing pronounced morphological changes as a result of natural and anthropogenic activities. The natural phenomena include occasional sea surges and tidal waves, while human activities include (i) haphazard construction of ill-designed jetties and groynes, (ii) sand mining, (iii) unplanned and accelerated infrastructural development, (iv) pollution and (v) general land degradation. Accelerated sea level rise (ASLR) of 0.5 - 1 metre that is anticipated for Nigeria would most likely worsen these problems. Many low lying areas will be affected by ASLR and increased flooding from storm surges due to global warming. Beach erosion could pose more threat as a result of ill-designed jetties/groynes which could cause alterations in current directions with the result that erosion could shift to other places as being witnessed on the Bar Beach on Victoria Island, Lagos. The filling up of some mangrove wetlands for development is already causing flooding in many areas and could be worsened by climate-change related ASLR.

## 5.4 VULNERABILITY ASSESSMENT

Following the Common Methodology model, vulnerability is discussed in relation to five groups of impact categories:

- *Socio-economic values at loss* - including capital values at loss, subsistence values at loss and people that may be relocated;
- *Socio-economic values at risk* - including capital values at risk, subsistence values at risk and people at risk;
- *Socio-economic values at change* - including land use damage due to the impacts of climate change and sea level rise, salinity factor and other financial damages;

- *Ecological values at loss* - including ecological areas at risk and at loss and other special areas at loss; and
- *Cultural/historical risks and losses* - including losses of historical sites.

Values (at loss, at risk and at change) are defined as the consequence of natural hazardous events times the probability of the occurrence of these events. However, risk is assessed without considerations of the systems response, while loss and change are assessed with consideration of the system response. Because of inadequate information, some assumptions and generalizations were made in the estimation of the values. The following are summary results for the country as a whole and for some ecological zones namely the coastal area and the Niger Delta, the Sudan-Sahel region and selected stations in the country.

#### *5.4.1 Nigeria as a whole*

Table 5.4 shows the result of Nigeria's Vulnerability Analysis with climate change and ASLR of 1.0m. The results of the analysis show that more than 13 million people are presently at risk and may be relocated due to climatic variations and sea level changes. With the projected climate change and sea level rise of about 0.5m, the number of people that may be relocated assuming there is no development would increase to more than 27 million. With development, the number will be about 53 million people. If sea level should rise by about 1.0 m with the projected climate change, the number of people that may be relocated assuming there is no development would be more that 48 million. With development and with the projected climate change, the number of people that may be relocated would be more than 92 million. The potential population has been taken into consideration in computing these figures. The projections of other parameters in the vulnerability analysis are summarized in Table 5.4.

In general, about 15% of the country's population is presently affected by climatic variation and sea level changes. With climate change, between 50% - 60% of the population and about 25%-40% of the capital values could be adversely affected. At present, the socio-economic values at risk and at loss, the socio-economic values at change, the ecological values at loss and the cultural-historical values at loss are high in the country, with the impacts of climatic variations and sea level changes. The situation in all these cases would be critical given the projected climate change and sea level rise. It is assumed that the coastal areas of the country would be seriously and adversely affected by flooding and erosion and salinization, that most of the Sudan and the Sahel savanna regions, which are already undergoing severe droughts and desertification processes, would be almost completely desertified following a change to drier conditions. It is also expected that considerable parts, of the current Guinea savanna region, at least about 50%, would equally be desertified.

Similarly, the effects of both water and wind erosion would be very severe in Sudan and sahel regions as more than 50% of the people will be affected. In the Guinea Savanna, on the other hand, less than forty percent of the people could be affected. Some details of the more critical areas, namely, the coastal areas, the Sudan-Sahel areas and the Niger Delta are discussed below.

**Table 5.4: Nigeria - Vulnerability Analysis With Climate Change and ASLR (0.5/1.0m)**

| IMPACT CATEGORY | UNITS | PRESE NT | NO MEASURE (BAU) | | PROTECTION (Mitigation) | |
|---|---|---|---|---|---|---|
| | | | NO DEVELOPMENT | 30-YEAR DEVELOPMENT (0.5/1.0m) | NO DEVELOPMENT (0.5/1.0m) | 30-YEAR DEVELOPMENT 0.5/1.0 m |
| SOCIO-ECONOMIC VALUES AT LOSS | | | | | | |
| -Cap.Val. At Loss | $m | H | C | C | | |
| -Subs Val. At Loss | $m | H | C | C | | L |
| -People that may be relocated | /1000 | | 103468/ 206937 | 196589/ 393180 | 10347/20694 | L 19659/39318 |
| SOCIO-ECONOMIC VALUES AT RISK | | | | | | |
| -Cap.Val. At Risk | $m | C | C | C | L | L |
| -Subs Val. At Risk | $m | C | C | C | L | L |
| -People At Risk | /1000 | 25847 | 47354/ 72350 | 78573/ 137503 | 6177/11738 | 15443/29942 |
| SOCIO-ECONOMIC VALUES AT CHANGE | | | | | | |
| -Land use Damage (Climate Change) | | H | C | C | L | L |
| -Land use Damage (Salinity) | | H | C | C | L | L |
| -Other Financial Damages | | H | C | C | L | L |
| ECOLOGICAL VALUES AT LOSS | | | | | | |
| Ecological Area Loss | $Km^2$ | C | C | C | L | L |
| Special Area Lost | $Km^2$ | C | C | C | L | L |
| CULTURAL / HISTORICAL LOSS | | | | | | |
| Cultural / Historical Sites | | C | C | C | L | L |

### *5.4.2 Coastal areas*

It is estimated that with the present situation (ASLR of about 0.2 m), about 10-20% of the people in the coastal zone are being affected by the physical changes (including flooding and erosion and increased salinization of both surface and groundwater). With ASLR of 0.5 m, 1.0 m and 2.0 m, the situation will be critical, with more than 50% of the people affected by the physical changes due to climate change and sea level rise. Table 5.5 shows the results of the vulnerability analysis as computed for the present, assuming no development, and assuming a 30-year development scenarios.

### *5.4.3 The Niger Delta*

It is already noted that about 15% of the Niger delta would be lost with no ASLR. However, with ASLR of 0.5, about 35% of the delta would be lost. With ASLR of about 1.0 m about 75% of the delta would be lost. The values will, of course, vary in time and space. The number of people at risk, assuming no measure and development, would be 0.9 million, 2.10 million and 4.50 million with ASLR of about 0.2 m., 0.5m., and 1.0m respectively, resulting in massive *environmental refugee.* With 30-year development and assuming population growth of about 3%, the people at risk would be 3.99 million and 8.55 million for ASLR of 0.5m and 1.0m respectively. If less than 10% of these are assumed to be at risk with protection, the corresponding values for ASLR 0.5 m. and 1.0 m. are respectively about 0.21 million and 0.45 million with no development and 0.69 million and 0.85 million with 30-year development (Table 5.6).

**Table 5.5: Coastal Areas Vulnerability Analysis with Climate Change, ASLR of 0.5/1.0m and Development Scenarios (based on proportion of areas obtained for the Niger Delta – modified after Awosika et al)**

| | | | NO MEASURE | | PROTECTION | |
|---|---|---|---|---|---|---|
| **IMPACT CATEGORY** | **UNITS** | **PRESENT** | **NO DEVELOP-MENT** | **30-YEAR DEVELOP-MENT** | **NO DEVELOP-MENT** | **30-YEAR DEVELOP-MENT** |
| SOCIO-ECONOMIC VALUES AT LOSS | | | | | | |
| - Cap. Val. At Loss | $m | 13,800 | 32,200 | 16,100 | L | L |
| - Subs Val. At loss | $m | 1,380 | 3,200 | 1,610 | L | L |
| - People that may be relocated | /1000 | 3028 | 5900/8574 | 11210/16290 | 590/857 | 1121/1629 |
| SOCIO-ECONOMIC VALUES AT RISK | | | | | | |
| - Cap. Val. At Risk | $m | 43,120 | 100,630 | 251,562 | L | L |
| - Subs Val. At Risk | $m | 4312 | 10,063 | 25156 | L | L |
| - People At Risk | /1000 | 4319 | 8806/12977 | 16731/24656 | 881/1298 | 1673/2466 |
| SOCIO-ECONOMIC VALUES AT CHANGE | | | | | | |
| - Land use Damage (Climate Change) | | H | C | C | L | L |
| - Land use Damage (Salinity) | | H | C | C | L | L |
| - Other Financial Damages | | H | C | C | L | L |
| ECOLOGICAL VALUES AT LOSS | | | | | | |
| Ecological Area At Risk/Loss | $Km^2$ | 23801/ 15868 | C | C | L | L |
| Special Area Lost | $Km^2$ | N.D | C | C | L | L |
| CULTURAL/ HISTORICAL LOSS | | | | | | |
| Cultural/Historical Sites | | N.D | C | C | L | L |

With the projected climate change and sea level rise the capital values at risk would be about $8.05billion and $17.5 billion respectively with ASLR of 0.2 m and 1.0 m. with no development and no measure. With 30 years development and no measure, and assuming a rate of economic growth of about 5%, capital values at risk with 0.5 m ASLR and 1.0 m would be $20.13 billion and $43.13 billion respectively. The capital values at risk with protection would be about $0.81 billion and $1.73 billion with no development. With 30 years development, the corresponding values would be $2.01billion and $4.31 billion for ASLR of about 0.5 m and 1.0 m respectively.

Assuming that the subsistence values at risk in the Niger delta is only 10% of the capital values at risk, the subsistence values at risk would be about $0.35 billion, $0.81 billion and $1.73 billion respectively for ASLR of 0.2 m, 0.5 m and 1.0 m respectively with no measure and no development. With a 30-year development, and no measure, the subsistence values at risk would be about $2.01 billion and $4.3 billion respectively for 0.5 m and 1.0 m. With protection and no development, the subsistence values at risk would be about $0.81 billion and about $0.17 billion. With protection and 30-year development, the corresponding values would be about $0.2 billion and $0.43 billion for ASLR of 0.5m and 1.0m respectively.

**Table 5.6: Niger Delta Vulnerability Analysis with Climate Change, ASLR of 0.5/1.0 m. and Development Scenarios (based on proportion of areas obtained for the Niger Delta - modified after Awosika et al).**

| | | | NO MEASURE | | PROTECTION | |
|---|---|---|---|---|---|---|
| IMPACT CATEGORY | UNITS | PRESENT | NO DEVELOP-MENT | 30-YEAR DEVELOP-MENT | NO DEVELOP-MENT | 30-YEAR DEVELOP-MENT |
| SOCIO-ECONOMIC VALUES AT LOSS | | | | | | |
| -Cap.Val. At Loss | $m | H | C | C | L | L |
| -Subs Val. At Loss | $m | H | C | C | L | L |
| -People that may be relocated | /1000 | 1200 | 2412/3216 | 4583/6110 | 241/322 | 458/611 |
| SOCIO-ECONOMIC VALUES AT RISK | | | | | | |
| -Cap.Val. At Risk | $m | H | C | C | L | L |
| -Subs Val. At Risk | $m | H | C | C | L | L |
| -People At Risk | /1000 | 1800 | 3600/4800 | 6840/9120 | 360/480 | 684/912 |
| SOCIO-ECONOMIC VALUES AT CHANGE | | | | | | |
| -Land use Damage (Climate Change) | | H | C | C | L | L |
| -Land use Damage (Salinity) | | H | C | C | L | L |
| -Other Financial Damages | | H | C | C | L | L |
| ECOLOGICAL VALUES AT LOSS | | | | | | |
| Ecological Area Loss | $Km^2$ | 6000/4000 | C | C | L | L |
| Special Area Lost | $Km^2$ | N.D. (H) | C | C | L | L |
| CULTURAL / HISTORICAL LOSS | | | | | | |
| Cultural / Historical Sites | | N.D. (H) | C | C | L | L |

## 5.5 ADAPTATION ACTIONS

In order to minimize the negative impact of climate change on the ecosystems, water resources, socio-economic domains, a number of adaptation measures are open to Nigeria. They range from education to inform and encourage behavioural change to changing location and use, preventing effects, modifying threats, sharing loss or simply bearing it.

### 5.5.1 Physical and Ecological Adaptation

Naturally, all multicellular organisms are able to sense and respond to abiotic factors and have evolved various mechanisms to track the set of the environmental conditions under which they are able to exist and reproduce. Thus, organisms and the ecosystems can adapt autonomously. However, the ability of the ecosystem to autonomously respond to climate change is inherently limited. Therefore, in addition to autonomous adaptation, there must also be planned adaptation and adoption of adaptation strategies. These will include, among others:

- Diversification and extension of protected areas for the conservation of ecosystems that are most vulnerable to climate change and sea level rise;

Table 5.7 shows the vulnerability analyses for the Sudan-Sahel.

**Table 5.7: Sudan-Sahel Areas Vulnerability Analysis with Climate Change, ASLR of 0.1/1.0m and Development Scenarios based on Proportion of Areas Obtained for the Niger Delta – modified after Awosika et al).**

| | | | NO MEASURE | | PROTECTION | |
|---|---|---|---|---|---|---|
| **IMPACT CATEGORY** | **UNITS** | **PRESENT** | **NO DEVELOPMENT** | **30-YEAR DEVELOPMENT** | **NO DEVELOPMENT** | **30-YEAR DEVELOPMENT** |
| SOCIO-ECONOMIC VALUES AT LOSS | | | | | | |
| - Cap. Val. At Loss | $m | H | C | C | L | L |
| - Subs Val. At loss | $m | H | C | C | L | L |
| - People that may be relocated | /1000 | 6470 | 12603/17887 | 23945/33985 | 1260/1789 | 2394/1789 |
| SOCIO-ECONOMIC VALUES AT RISK | | | | | | |
| - Cap. Val. At Risk | $m | H | C | C | L | L |
| - Subs Val. At Risk | $m | H | C | C | L | L |
| - People At Risk | /1000 | 9456 | 18810/26697 | 35739/50724 | 1881/2669 | 3574/5072 |
| SOCIO-ECONOMIC VALUES AT CHANGE | | | | | | |
| - Land use Damage (Climate Change) | | H | C | C | L | L |
| - Land use Damage (Salinity) | | H | C | C | L | L |
| - Other Financial Damages | | H | C | C | L | L |
| ECOLOGICAL VALUES AT LOSS | | | | | | |
| Ecological Area At Risk/Loss | $Km^2$ | 133944/ 89297 | C | C | L | L |
| Special Area Lost | $Km^2$ | N.D (H) | C | C | L | L |
| CULTURAL/ HISTORICAL LOSS | | | | | | |
| Cultural/Historical Sites | | N.D (H) | C | C | L | L |

- Maintaining ecological structure and processes at all levels and reducing existing pressure on natural ecosystems;
- Reducing population and ecosystem vulnerability to climate change and reorientation of their evolution towards higher resistance to the changes;
- Incorporating biodiversity conservation into adaptation strategies in the other sectors of the Nigerian economy;
- Establishment and maintenance of protected area (*in situ* preservation), and the active management of wild populations outside of protected areas (*ex situ* management);
- Development and implementation of programmes for restricted areas and buffer zones, resource harvesting on a sustainable basis, ecological restoration, sustainable management and agro ecosystems; and
- Monitoring to evaluate species and ecosystems stability from climate change perspective.

#### *5.5.1.1 Degradation of Soils and Land Resources*

- Implementation of agricultural systems adequate to protect the soil from erosion.
- Establishment of mechanical and engineering structures (e.g check dams, storm diversion channels, bench terraces, contour bunds), as well as biological measures (e.g. cover cropping, mulching, contour cultivation, minimum or zero tilling) that could reduce soil erosion;

- Efficient use of compost to replenish humus losses from soils;

#### *5.5.1.2 Saltwater Intrusion*

Adaptation options would include:

- Construction of dykes, barrages, storm surge barriers and storm diversion channels;
- Relocation and resettlement of affected people;
- Realignment of transportation routes and nodes;
- Adoption of new or different livelihoods;
- Adoption of new building and other construction technologies.

#### *5.5.1.3 Drought and Desertification*

- Restoration or rehabilitation of overgrazed and irrigated agricultural land;
- Minimization and management of biomass burning especially in the Sudan-Sahel region;
- Minimization of forest and woodland destruction;
- Restoration of degraded forests and woodlands;
- Promoting socio-economic and political sustainable management of the Sudan-Sahel region
- Resettlement.

### 5.5.2 Agriculture

There are many possible adaptation options in agriculture for responding to climate change. They include, among others:

#### *5.5.2.1 Crop production*

- Adaptation by crop choice including:
  - Creation, diversification and study of local vegetation resources in order to find new plant species and varieties that would have higher resistance to anticipated temperature increase and reduced rainfall;
  - Improving local agricultural crop varieties that are well acclimated and drought and pest resistant;
  - Development of varieties and hybrids that would allow separation in time of critical development phases from the limiting environmental factors, particularly rainfall, affecting productivity;

- Adaptation by altering tillage and husbandry through:
  - Use of minimum or zero tillage and other appropriate technologies that would reduce soil erosion and loss of organic matter and nutrients, but increase soil moisture availability to plants and reduce weed and pest infestation.
  - Development and implementation of appropriate hydro and agro-technical systems for accumulation and efficient use of rainfall;

- Adaptation by alteration of input
  - Introduction of new irrigation schemes to dry land management to improve water use efficiency and minimize moisture stress for crops, particularly in the Sudan-Sahel zone where climate change is expected to result in reduced amount of rainfall for rain-fed agriculture;
  - Improved use of fertilizer, including varying the amounts and timing of application and promotion of organic fertilizer to match application to altered pattern of rainfall, avoid pest, weed and disease damage.

- Adaptation by promoting policy-enabling environment through:
  - Adaptation of the natural resources utilization processes in agriculture to sustainable development principles;
  - Creation of socio-economic conditions for profitable agricultural activities;
  - Implementation of medium-to-long term development strategy for industries based on sustainable agricultural principles.

- Linking crop production to meteorological forecast.
  - Meteorological Agency to alert farmers on weather
  - Farmers encouraged to use meteorological forecasts

#### *5.5.2.2 Livestock*

Adaptation strategies in the livestock sector would include:

- Reduction in stocking rates or livestock density;
- Adoption of supplementary feeding;
- Change in mix of grazers or browsers;
- Flexibility in the location of the watering points to promote alteration of animal distribution;
- Restoring degraded areas;
- Increasing rangeland vegetation and/or adapted species;
- Modification of price supports and other government programmes to enable cattle farmers to respond quickly to climate change, for example, through stabilization programmes and subsidies, tariffs and other trade barriers;
- Development of large-scale watershed projects;
- Encouragement in production in the most efficient area by discouraging the use of marginal lands and protecting areas that are degraded;
- Enhancement of veterinary and extension services; and
- Public awareness.

#### *5.5.2.3 Fisheries*

- Change in harvest technology;
- Stocking marine water and contaminated inland water bodies with salt tolerant or hardier fishes
- Expansion of aquaculture production systems;
- Improvement of processing and storage facilities;
- Enforcement of legislation on appropriate and acceptable fishing practices.

### 5.5.3 Water resources

- Modification of existing physical structures (e.g. changing location or height of water intakes; using closed conduits instead of open channels; using artificial recharge to reduce evaporation; raising dam height; adding more turbines; removing sediment from reservoirs for more storage.
- Increasing water supply capacity through construction of new structures (e.g. reservoirs, hydro-plants, delivery systems for inter-basin transfer)
- Alternative management of new structures (e.g. change in operating rules) and integration of water supply systems;
- Promoting water recycling and re-use;
- Development of groundwater supplies;
- Improving efficiency of sources of water already developed;
- Protection of watersheds and reservoir sites through establishment of intensive vegetation cover to minimize evaporation;
- Monitoring ground-water resources;

- Improving on rain-harvesting techniques and construction of rain catchments back-up tanks.

### 5.5.4 Socio-economic sector

#### *5.5.4.1 Economic Base*

- Diversification of Economy

#### *5.5.4.2 Energy*

- Readiness to relocate threatened power generation and transmission facilities;
- Citing new facility development in location that are minimally threatened by sea level rise;
- Vigorous and extensive tree planting for fuelwood and other purposes;
- Physically protect highly sensitive energy production facilities (e.g. oil rigs with physical barriers);
- Develop and enhance utilization of renewable energy resources solar energy.

#### *5.5.4.3 Industry*

- Readiness to relocate to more favourable sites;
- Appropriate location for new industries in view of anticipated sea level rise;
- Development of appropriate mining techniques and industries for transiting climatic conditions.

#### *5.5.4.4 Transport*

- Use of protective devices to shield sensitive equipment from excessive dust and humidity;
- Drainage construction in and around ports in coastal areas;
- Emplacement of storm surge barriers around airports;
- Appropriate choice of sites for airports and motor parks;
- Careful design of highways and railway lines taking into account expected changes in soil moisture changes due to climate change.

#### *5.5.4.5 Health*

- Consistent attack on disease vector population;
- Strengthening the health care delivery system;
- Sustained public awareness on health issues;
- Improved public sanitation and immunization coverage.

### 5.5.5 Coastal areas

- Among the adaptation strategies that could be applied are technical, engineering and structural; biophysical and ecological and non-structural.

- Technical, engineering and structural adaptation responses include the use of protection devices (e.g. dykes, levees, flood walls, sea walls, revetments, and bulkheads, groynes, detached breakwaters, floodgates and tidal barriers, salt-water intrusion barriers) and other soft options such as beach nourishment (beach fill), dune restoration and creation, wetland restoration and creation and afforestation;

- Biophysical and ecological options include modification of land use, changes in planting date, changes in cultivars, application of irrigation, and changes in crop. Others include replacing lost resources, developing of alternative habitat areas, (e.g. creating wetlands and sand dunes), protecting threatened ecosystems, afforestation, stabilizing sand dunes (e.g. by planting vegetation) and adaptation to salt water intrusion (e.g. by preventing salinity increases).

- Non-structural options include retreating from the shore, by (i) limiting development in areas likely to be flooded (ii) allowing for development subject to the requirement that it will eventually be removed (presumed mobility) and (iii) doing nothing about the problems and eventually requiring the developed areas to be abandoned

- Resettlements.

# CHAPTER SIX

# RESEARCH AND SYSTEMATIC OBSERVATION

## 6.1 GLOBAL INITIATIVES IN RESEARCH AND SYSTEMATIC OBSERVATION

In April 1993, an Inter-governmental Meeting on the World Climate Programme (WCP) was organized in Geneva by the World Meteorological Organization (WMO) in co-operation with UN and non-governmental partners. The meeting provided opportunity for governments to review the WCP, established in 1979, in the light of the United Nations Conference on Environment and Development (UNCED) outcome. The meeting adopted four main thrusts for future WCP activities and called for greater integration of efforts with International Geosphere-Biosphere Programme (IGBP) of the International Council for Science (ICSU) and Global Climate Change Programme (GCCP) of the International Social Sciences Council (lSSC). The four main thrusts are (a) Climate services for sustainable development - improved basic data and their applications, (b) New frontiers in climate science prediction - reducing uncertainties about global warming, (c) Dedicated observations of the climate system - planning and implementation of the Global Climate Observation System (GCOS), and (d) Studies of climate impact assessment and response strategies to reduce vulnerability.

## 6.2 NIGERIA'S IMPROVED PROGRAMMES

As a large African country highly vulnerable to flood and erosion as well as drought and desertification which will be exacerbated by climate change, Nigeria took active part in all activities subsequent to that intergovernmental meeting in line with her leadership role in the actualization of the African Centre of Meteorology Application for Development (ACMAD). Since 1996, Nigeria's Department of Meteorological Services, now the Nigerian Meteorological Agency (NIMET) has been engaged in a revolutionary and innovative programme in research and systematic observation.

Although NIMET is charged with systematic observations and analyses for forecasting purposes among others, other agencies and institutes have field experiment stations for their specific needs.
Hydropower Development Department of the National Electric Power Authority (NEPA);

- National Institute for Freshwater Fisheries Research, Kainji, New Bussa;
- National Water Resources Institute for, Kaduna,
- National Space Research and Development Agency (NASRDA), Abuja
- FMEnv.-University Linkage Centre for Climate Change, Minna;
- National Centre for Remote Sensing, Jos
- National Center for Arid Zone Studies, Maiduguri
- Other Universities

### 6.2.1 International Activities In Research And Systematic Observation

Nigeria has been involved through NIMET in activities significant for (a) reducing the magnitude of climate change and/or (b) mitigating the consequences of climate change and sea level rise. In addition to the WMO, other institutions have played significant roles in which

Nigeria has been effectively involved. Many of these institutions in general co-operate with the WMO and its members countries in advancing response measures related to climate change and other climate issues important to Africa. These institutions include ACMAD, and Agricultural and Hydro metrology (AGRHYMET), and HYDRONIGER all with headquarters in Niamey, Niger Republic.

In addition, Nigeria hosts the WMO Regional Meteorological Training Centre and the sub-regional office of the WMO for Region I: Africa. The Training Centre started operations in 1963 and has trained WMO Classes IV to II Meteorologists for many countries in Africa including Senegal, Gambia, Sierra Leone, Ghana and Cameroon, as well as for the Nigeria Air Force. In collaboration with the Federal University of Technology, Akure, Nigeria, the WMO has been providing training for Class I Meteorologists from across the continent.

Nigeria is involved in the World Weather Watch (WWW) and the Global Climate Observation System (GCOS) of the WMO and it has participated in the Ocean and Coastal Areas Programme Activity Centre (OCA/PAC) of the United Nations Environment Programme (UNEP). Unfortunately, the country is yet to evolve its own centrally co-ordinated national climate programmes by taking advantage of the above activities.

### 6.2.2 Local Activities

#### 6.2.2.1 Nigerian Meteorological Agency (NIMET)

Currently, Nigeria depends largely on products from Reading in U.K, Paris in France and the Global Telecommunications System (GTS) for daily weather service. The major problems are inadequate expertise, equipment and funding particularly for modeling and weather prediction. However, the weather broadcasts through television have shown marked improvement in spite of these shortcomings.

Surface synoptic observations are adequate but for meaningful research upper-air data must complement the abundant surface information. It is to be noted that only 3 radio sonde stations and 6 pilot balloon/radar wind stations currently exist in Nigeria. These limited observations are augmented by data from neighboring countries collected through the Geographic Information Systems (GIS), and verification is carried out with products from Europe for forecasting purposes. These will be grossly inadequate if Nigeria is to effectively combat climate change. NIMET has prepared a comprehensive observation and analysis programme calling for increased number of surface synoptic, upper-air pilot balloon and radio sonde stations. These will be complemented by radar and satellite data acquisition, analysis and prediction.

#### 6.2.2..2 National Electric Power Authority (NEPA)

All the hydro and thermal electricity generating stations have mini-meteorological observation posts. These only compile such parameters as temperature, wind, evaporation, radiation and rainfall for record purposes and research on problems that may be weather-related. These include the problem of water elevation, thunderstorms, and high intensity precipitation which is used to determine spill-way operations.

#### 6.2.2.3 National Institute for Freshwater Fisheries Research

This Institute concentrates on survey and monitoring activities with particular emphasis on:

- Provision of biological and socio-economic data for sustainable fisheries development and management
- Data collection on aquatic resources and inland water bodies usually published as reference documents for aquatic resource database for the country
- Monitoring of environmental pollution, parasitic helminthes, and aquatic macrophytic fauna
- Maintenance of documentation library services with emphasis on:
  i. Database on Nigerian fisheries and aquatic sciences.
  ii. Bibliography on Nigerian fisheries and aquatic sciences

#### 6.2.2.4 National Water Resources Institute, Kaduna.

This Institute maintains all the hydro-meteorological sites in Nigeria. It is responsible for collaboration in the HYDRONIGER Project which utilizes satellite data for appraisal of the Niger and Benue Basins.

#### 6.2.2.5 National Space Research and Development Agency (NASRDA)

Government is about to launch two satellite for resource monitoring and communication This will improve the spatial coverage of observations in the country.

#### 6.2.2.6 FMEnv-University Linkage Centre for Climate Change

This is one of the many linkage programmes of the Federal Ministry of Environment. It is charged with:

- National climate data banking
- Research and training in climate analysis and prediction;
- GIS for climate research and freshwater resource studies etc.

The Centre has acquired considerable climatic and meteorological data

#### 6.2.2.7 National Centre for Remote Sensing, Jos

The Centre specializes in natural resources mapping.

#### 6.2.2.8 National Centre for Arid Zone Studies, Maiduguri

The Centre carries out meteorological and landuse research with emphasis on drought and desertification.

## 6.3 CRITICAL AREAS FOR CLIMATE RESEARCH AND PREDICTION

It is necessary to establish and strengthen national climate committees and programmes. Such programmes would, for example, more easily promote activities related to climate monitoring and observation networks, education and training, capacity building, climate research and the development of models, technology transfer and adaptation of technology, development and implementation of impact assessments, improved climate information services and public awareness of applications of climate information. The programmes would also facilitate co-operation, collaboration, and co-ordination at all levels especially with tertiary institutions. In these regards and as a matter of urgency NIMET should, initiate action to collaborate with

Federal Ministry of Science and Technology as well as the NCCC. It is important for Nigeria to continue to support the WCP and UNFCCC, in addition to strengthening links with other programmes such as International Geosphere- Biosphere Programme (IGBP).

The initiatives and research should be geared towards

- applying climate information for national planning and policy making
- improving understanding of climatic processes and ability to predict of climate change as well as human on climate;
- creating an adequate capability for early warning systems;
- establishing capability for mitigation of adverse consequences of climate change

### 6.4 IMPLEMENTATION

Government shall:

(i) Improve the capability of the meteorological satellite receiving facilities at the Airports in Lagos, Kano, Maiduguri, Enugu and Calabar and in addition, establish many more of such facilities;
(ii) Establish radar and radar wind stations at each of the nation's airports;
(iii) Encourage effective collaboration between NIMET and research/educational establishments especially with regard to training of scientists, engineers and technologists;
(iv) Establish and encourage national and international co-operation in climate change studies as a contribution towards mitigating the impact of climate change;
(v) Encourage end-users of meteorological data to invest in capacity building and infrastructural development;
(vi) Encourage the efficient utilization of existing scientific data as input into national development plans; and
(vii) Encourage long-term planning to equip the nation to cope adequately with climate change.

# CHAPTER SEVEN

## SUSTAINABLE DEVELOPMENT AND INTEGRATED PLANNING

### 7.1 INTRODUCTION

Sustainable Development (SD) refers to efforts at improving the socio-economic, political and cultural conditions as well as the environment of the people without jeopardizing the future. Nigeria's National Policy on Environment reflects her subscription to this definition. The policy emphasises development based on a proper management of the environment to meet both present and future needs. Proper management of the environment includes careful assessment of climate change and its impacts on Nigerians and their environment.

As particularly concerns with climate change and its effects, the major problems summarized in the preceding chapters include the following:

- Deforestation
- Flooding
- Drought and desertification
- Inland and coastal erosion
- Degradation of rangelands
- Salt-water intrusion and salinization
- loss of Biodiversity
- Gas flaring
- Population dislocation
- Ill-health
- Infrastructural deterioration.

The major factors responsible for the aforementioned problems are as follows:

- The general inability of the agencies responsible for the environment to enforce laws and regulations, particularly with respect to urban planning and development, prospecting for minerals, adherence to industrial standards, and erection of structures and utilities in ecologically sensitive areas;
- Inappropriate agricultural practices;
- The destruction of watersheds leading to siltation of rivers, soil erosion, and loss of water courses;
- Uncontrolled logging aggravated by lack of re-planting;
- Bush burning and fuelwood extraction;
- Gas flaring and the resultant problems of ecosystem destabilisation, heat stress, acid rain, and their effects on freshwater and aquatic lives;
- Mining without adequate land reclamation;
- Unregulated dumping of toxic and comparable waste materials.

### 7.2 NATIONAL STRATEGIES TO ADDRESS ENVIRONMENTAL PROBLEMS

Much effort has been made at various levels to address the numerous environmental problems already outlined. Of particular interest is the climate change problem. Apart from Nigeria's participation at the pre and post-1992 United Nations Conference on Environment and Development (UNCED) where the Climate Change Convention, among other environmental conventions, were negotiated and eventually signed, the country has evolved national strategies to deal with these problems threatening the existence of humankind. Government efforts and responses to these problems may be classified into five main categories. These are discussed below

#### 7.2.1 Legal and Institutional Policy Framework:

The Federal Environmental Protection Agency (FEPA) was established in 1988 and its mandate was expanded in 1992 to include the overall responsibility for biological diversity conservation and sustainable development of Nigeria's natural resources. The Agency's strategy towards the discharge of its mandate comprises policy formulation, setting of standards, establishment of guidelines and regulations, enlightenment and compliance promotion, monitoring and enforcement of standards, guidelines and regulations. Simultaneously, Environmental Protection Agencies were created in the various states of the Country. The State Environmental Protection Agencies (SEPA) are still being assisted by FMEnv. in the areas of training and infrastructural development.

#### 7.2.2 Capacity Building and Institution Strengthening

The effort was pursued in a number of initiatives on public awareness, training, institution strengthening, infrastructural development, and enhancement of the activities of the environmental non-governmental organisations (NGOs).

#### 7.2.3. Private Initiatives

Just as many communities in Nigeria are directly involved in one or more environmental projects, so also the number of environmental NGOs has been increasing and government has been supporting some of them. This move is partly based on the need for greater private sector involvement in the protection of Nigeria's environment for sustainable development. A number of these organizations have been able to attract some inflow of funds for environmental projects in Nigeria.

#### 7.2.4 Collaboration with International Organisations

In recognition of the importance of co-operation with other nations, the government has ensured collaboration with the international community in the area of environmental protection. Such collaborative efforts have resulted in positive contributions to the development of appropriate policies, legislation, action plans and programmes at regional and international levels. Nigeria has signed and ratified a number of international conventions one of which is UNFCCC.

#### 7.2.5 Financial Support

The Federal Government has been making vigorous effort to provide funding to back up the country's participation in the work of the various organizations and relevant conventions including WMO and UNFCCC. Part of this effort in the past was the creation of an Ecological Fund through which ecological disasters are addressed. Other sources of funding environmental protection activities in the country include funds from crude oil revenue and bilateral and multilateral financial assistance from the World Bank, UNDP, UNEP and other agencies and governments.

## 7.3 SECTORAL CONTRIBUTION TOWARDS SUSTAINABLE DEVELOPMENT

### 7.3.1 Environment Sector

In furtherance of Nigeria's commitment to the implementation of the global Agenda 21, the FMEnv has been empowered to tackle the environmental problems in the country. It remains the focal point for implementating environmental conventions to which Nigeria is a party.

To execute its mandate effectively, the following instruments have been put in place:

- National Policy on Environment (1999);
- National Agenda 21 (1999);
- National Guidelines and Standards for Environmental Pollution Control in Nigeria 1(991);
- National Effluent Limitation Regulation (1991);
- Pollution Abatement in Industries and Facilities Generating Waste Regulations of 1991;
- Waste Management Regulations;
- Environmental Impact Assessment (EIA) Decree No 86 (992);
- National Procedural and Sectoral Guidelines for EIA for Agricultural and Rural Development; Manufacturing and Mining; Oil and Gas and facilities;
- Natural Resources Conservation Action Plan.

### 7.3.2 Agricultural Sector

The National Agricultural Policy was reviewed to include the first National Policy on Integrated Rural Development and its Implementation Strategy. This places emphasis on the need for EIA of the various agricultural and freshwater resources development projects.

### 7.3.3 Energy Sector

In order to strengthen the institutional framework to promote sustainable energy development, Nigeria has established several Ministries and some parastatals with policy and planning responsibilities on energy matters. These are Ministries of Petroleum Resources; Power and Steel; Solid Mineral Development, and Science and Technology. The relevant parastatals under the Ministries includes Nigeria National Petroleum Corporation (NNPC), National Electric Power Authority (NEPA), Nigerian Coal Corporation (NCC), Nigeria Nuclear Regulatory Authority (NNRA) and Energy Commission of Nigeria

Apart from institutional development, government has taken certain measures to ensure sustainable energy consumption. For instance, government has removed petroleum subsidy and is seriously considering the privatisation of oil refining and the marketing liquefied natural gas. The National Energy Policy Act has been passed. While NEPA is being considered for privatisation, inventory of potential hydro-electric power stations that would boost the use of environment-friendly energy sources is being undertaken.

Government has established several thermal stations and is planning for more, to supplement the existing power generation.

## 7.4 COORDINATING ROLE OF FEDERAL MINISTRY OF ENVIRONMENT

### 7.4.1 Inter-ministerial Committee on Climate Change

Prior to the establishment of the Federal Ministry of Environment consultations with relevant government agencies and NGOs were undertaken by FEPA. The relevant line organizations as well as representatives of the academia and NGOs were constituted into the Inter-ministerial Committee on Climate Change (ICCC). This committee advises government on issues relating to climate change. The ICCC consists of representatives from:

i. Federal Ministry of Agriculture
ii. Federal Ministry of Water Resources
iii. Federal Ministry of Finance
iv. Federal Ministry of Industry
v. Federal Ministry of Justices
vi. Ministry of Petroleum Resources
vii. Ministry of Foreign Affairs
viii. Nigerian Meteorological Agency
ix. National Planning Commission
x. Energy Commission of Nigeria
xi. National Electric Power Authority

### 7.4.2 National Committee on Climate Change

The Composition of the National Committee on Climate Change (NCCC) differs only a little from that of the ICCC in that NCCC includes private sector and more of academia and Non-Governmental Organisations. The NCCC functions as the supervising body for the preparation of technical documents including Nigeria's first national communication for the implementation of the Climate Change Convention. Memberships of Government organizations in the NCCC are drawn from:

i. Ministry of Finance
ii. Ministry of Foreign Affairs
iii. Ministry of Petroleum Resources
iv. Nigeria Meteorological Agency
v. Energy Commission of Nigeria
vi National Planning Commission

### 7.4.3 Creation of Programmes for Education and Awareness

Article 6 of the UNFCCC is unequivocal regarding the importance of education, training and awareness creation in the implementation of the convention. The Article requires Parties to the Convention to promote and facilitate the development and implementation of educational and public awareness programmes on climate change and its impacts. This is in recognition of the fact that a larger percentage of people in the developing countries have little or no knowledge about climate change and the magnitude of its impacts. Education, training and awareness raising should constitute integral parts of the implementation of the Convention.

In general, the public information and education programmes would

- promote awareness and knowledge of climate change issues;
- provide guidance for positive practices to limit and/or adapt to climate change; and
- encourage wide participation of all population sectors in addressing climate change issues and developing appropriate adaptation strategies.

A number of national and international actions are necessary for disseminating information on climate change. For example, it would be necessary to establish national committees to collate develop and disseminate educational materials on climate change issues. These committees would serve as focal points for information gathering and dissemination. At the tertiary education level, efforts shall be geared towards the inclusion of the subject of climate in the General Studies programmes. In this regard, institutions which already have programmes on climate shall be encouraged to strengthen such courses by providing for deeper focus on climate change. Topics on climate change shall be included in such subjects as Social Studies and Geography at the secondary school level. At the same time, secondary schools shall be actively encouraged to form Nature Clubs and Conservation Societies and embark on environmental awareness campaigns. Similarly, in primary schools the syllabus should be expanded to include topics on climate change and its impacts. The pupils can also engage in environmental sensitization activities including excursions. Among the items to be included for instruction at various educational levels are the following:

- Nature of weather and climate
- Role of weather and climate in human affairs
- Nature of climate change
- Hazards and general effects of climate change
- Adaptation and adjustment to climate change

For the public at large, seminars, workshops, and informal discussions will be organized towards enlightenment and awareness creation. Information, Education and Communication (IEC) materials such as posters, leaflets, stickers and face caps shall be developed for public education. It is heartening that some Nigerian dailies have been devoting space in their magazines to environmental issues just as the FMEnv publishes a magazine titled *Environment News.* These media need to be encouraged to focus more on climate change issues. It is necessary also that policy makers shall be adequately sensitized and made knowledgeable about climate change issues.

At the policy level, several cross-sectoral organizations, both government and non-governmental have been co-opted into ICCC and NCCC. While the former is responsible for advising Nigerian government on policy issues regarding negotiation and implementation of Climate Change, the later coordinates activities towards the preparation of the National Communication on climate change.

## 7.5 STRATEGIES TO INTEGRATE CLIMATE CHANGE CONCERNS INTO THE NATIONAL DEVELOPMENT PLANS

### 7.5.1. Vision 2010

Further recognition of the importance of sustainable socio-economic development led the Federal Government of Nigeria to set up in 1996 a Committee that prepared the "Vision 2010 Report". Generally, the objective of Vision 2010 is to move the nation forward towards political stability, economic prosperity and social harmony. Within the broader context, the vision for the environment is to have a safe and healthy environment that secures the economic and social well-being of the present and future generations.

Vision 2010 recognized the problem of climate change and ozone layer depletion as being driven by the increased concentrations of atmospheric warming gases (the greenhouse gases) especially carbon dioxide. One of the objectives to be pursued under the programme with particular reference to climate change is forest protection whereby the forest reserves are increased from the present 10% to 25% of the total area of the country by the year 2010. Another effort by the programme will involve attaining full compliance with pollution control standards in industries, motor vehicles, aircraft and generating plants in addition to the elimination of gas flaring. While the increase in forest cover is partly to serve as a sink for $CO_2$, improved technologies are expected to reduce emissions of GHGs from all identified sources. Specifically, the Vision 2010 is to ensure that:

- The air is virtually free of pollutants and dangerous gases with total elimination of gas flaring by the year 2008;
- The rivers, seas and coastal areas are virtually free of oil spillage;
- Natural habitats of wildlife and plants are well conserved;
- Vegetation and soil are relatively free of gully erosion;
- Desertification and flooding are minimized, and
- Cities are well planned and free of industrial and municipal wastes.

### 7.5.2 National Agenda 21

Nigeria has embarked on the formulation of a national Agenda 21 with support from UNDP. The National Agenda 21 seeks to integrate environmental concerns into development planning, sectoral policies and decision making process. The strategy for achieving this important objective will necessarily:

- Incorporate environmental costs in the decisions of producers and consumers so as to reverse the tendency to treat the environment as a 'free good' and to stop passing these costs on to other sections of society or to future generations;

- Factor negative social and environmental externalities into economic activities so that prices will appropriately reflect the true and total value of resources and contribute towards the prevention of environmental degradation;

- Include, wherever appropriate, the use of market prices in the framing of economic instruments and policies;

- Intensify monitoring of GHGs from various sources;

- Develop and implement a mechanism for charging emission fees and fines, “Polluters Pay Principle”; and

- Provide incentives to industries and establishments adopting environmentally cleaner technologies.

# CHAPTER EIGHT

## PROPOSED PROJECT CONCEPTS FOR CLIMATE CHANGE STUDIES

In the course of undertaking the studies presented in this document, certain gaps were identified. These gaps need to be filled in order to enhance the quality of the second national communication. Towards this end, some project concepts have been identified and briefly developed. In this Chapter, brief presentation of the proposals is made pending the submission of detailed ones.

***PROJECT 1:*** **Satellite Remote Sensing Determination of Vegetation Loading and Land use Change between 1995 and 2005 as Influenced by Human Activities and Biomass Burning.**

***Introduction:***
It is generally known that Nigeria's forest estate has decreased from about 60million hectares (mha) to approximately 9.6 mha during the 20$^{th}$ century. However not much data exist on annual evolution of landuse types in the different geographical zones of Nigeria, the biomass stocks in them, including above and below ground biomass, annual biomass growth rates, biomass harvests and biomass burning in different parts of the country. The current data are from World Resources Institute (WRI), Food and Agriculture Organisation (FAO) and recent remote sensing study of the forest and savanna zones of Nigeria (FORMECU, 1996). The study provided the best estimate of landuse change in Nigeria, comparing the 1976/78 landuse classes with the 1993/95 vegetation and land use classes on comparative scales. However, even this data set is already close to 10 years old and needs update and re-validation. For improved estimates of GHG emissions from LULUCF, the areas of need, likely to reduce current high uncertainties include the determination of:

- Annual growths and carbon uptake in different forests and savanna zones to complement IPCC data.
- Extent of biomass harvest and the fraction burnt in the field.
- Forest conversion to agricultural and other land use types, and
- Abandonment of managed lands.

Other sub-sectors, related to landuse change with substantial improvement in the activity data include data on:

- Livestock population, wastes and management techniques
- Rice cultivation by type and by state (totally flooded, seasonally flooded and non-flooded)
- Total land area of each savanna zone and the fraction of savanna burnt annually, complemented by biomass loading of each savanna zone, including above ground and below ground biomass and soil carbon and nitrogen stock.
- Fertilizer consumption (nitrogen fertilizers) in different parts of the country and by type of crop farming.
- Field burning of crop wastes especially waste to crop ratios for all crop types in Nigeria and actual crop production needs.

***Objectives:***
Satellite remote sensing remains the most viable tool to improve the current poor data in the land use change and agriculture sectors. The main aim of the project is to use the satellite remote sensing tool to provide new data and update existing ones so that the uncertainties in future GHG inventories could be reduced.

***Project Duration:*** 3 years (2004 to 2006).

***PROJECT 2:*** **Audit of Downstream Energy Sector Technologies, Fuel Consumption and Projected Demand Side Analysis for the Downstream Sector**

***Introduction:***
Substantial gaps exist in the database of both the emission inventories and mitigation analyses. For instance, in the downstream energy sector, data are obtained from NNPC Annual Reports, FOS Annual Abstracts of Statistics, among others reports. These reports are lacking in respect sectoral energy consumption, which is necessary for emission inventories. The basic downstream petroleum products consumption data currently lacking include:

- Gasoline consumption by road transport and other transport sectors,
- Diesel consumption by road transport and other transport sectors
- Coal consumption by rail transport, households and industries.
- Diesel and fuel oil consumption by industries.
- Diesel and gasoline consumption for power generation in industries.
- Diesel and gasoline consumption by private electric generators.
- Diesel consumption by off-road transport sectors, forestry and agriculture.
- Energy consumption by public and business sector enterprises, including hotels, schools and other institutions.
- The partition in the consumption of aviation fuel between local and international aviation.
- Consumption of bunker fuels.

Similar gaps in the database are observed in all other emission relevant sectors such as upstream energy sector, industries, agriculture, landuse change and wastes management. The back-up statistics which could have made the estimation of petroleum products consumption in the downstream sectors possible are also currently weak. For instance, there are no annual statistics on the total number of vehicles in Nigeria. The aircraft fleet and their fuel consumption capacities and annual flying hours could have been used to evaluate fuel consumption from domestic and international aviation. However, such data are yet to become accessible. In addition, the industrial consumption of petroleum products could have been inferred if energy consumption per unit production in various industrial sectors were available. This means that efforts are to be made in the next few years to build up these statistics to support more accurate estimates of downstream energy sector fuel consumption.

**Objectives:**
The objective of this project is to undertake field surveys to provide data for energy consumption in the downstream energy sector. The surveys will involve development and administration of

questionnaires as well as actual field estimate (vehicle counts, survey of vehicle fuel consumption, survey of fuel consumption in public sector and institutions, among others). This information will be used to develop demand-side energy consumption data. The study will cover all major downstream energy sectors: road, rail, internal navigation, domestic and military aviation, industrial heat generation, industrial and, private electricity generation, public and business sector energy consumption, etc.

**Project Duration:** 2 Years: 2004 to 2005

***PROJECT 3:*** **Development of National Emissions Data Systems (NEDS*)***

There is currently no formal institution mandated with the task of developing and reporting of GHG emissions and mitigation options for Nigeria. The development of and implementation of a National Emissions Data Systems (NEDS) is part of the framework to ensure the availability of an institutional framework for data collection and archiving to support emissions inventories and mitigation assessment options. The NEDS is needed to make emission inventory data available to different levels of stakeholders electronically, probably using the Internet, and would serve as the link between scientists and policy makers on emissions and mitigation options assessment. It would also partly be mandated to provide sustainable data collection and streamlining of data collection process needed to ensure uninterrupted collection and processing for inventories and mitigation analysis. Such a process may be achieved by bringing relevant sources of national data together as stakeholders in emission inventories and mitigation analysis exercise in a way that would provide unrestricted access to raw data files of the archives of these important national data banks. The agencies currently considered relevant include the Department of Petroleum Resources (DPR), Federal Office of Statistics (FOS), Manufacturers Association of Nigeria (MAN), Departments of Forestry, Livestock, and Waste Management Agencies at national and state levels. Such access will enable re-processing of raw data to present them in format acceptable by emission inventory models.

***Objectives:***
The objective of this project is to develop and implement an institutional framework which would support the sustainable evolution and implementation of NEDS under the Federal Ministry of Environment. A suitable R&D institution with capability in GHG inventories and mitigation options is to be identified and tasked with the following:

(a) Development of linkages with major database networks within the country for purposes of providing inputs to emission inventories and mitigation assessment routinely.
(b) Periodic review of GHG emissions and mitigation options for all IPCC recognized sectors.
(c) Development and implementation of an institutional framework to support the operation of NEDS could operate with mandate to provide data needed for research and national planning.
(d) Development and implementation of a emissions data systems, which would be available either on the internet or LAN, to link various users of GHG inventory and available mitigation options.
(e) Nation-wide capacity development on various aspects of emissions inventories: emission measurements, process modeling, database development, inventory spreadsheets development, etc.

**Project Duration**: 2 Years (2004 to 2005) to support establishment and preliminary implementation of NEDS.

***PROJECT 4:*** **Technology Characterization Inventory to Support the Development of Technology Baselines and Options GHG Emission Reduction in Nigeria**

Technology plays and will continue to play a major role in development. The current efforts at providing mitigation to GHG emissions in various sectors require substantial knowledge of the technology base from which these sectors are currently operation. Such a technology characterization inventory (TCI) has never been carried out in Nigeria, even though mitigation options assessment are being carried out.

***Objectives:***
The objective of this project is to undertake a TCI for all relevant sectors and for small, medium and large scale sectors. The specific objectives shall include to:

- Establish the current (business as usual) technologies in operation, the levels of efficiency and maintenance for these technologies.
- Future technology needs to improve energy supply and utilization efficiencies, industrial and other process efficiencies to ensure that emissions into the atmosphere are minimized.
- Human capacity and other institutional capacity development needs to assist in the development, adaptation and implementation of proposed new technologies.

***Project Duration:*** 2 Years (2004 to 2005)

***PROJECT 5:*** **Audit of Source Strengths for Solvents and Other Chemicals Use in Nigeria**

The solvents are other chemicals use is one of the sectors recognized by IPCC as contributing to GHG emissions. For Nigeria, there is hardly any data on solvents use. These include data on various paints applications, use of various organic and inorganic chemicals are volatile, especially the consumption of dry cleaning chemicals. Extensive field data collection is needed to support these.

***Objectives:***
The objective of this project is to develop a programme for field surveys of the various sub-components of solvents and other products use in Nigeria and to be able to quantify their contribution to GHG emissions.

***Project Duration:*** 1 Year (2004 or 2005)

***PROJECT 6*: The Assessment of CH4 Emissions from Leak Facilities in the Upstream Oil and Gas Sector and Options for Reduction**

The oil and gas industry has in the last 30 years served as the main support for the Nigerian economy. This has been because, crude oil export during the period contributed more than 90% of the country's gross export earnings. Despite the enormous positive impact on the economy, national and world attention has become recently focused on the high degree of perceived environmental degradation of the Niger Delta. Such assessment has principally been driven by sharp practices such as gas flaring, oil spillage, land use change induced by oil and gas exploitation activities, and other agents of global change. The government of the Federal Republic of Nigeria has placed a dateline for all oil/gas producing companies to eliminate gas flaring by the year 2010. With this dateline, it is most likely that pipeline leakage emissions may remain the single most significant source of methane, and a substantial contributor to non-methane volatile organic compounds in the country. The control pipeline leak associated methane ($CH_4$) and non-methane volatile organic compounds (NMVOC) emission, has thus become an issue of high priority in the action plans and programs to reduce greenhouse gas emissions and the future potential impacts of climate change in Nigeria. This is especially so when considered along-side other important benefits such as improved ambient air quality, safe and efficient management of natural gas facilities in the Niger Delta.

**Project Rationale:** Nigeria operates both on-shore and offshore oil and gas production facilities. These involve enormous gas pipeline infrastructure, from oil wells to gas utilities. Nigeria, in addition, has a large array of investment in petroleum refining, petrochemical, liquefied natural gas industry, condensate extraction and refining, etc, which all have high potential for $CH_4$ and NMVOC emission. Greenhouse gases (GHG) emissions (e.g. $CH_4$) and their precursors (e.g. NMVOC) are known to be associated with fugitive processes in energy (especially oil and gas) production, transportation, storage, and distribution systems. In 1990, the gross national emissions of $CH_4$, NMVOC and $CO_2$ from fugitive processes in the energy sector were summarised to be 55.81 Tg $CO_2$ (mainly from gas flaring), 964 Gg $CH_4$ and 210 Gg NMVOC. Oil and gas systems are responsible for more than 99% of the fugitive $CH_4$ emissions. The current estimates of $CH_4$ and NMVOC from oil and gas pipeline fugitive sources are expected to have high level of uncertainties which arise from the high uncertainties in the estimates of the population and emission factors of leak inducing modules. The major factors responsible for the high uncertainties in the estimate of $CH_4$ and NMVOC emissions from the oil and gas sector in Nigeria are:

- Lack of data on the population of installed leak modules (valves, pneumatic systems, pressure relief systems, etc) and their population in the different aspects of the industry operations.
- Lack of data on the systematic maintenance or replacement of these leak modules.
- The leak rates or emission factors associated with each leak module and how these may be affected by operational practice associated with the day to day systems operations and maintenance.

As a result of such a high level of uncertainty, it becomes very difficult to use the currently available data to proffer mitigation options or action plans for the control of fugitive emissions associated with pipeline leakage in the oil and gas sector in Nigeria. This project is therefore conceived based on the need to provide the necessary database for which the control of fugitive $CH_4$ and NMVOC emissions in the upstream oil and gas sector is to be provided. The Nigerian National Petroleum Corporation (NNPC) and the operating oil and gas companies in Nigeria are at the moment committed to the elimination of gas flaring in Nigeria by 2010. Hence substantial financial investment is being borne by the government which are of direct benefit to climate change mitigation.

The Government of the Federal Republic of Nigeria is seeking GEF assistance in this project on full cost basis, as the full incremental costs for abatement. This will ensure that the reduction in CH4 and NMVOC emissions from pipeline leak modules are carried out along-side with the gas flare elimination scheme in Nigeria, being planned for execution between now and the year 2010, thereby optimising its global benefits.

**Objective**

In this regard, the main objectives of this study are as follows:

- The determination of the components leading to fugitive emissions in the oil and gas sector in Nigeria, and the contribution of each generic components to the overall methane emission in the sector.
- The assessment of the maintenance requirement needed to reduce future methane emissions to minimal levels..
- The assessment of the adequacy of trained technical and managerial manpower capable of managing the maintenance of these systems in order that leak emissions are minimised.
- Based on the fore-going, the determination of leakage emissions associated with oil and gas production and utilisation in Nigeria

The determination of the mitigation options needed to reduce these emissions to minimal levels.

**Expected Outcomes**:

The project is expected to provide data needed for accurate estimates of fugitive emissions from pipelines and other modules in the oil and gas sector. These include the population of leak-related modules and the estimated emission factors for each generic module. This database is required for efficient and effective control of methane emissions and non-methane VOC emissions (which are GHG precursors). Based on the data primary emissions database, the project will evaluate and model the cost-effective options for managing emissions leak related emissions from oil and gas facilities through effective maintenance and local technical and managerial capacity building. By its implementation, the reduction in greenhouse gases emissions is expected. It will equally improve environmental quality and safety through a more secure pipeline operation.

***PROJECT 7:*** **Baseline Data Analysis for Risk Assessment of Impacts of Flood and Drought given climate change scenario in Nigeria.**

**Project Rationale**:

Flood and Drought are considered the greatest challenge facing Nigeria as a result of climate change in the 21st Century [Obasi, 2000]. The IPCC has continued to amplify this for all developing countries stating that:

> "Serious impacts will be experienced in relation to flood and drought at regional levels as a result of changes in weather associated with climate especially developing countries" [Watson, 2001].

Although studies on flood and Drought in Nigeria have confirmed their increasing intensity [albeit aperiodic in nature] within the past three decades, Risk Assessments have been speculative – falling short of IPCC required methodologies due to lack of baseline Data on losses of life, properties and production base (agricultural land recourses and animal habitats).

The 1999 Nationwide flood in the country was devastating and losses to the Gross National Product (GNP) were estimated to be about 4% (Adefolalu et al, 2001). There was, however no 'bench-mark' data for 'reference' as prescribed by the IPCC while the causative aspects with respect to spatial flood types [sheet flow in the north in contrast to coastal inundation in the marine environment in the south] need more specific categorization or classification to be at the same level of quantification as Sea Level Rise [SLR] scenarios and respective Risks.

The literature is overflowing with data and analysis on special aberrations on water and air-borne diseases which will increase under more severe flood and Drought, respectively. Erosion – induced soil degradation will render all flood security measures (through better and higher production) ineffective. Poverty, which is linked to increasing malnutrition and health problem, will thus be difficult, if not impossible, to ERADICATE. All these make Baseline Data and analysis expedient in order to avert economic recession by changing the endemic 'Business As Usual' approach which, in the case of Nigeria, is 'INTERVENTION AFTER DISASTERS'. Government at all levels in the country will have the requisite information for pro-active measures to reduce losses while EARLY WARNING SYSTEM (EWS) will reduce the risk to which people and the Geo- Environment are subjected presently.

**Objectives:**
The studies proposed will aim at:

i. Providing specific Baseline Data for Risk Assessment on Flood and Drought in Nigeria;
ii. Delineating States (parts thereof), or geographical / Ecological zones prone to Flood and Drought with emphasis on flood /Drought types;
iii. Quantifying the Risk levels of the different flood or Drought prone zones in order to assess the type (s) of intervention (local or international) required for adaptation.

**Expected Outcomes**

(i) Data Bank for GIS Products on Risk Assessment and Early Warning System on Flood, Erosion
(ii) Vulnerability Assessment of Specific disorders including Groups (and levels) of
  - People at Risk
  - Capital values at Risk
  - Subsistence Values at Risk

(iii) Protection / Adaptation cost on Socio – Economic and Ecological values at loss / Risk
(iv) Cultural / Agricultural / Land Resources at loss / Risk for Adaptation measures.

**Expected Project Duration**: 15 months.

***PROJECT 8*:** **Modeling and Verification of Severe storms (cyclonic depressions) in the Niger Delta, Nigeria.**

**Project Rationale:**
The Niger Delta Development Commission (NDDC) has mandate to carry out development Projects identified to be a fallout from Environmental degradation in the oil producing areas of Nigeria. This is to be carried out in close collaboration with multi – nationals.

But it is important that activities include, in addition to man – induced disasters such as oil spillage, gas flaring resulting in general Biodiversity degradation, Natural Disasters such as climate change effects: Sea Level Rise (SLR) and severe storms that will develop due to higher Sea Surface Temperatures (SST).

The NDDC can only take the latter disasters 'on-board' at planning stage if it is in possession of scientifically sound 'proof' of imminent development of such severe weather events, that the present study aims at quantifying.

Hitherto, line squalls (moving belts of thunderstorms) have been a normal seasonal weather phenomena in Southern Nigeria between March and October. These systems usually move in from the Cameroon mountains and die out at sea due to low SST which suppresses convection, especially at the peak of the Summer Monsoon in August when SST used to be as low as 22 – $24^0$C.

Local storms also originate off the Delta over the Atlantic in early afternoon and move inlands as showers which are usually short lived. But with SSTs now approaching the $T_{critical}$ $27^0$ – $28^0$C for triggering severe cyclonic weather events like Tornadoes, the 'picture' of mild to moderate disasters associated with thunderstorms will change. The extent of impact of such a 'change' needs to be quantified so that the socio-economic disorders in the oil sector – the single most important revenue source of Nigeria now can be 'averted' in advance.

Nigeria's GNP is made up of 95% crude oil revenue and 5% from all other sources combined (Agriculture, Taxes, Import Duties etc.) The country's economy is thus most vulnerable to impact of climate change in relation to tornado-type storms that could destroy all the infrastructure used in Oil Drilling. With all States and the NDDC relying mainly on revenue sharing accruing from oil, the damage to 'grass root' activities will be colossal if such storms strike without warning and adequate adaptation measures are not put in place!.

**Objectives**
With a lead time of no more than 2 –5 years before the $T_{critical}$ of $27^0$ – $28^0$C is reached for these Tornado – type storms to start wrecking havoc in the Delta area, it is expedient to carry out this study so that advisories can be issued to Governments and their Agencies and adaptation measures put in place (a priori) of storm occurrence. Measures are in place ahead of seasonal severe storms.

Specifically, the study shall aim at the following:
(i) Design empirical and numerical models occurrence of tornado – type storms in the Niger Delta based on $T_{critical}$ Scenarios using SST values.

(ii) Predict (a head in time) the possible incidence of such tornado - type storms.

(iii) Provide advisories on the outcome of (i) and (ii) above.
(iv) Suggest adaptation measures to curb or reduce losses including socio-economic values at loss / Risk (people, Capital value, Wetland / Land Resources, Biodiversity etc.

**Expected Outcome**

(v) Empirical and numerical model results to determine level of susceptibility of the Niger Delta to storm surges of tornado origin.

(vi) Estimation of socio-economic disorders (people/capital; value/national resources at/risk) and adaptation measures to be recommended.

**Expected Project Duration**: About 12months

***PROJECT 9***: **GCM Climate Modeling of Temperature/ Precipitation and Crop Yield relationship for Food Security.**

**Project Rationale**

Studies on Crop failure that may be climate – induced is on- going on the possibility of large scale food shortage – especially cereals and other grains in drought prone areas like Nigeria. GCM Models used on experimental (pilot) scale using Data for two locations (Kano and Port Harcourt) are inconclusive with doubled $Co_2$ adopted in GISS, UKMO and GFDL models.

IPCC strongly recommends involvement of developing countries in taking pro-active action on Food Security based on GCM models adapted for regional application. Nigeria, being one of the most vulnerable countries (in tropical Africa) to climate – related crop failures due to its high population growth rate, Ecological and socio-economic 'disorders' should embrace the High – Tech approach for assessing the impact of climate change in the Agricultural sector.

**Objectives**

i) Simulate Temperature and Precipitation regimes under doubled $CO_2$ [ Extreme Warming above 1990 base – line level);
ii) Apply GCM models [GISS, UKMO, GFDL) tested in other tropical environments for simulation of crop- climate relationship under normal (1961 – 90) and climate change scenarios to predict crop yield especially cereals and tubers.
iii) Provide long – term Food Early Warning for the 21$^{st}$ Century (in decadal stages).

**Expected Outcome**

The immediate outputs of the project will include the following:

(i) Predictions of Crop yield under normal and doubled $CO_2$ scenarios for formulation of FOOD SECURITY Policies through Early Warning.
(ii) Identification of crops that are most vulnerable in terms of poor yield and low quality under extreme climate conditions.
(iii) Determination of the most appropriate GCM models for operational use in Nigeria 'quick – look'.
(iv) Software, easy- to – use for algorithms simple applications in field operations where there is no direct access to mainframe systems.

**Expected Project Duration**: 12 months.

***PROJECT 10*: Creation of Public Awareness on Climate Change.**

**Project Rationale**

Climate Change as a result of human activities will have a devastating effect on land and life in Nigeria. With the variations being experienced in climatic conditions, there have been signs of adverse impacts of these changes. Temperatures are already rising with negative effects on health, agricultural production, water resources and other socio-economic sectors. It is therefore necessary to create awareness on (a) the need to reduce the emissions of GHGs, which are responsible for climate change and (b) the need to implement adaptation measures for reducing the adverse consequences of the impacts of climate change.

**Objectives**

The general objective of the awareness is to sensitize the general public to integrate measures in their programmes to reduce the emission of the GHGs and, where necessary, to co-operate on adaptation measures for the impacts of climate change. Specific objectives include

(a) making the public aware of the dangers of uncontrolled emission of GHGs

(b) assisting the public to identify the sources of emission of GHGs

(c) developing teaching and learning materials in the field of climate change for educational institutions

(d) promoting informal education stakeholders.

**Expected Outputs**

- A public well informed about the dangers of emission of GHGs emission and necessary for adaptation measures
- Teaching/Learning materials on climate change
- Effective teaching of climate change related issues in educational institution

***PROJECT 11:* Improving the Quality of Meteorological Data for Climate Change Impact and Application Studies**

**Project Rationale**

Data collection and archiving are faced with a lot of problems most of which the country has been unable to solve due to lack of, or inadequate, facilities including instrumentation, technological development, trained personnel and infrastructures. There is paucity of data on the commonly measured meteorological elements (e.g. rainfall, temperature, etc) and there are minimal data on such parameters such as radiation, humidity and wind. Since the mid-1990s, satellites have been used to monitor meteorological systems, but the data collected have not been stored because of lack of storage facilities.

**Objectives**

The main objective of the project is to improve the availability and quality of meteorological data in Nigeria. Specific objectives include

(a) Increasing the number stations used for collecting the data to meet the World Meteorological Organization (WMO) standards

(b) Increase the quantity and quality weather measuring instruments

(c) Adopting modern state –of - earth technologies for data collection and management

(d) Improving the quality of personnel in NIMET and some other institutions that collect meteorological data

**Project Duration: 24 months. (Some details of this include)**

(a) Survey of infrastructure, equipment and personnel needs of NIMET
(b) Needs assessment of other institutions and Agencies
(c) Acquisition and installation of equipment
(d) Manpower development with emphasis on technical training

**Expected Outputs:**

(a) Equipments acquired and installed
(b) Improved number of skilled personnel
(c) enhanced quality and quantity of meteorological records
(d)Improved meteorological database management systems (DBMS)

***PROJECT 12*: Climate Change Impacts and Vulnerability Assessment in the Sudan-Sahel Region**

**Project Rationale**

All countries in the Sudan-Sahel regions have been adversely affected by climatic variability and changes as well as climatic events. Especially during the past three or four decades, the Sudan – Sahel region have been a centre of worry and disturbing concern especially because of the impacts of droughts and desertification. It has also been a region where greater focus and attention have been given on the need to find solutions to the problems of environmental crisis caused by climatic variability and climatic events, (especially droughts and desertification, soil erosion and other such consequences of climatic variations and variability) . The impacts of these climatic variability and climatic changes have led to the decline in resources potential in the region and have generated a chain of connecting events such as food shortages, famine, malnutrition, death and mass migration. The impacts are socially disruptive and the political fallouts have been considerable. Based on the current knowledge and evaluation of the possible impacts of the projected climate change, these problems of environmental crisis may be aggravated.

**Objectives**

The main objectives of the project is to study the impacts of climate change on physical and socio-economic sectors of the Sudan – Sahel region, (with particular reference to agriculture and water resources) and put forward adaptation strategies for reducing the probable impacts of climate change. Specific objectives of the study include (a) To assess the potential impacts of climate change on agricultural production (b) To assess the potential impacts of climate change on surface and groundwater resources (c) To assess the impacts of climate change on water quality and how it can affect the water supply-demand systems (d) To evaluate the impacts of climate change on domestic, industrial, agricultural and other avenues of water demands (e) To evaluate water supply-demand systems and project the water balance (surplus or deficits) in the region based on implications of climate change on population and various socio-economic factors

**Project Duration:** 24 Months

**Expected Output:**
(a) Estimates of quantity and quantity of surface and groundwater resources in the Sudan – Sahel region of Nigeria (the estimates will also be carried out for the various states in the region)
(b) Vulnerability analysis of the climate change impacts on the study region but specifically on agriculture and water resources sectors
(c) Projection of water resources supply and demand as well as water balance characteristics based on water supply and demand in the region (d) Specific adaptation strategies for implementation in the region

***PROJECT 13:*** **Improving Efficiency of Transport System in Nigeria**

**Project Rationale:**
The Transport System in Nigeria presents a major problem for environmental and socio-economic development in the country. In particular, about 98% of the passenger travel in the country is by road, the other modes of transport forming only about 2 per cent. Unfortunately, the road transport system is very inefficient with the bulk of the transport consisting of small vehicles and private cars. In the urban centres, the situation is worsened by the centralization of commercial activities in the heart of the cities, especially the Central Business District (CBD). This situation causes heavy traffic congestion usually leading to "near impossible" movement in such cities as Lagos, Port Harcourt, Kano and Abuja. This has led to the urgent need to improve the efficiency of the transport system especially in the urban centres.

**Objectives:**
The main aim of the project is to improve the quality of the environment through the reduction of the number of the road transport vehicles in particular corridors, and decongest city centres of commercial activities. Specific objectives include: (a) To study the purpose of journeys and relate this to the density of road transport (b) To study the level of gas emissions of the various classes of vehicles (c) To examine the possibilities of reduction or change in the travel modes to modes that are more environmentally friendly (including (i) those modes with reduced exhaust emissions and (ii) those that would reduce transport congestion in the cities) (d) to assist in the formulation of policies towards the improvement of mass public transport system (e) To examine the possibility of the use of other modes of transport for both inter and intra city travels (f) To

examine the possibility and ways of reducing the use of small private vehicles and their replacement by efficient traffic management measures

**Project Duration**: 15 months. Some details of the activities to be performed include

(a) Preliminary Meetings and Surveys (Reconnaissance) – One month
(b) Main Survey (including data collection) – Six months (three months in the rainy season and three months in the dry season)
(c) Data analysis – Two months
(d) Report writing – Two months

**Expected Output:**
(a) Reduction in the level of exhaust emissions (b) Use of alternative modes of transport such as rail for mass transit and freight (c) efficient transport system (d) Evolution of various traffic management measures to encourage public transport use as against the use of small road transport vehicles (e) Reduction in the use of fuel which in turn will lead to reduction in emission of GHG (f) Improvement in Transport efficiency, which will transmit to efficient running of the economy, reduced costs and improvement in the economy through the distributive sector.

***PROJECT 14*:** **Climate Change and Assessment of pollution – related health hazards in Livestock**

**Project Rationale:**
Although changes in climate affect existing systems adversely, some systems for which adaptation is possible may benefit greatly from these changes. Climate change is also assessed in terms of economic development, which may make some countries more Vulnerable to climate change, for example, countries like Nigeria, which do not manage their natural resources properly and have high population growth rates, may be more vulnerable to potential changes in relation to environmental degradation – the basic cause of dust population. The dust in Nigeria may be ‘carcinogenic’ due to the presence of residues of chemical additives (in soils) to enhance or increase crop yield. Thus, livestock may be liable to epidemics which could be fatal under present trends of climate change when the Harmattan Season is synonymous with extremely cold nights and very hot dusty afternoon.

The resurgence of vector – borne disease and highly lethal gaseous effluents in the air may be as a result of climate change which could prove economically disastrous in a ‘Low Tech’ environment like Nigeria if advanced countries like Great Britain could be ‘Caught napping’ by the Foot – and – Mouth Epidemics that devastated the livestock Industry in 2000 / 2001 in that country resulting in the slaughtering of over 10million heads of cattle. It occurred in association with unprecedented rain events – the heaviest in more than 100years as clear evidence of Impact of Climate Change. Only recently [May 2002], Germany also had to kill about one million chickens after discovering that they have been infected with a mysterious virus.

These events indicate that, if advanced economies after doing all possible could not avert these catastrophes, it is expedient that in Weaker, evolving economies like Nigeria assessment of impact of climate change in the Poultry sub-sector of agriculture which tends to hold high promise in the country is expedient in order to provide Bench – mark data against which aberrations due to climate change can be ‘measured’.

**Objectives**:
(i) Establish Bench – marks for Risk assessment of Livestock (Poultry) against which Poultry losses during the 2000 / 2001 in the southwestern parts of Nigeria (prone to Harmattan Season epidemics) based on Pre – 1994 losses;
(ii) Identify ‘local’ and ‘Agric’ hybrids for stratification of possible specific worst affected by epidemics in each state and estimate Economics values at loss and capital value at loss and capital value at Risk;
(iii)Design protection / Adaptation measures to minimize or eliminate losses in future.

**Expected Project Duration:** Nine (9) Months.

**Expected Outcome**:
Vulnerability assessment in relation to Economic values at loss and risk including determination of Time Trends in relation to cyclic recurrence patterns of epidemics which will not only be applicable in Poultry development but can also be adapted for other livestock.

# APPENDIX A: DETAILS OF GROSS NATIONAL EMISSIONS: TOP-DOWN METHOD

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| COUNTRY | NIGERIA | | | | | | | | | | | | | | | | |
| YEAR | 1994 | | | | | | | | | | | | | | | | |
| SECTOR | ENERGY | | | | | | | | | | | | | | | | |
| ACTIVITY | CO2 EMISSIONS FROM ENERGY - TOP DOWN APPROACH | | | | | | | | | | | | | | | | |
| FUEL TYPE | UNIT A | PROD. (UNIT A) | IMPORT (UNIT A) | EXPORT (UNIT A) | INTERN. BUNKERS (UNIT A) | STOCK CHANGE (UNIT A) | APPRNT CONSPTN (UNIT A) | NCV (TJ/Unit A) | APPRNT CONSPTN (TJ) | EMISSION FACTOR (t C/TJ) | CARBON CONTENT (Gg C) | CARBON STORED (Gg C) | NET CARBON EMISSIONS (Gg C) | CARBON OXIDIZED (FRACTION) | NET CO2 EMISSIONS (Gg CO2-C) | (Gg CO2) | AGGR. EMISSION FACTOR (t CO2/TJ) |
| **LIQUID FUEL** | | | | | | | | | | | | | | | | | |
| Crude Oil | Mt | 92.88 | 0.00 | 86.31 | 0.00 | 6.56 | 0.00 | 42750 | 0 | 20 | 0 | 0.00 | 0.00 | 0.99 | 0 | 0.00 | |
| NGL | kt | 3574.32 | 0.00 | 3492.98 | 0.00 | 0.00 | 81.34 | 42.74 | 3476.62 | 17.2 | 59.80 | 59.80 | 0.00 | 0.99 | 0.00 | 0.00 | 0 |
| LPG | kt | 0.00 | 9.33 | 0.00 | 0.00 | 58.12 | -48.79 | 47.31 | -2308.34 | 17.2 | -39.70 | 0.00 | -39.70 | 0.99 | -39.31 | -144.12 | 62.436 |
| PMS | kt | 0.00 | 2008.36 | 0.00 | 0.00 | -2402.16 | 4410.52 | 44.8 | 197591.08 | 18.9 | 3734.47 | 0.00 | 3734.47 | 0.99 | 3697.13 | 13556.13 | 68.607 |
| Other Kero. | kt | 0.00 | 504.99 | 0.00 | 0.00 | 258.85 | 246.14 | 44.75 | 11014.62 | 19.6 | 215.89 | 0.00 | 215.89 | 0.99 | 213.73 | 783.67 | 71.148 |
| Jet Kero. | kt | 0.00 | 0.27 | 0.00 | 0.00 | -556.39 | 556.65 | 44.59 | 24821.17 | 19.5 | 484.01 | 0.00 | 484.01 | 0.99 | 479.17 | 1756.97 | 70.785 |
| Gas/Diesel Oil | kt | 0.00 | 269.73 | 0.00 | 84 | -1379.06 | 1564.79 | 43.33 | 67802.20 | 20.20 | 1369.60 | 0.00 | 1369.60 | 0.99 | 1355.91 | 4971.66 | 73.326 |
| Residual Fuel Oil | kt | 0.00 | 0.00 | 0.00 | 256 | 658.54 | -914.54 | 40.19 | -36755.49 | 21.10 | -775.54 | 0.00 | -775.54 | 0.99 | -767.79 | -2815.21 | 76.593 |
| Naphtha | kt | 0.00 | 0.00 | 0.00 | 0.00 | -101.35 | 101.35 | 40.19 | 4073.46 | 22 | 89.62 | 67.21 | 22.40 | 0.99 | 22.18 | 81.33 | 19.965 |
| Bitumen | kt | 0.00 | 0.00 | 0.00 | 0.00 | -35.75 | 35.75 | 40.19 | 1436.74 | 22 | 31.61 | 31.61 | 0.00 | 0.99 | 0.00 | 0.00 | 0 |
| Lubricants | kt | 0.00 | 0.00 | 0.00 | 0.00 | -147.82 | 147.82 | 40.19 | 5940.77 | 20 | 118.82 | 59.41 | 59.41 | 0.99 | 58.81 | 215.65 | 36.3 |
| Petroleum Coke | kt | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 40.19 | 0.00 | 27.2 | 0.00 | 0.00 | 0.00 | 0.99 | 0.00 | 0.00 | |
| Refinery F/S | kt | 0.00 | 0.00 | 0.00 | 0.00 | -6570.00 | 6570.00 | 44.8 | 294336.00 | 20 | 5886.72 | 1942.62 | 3944.10 | 0.99 | 3904.66 | 14317.09 | 48.642 |
| Other Oil Products | kt | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 47.49 | 0.00 | 16.8 | 0.00 | 0.00 | 0.00 | 0.99 | 0.00 | 0.00 | |
| **TOTAL: Liquid Fuel** | | 96450.67 | 2792.68 | 89806.20 | 340.00 | -3653.87 | 12751.02 | | 571428.82 | | 11175.29 | 2160.64 | 9014.65 | | 8924.50 | 32723.16 | 57.265508 |
| **SOLID FUEL** | | | | | | | | | | | | | | | | | |
| Coking Coal | kt | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.99 | 0.00 | 0.00 | |
| Other Bituminous Coal | kt | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.99 | 0.00 | 0.00 | |
| Liqnite (Brown Coal) | kt | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.99 | 0.00 | 0.00 | |
| Sub-Bituminous Coal | kt | 13.15 | 0.00 | 0.00 | 0.00 | 0.00 | 13.15 | 25.75 | 338.61 | 26.2 | 8.87 | 0.00 | 8.87 | 0.99 | 8.78 | 32.20 | 95.106 |
| Peat | kt | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.99 | 0.00 | 0.00 | |
| Coke | kt | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.99 | 0.00 | 0.00 | |
| BKB/Patent Fuel | kt | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.99 | 0.00 | 0.00 | |
| Anthracite | kt | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.99 | 0.00 | 0.00 | |
| **TOTAL: Solid Fuel** | | 13.15 | 0 | 0 | 0 | 0 | 13.15 | | 338.61 | | 8.87 | 0.00 | 8.87 | | 8.78 | 32.20 | 95.11 |
| **NATURAL GAS:** | | | | | | | | | | | | | | | | | |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Natural Gas (Dry)** | **PJ** | 1309.82 | 0.00 | 0.00 | 0.00 | 0.00 | 1309.82 | 1000.00 | 1309820.0 | 15.30 | 20040.25 | 0.00 | 20040.25 | 0.99 | 19839.84 | 72746.09 | 55.54 |
| **TOTAL: Natural Gas** | | | | | | | 1309.82 | | 1309820.0 | | 20040.25 | 0.00 | 20040.25 | | 19839.84 | 72746.09 | 55.54 |
| | | | | | | | | | | | | | | | | | |
| **BIOMASS** | | | | | | | | | | | | | | | | | |
| **Biomass – Solid** | **Mt** | 72.347 | 0.00 | 0.00 | 0.00 | 0.00 | 72.35 | 9.30E+03 | 672827.10 | 29.90 | 20117.53 | 0.00 | 20117.53 | 0.99 | 19916.35 | 73026.63 | 108.537 |
| **Biomass – Liquid** | **TJ** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.99 | 0.00 | 0.00 | |
| **Biomass – Gas** | **TJ** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.99 | 0.00 | 0.00 | |
| **TOTAL: Biomass (Biom.)** | | | | | | | 72.35 | | 672827.10 | | 20117.53 | 0.00 | 20117.53 | | 19916.35 | 73026.63 | 108.537 |
| | | | | | | | | | | | | | | | | | |
| **INT-T'L BUNKERS** | | | | | | | | | | | | | | | | | |
| **Jet Kerosene** | **TJ** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 19.50 | 0.00 | 0.00 | 0.00 | 0.99 | 0.00 | 0.00 | |
| **Gas/Diesel Oil** | **TJ** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3639.72 | 1.00 | 3639.72 | 20.20 | 73.52 | 0.00 | 73.52 | 0.99 | 72.79 | 266.89 | 73.326 |
| **Residual Fuel Oil** | **TJ** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10288.64 | 1.00 | 10288.64 | 21.10 | 217.09 | 0.00 | 217.09 | 0.99 | 214.92 | 788.04 | 76.593 |
| **Sub-Bituminous Coal** | **kt** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 26.20 | 0.00 | 0.00 | 0.00 | 0.99 | 0.00 | 0.00 | |
| **Other Bituminous Coal** | **kt** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 25.80 | 0.00 | 0.00 | 0.00 | 0.99 | 0.00 | 0.00 | |
| **Gasoline** | **TJ** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 18.90 | 0.00 | 0.00 | 0.00 | 0.99 | 0.00 | 0.00 | |
| **Lubricants** | **TJ** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 20.00 | 0.00 | 0.00 | 0.00 | 0.99 | 0.00 | 0.00 | |
| **Other Kerosene** | **TJ** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 19.60 | 0.00 | 0.00 | 0.00 | 0.99 | 0.00 | 0.00 | |
| **TOTAL: Int-t'l Bunkers(IB)** | | | | | | | 13928.36 | | 13928.36 | | 290.61 | 0.00 | 290.61 | | 287.71 | 1054.92 | 75.74 |
| | | | | | | | | | | | | | | | | | |
| **TOTAL (Excl. Biom., IB)** | | | | | | | 14073.99 | | 1881587.4 | | 31224.41 | 2160.64 | 29063.76 | | 28773.13 | 105501.46 | 56.07 |

## APPENDIX 2.2: SUMMARY OF GROSS NATIONAL EMISSIONS FROM THE BU-METHOD

| SECTOR/SUB-SECTOR | | ENERGY CONSUMPTION (PJ) | 1994 EMISSIONS CO2 (Gg-CO2) | CH4 (Gg-CH4) | N20 (Gg-N2O) | C0 (Gg-CO) | NOX (Gg-NOX) | NMVOC (Gg NMVOC) |
|---|---|---|---|---|---|---|---|---|
| PUBLIC ELECTRICITY | | | | | | | | |
| | SOLID | 0.0034 | 0.3254 | 0.0000 | 0.0000 | 0.0001 | 0.0029 | 0.0000 |
| | LIQUID | 0.6412 | 41.0773 | 0.0000 | 0.0041 | 0.0094 | 0.0544 | 0.0000 |
| | GASEOUS | 100.2527 | 5644.9194 | 0.0100 | 0.2005 | 1.2933 | 5.7645 | 0.0000 |
| | ***TOTAL*** | ***100.8973*** | ***5686.3221*** | ***0.0100*** | ***0.2046*** | ***1.3027*** | ***5.8218*** | ***0.0000*** |
| AUTOGENERATION | | | | | | | | |
| | LIQUID | 9.5412 | 706.6884 | 0.0191 | 0.0181 | 3.3394 | 9.5412 | 0.1240 |
| | GASEOUS | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | ***TOTAL*** | ***9.5412*** | ***706.6884*** | ***0.0191*** | ***0.0181*** | ***3.3394*** | ***9.5412*** | ***0.1240*** |
| PETROLEUM REFINING | | | | | | | | |
| | LIQUID | 765.8987 | 6098.8513 | 0.6127 | 2.9104 | 28.3383 | 4.1359 | 12.1012 |
| | GASEOUS | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | ***TOTAL:*** | ***765.8987*** | ***6098.8513*** | ***0.6127*** | ***2.9104*** | ***28.3383*** | ***4.1359*** | ***12.1012*** |
| INDUSTRY | | | | | | | | |
| | SOLID | 0.3184 | 46.7438 | 0.0002 | 0.0000 | 0.0316 | 0.1678 | 0.0000 |
| | LIQUID | 17.9556 | 1389.1657 | 0.0521 | 0.1239 | 0.2693 | 2.8909 | 0.0359 |
| | GASEOUS | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | ***TOTAL*** | ***18.2740*** | ***1435.9095*** | ***0.0523*** | ***0.1239*** | ***0.3009*** | ***3.0587*** | ***0.0359*** |
| TRANSPORT | | | | | | | | |
| AIR | DOMESTIC | 16.5670 | 1184.5404 | 0.0331 | 0.0000 | 1.9880 | 4.8044 | 0.2982 |
| | INTERNT'L. | 14.0122 | 1001.8754 | 0.0294 | 0.0000 | 1.6815 | 4.0650 | 0.2536 |
| | OTHER | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | *Sub-Total* | *30.5792* | *2186.4158* | *0.0626* | *0.0000* | *3.6695* | *8.8694* | *0.5518* |

| | | | | 1994 EMISSIONS (Gg) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | CO2 | CH4 | N20 | C0 | NOX | NMVOC |
| ROAD | CARS | | | | | | | | |
| | | DIESEL | 228.2034 | 15814.4979 | 4.7923 | 0.2282 | 2991.7470 | 130.0760 | 273.6159 |
| | | GASOLINE | 24.5843 | 1820.8771 | 0.0492 | 0.0983 | 6.8836 | 6.3919 | 1.6717 |
| | | *Sub-total* | *252.7877* | *17635.3749* | *4.8414* | *0.3265* | *2998.6306* | *136.4679* | *275.2876* |
| | LDT | | | | | | | | |
| | | DIESEL | 117.4519 | 8139.4134 | 2.1141 | 0.1175 | 978.3739 | 77.5182 | 125.9084 |
| | | GASOLINE | 44.3647 | 3285.9506 | 0.0444 | 0.1775 | 18.1895 | 16.4150 | 4.8358 |
| | | *Sub-total* | *161.8166* | *11425.3640* | *2.1585* | *0.2949* | *996.5635* | *93.9332* | *130.7441* |
| | HDT | | | | | | | | |
| | | *DIESEL* | *35.1810* | *2605.7379* | *0.2111* | *0.1055* | *29.5520* | *35.1810* | *6.4733* |
| | MOTORCYCLES | | | | | | | | |
| | | *GASOLINE* | *41.3840* | *2867.9141* | *4.7592* | *0.0828* | *695.2519* | *2.4830* | *482.1241* |
| | *Sub-Total* | | *491.1693* | *34534.3909* | *11.9702* | *0.8098* | *4719.9980* | *268.0651* | *894.6292* |
| RAIL | | | | | | | | | |
| | COAL | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | DIESEL | | 3.6735 | 271.5183 | 0.0180 | 0.0073 | 2.2416 | 6.6127 | 0.4768 |
| | *Sub-Total:* | | *3.6735* | *271.5183* | *0.0180* | *0.0073* | *2.2416* | *6.6127* | *0.4768* |
| NAVIGATION | | | | | | | | | |
| | INTERNAL | | 4.8038 | 355.8040 | 0.0235 | 0.0096 | 2.4019 | 7.6861 | 0.5275 |
| | IMB | | 14.8767 | 1125.3149 | 0.0000 | 0.0290 | 0.6836 | 31.2404 | 0.0000 |
| | *Sub-Total* | | *19.6806* | *1481.1189* | *0.0235* | *0.0386* | *3.0855* | *38.9265* | *0.5275* |
| | ***TOTAL*** | | ***545.1026*** | ***38473.4439*** | ***12.0743*** | ***0.8557*** | ***4728.9945*** | ***322.4736*** | ***896.1853*** |

| | | | 1994 EMISSIONS | (Gg) | | | | |
|---|---|---|---|---|---|---|---|---|
| SMALL COMBUSTION | | | CO2 | CH4 | N20 | C0 | NOX | NMVOC |
| RESIDENTIAL | | | | | | | | |
| | HEAT GEN. | 728.0962 | 3964.4520 | 444.8401 | 3.2888 | 4090.3591 | 118.0919 | 1.0364 |
| | AUTO-GEN. | 7.5480 | 527.1179 | 0.3380 | 0.0070 | 47.1986 | 5.5379 | 3.0273 |
| *Sub-total* | | *735.6442* | *4491.5699* | *445.1780* | *3.2958* | *4137.5577* | *123.6299* | *4.0637* |
| AFF | | | | | | | | |
| | OFF-ROAD VEHICLES | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | OTHER AFF | 2.8258 | 209.2968 | 0.0316 | 0.0622 | 1.6958 | 4.2401 | 0.6496 |
| | *Sub-total* | *2.8258* | *209.2968* | *0.0316* | *0.0622* | *1.6958* | *4.2401* | *0.6496* |
| INST/COMM | | *0.0000* | *0.0000* | *0.0000* | *0.0000* | *0.0000* | *0.0000* | *0.0000* |
| ***TOTAL*** | | ***738.4700*** | ***4700.8667*** | ***445.2097*** | ***3.3579*** | ***4139.2535*** | ***127.8700*** | ***4.7134*** |

| FUGITIVE PROCESSES | | 1994 EMISSIONS (Gg) | | | | | |
|---|---|---|---|---|---|---|---|
| | | CO2 | CH4 | N20 | C0 | NOX | NMVOC |
| UPSTREAM OIL/GAS | | | | | | | |
| OIL PROD./DISTR. | 1.2582 | 0.0000 | 0.0231 | 0.0000 | 0.0000 | 0.0000 | 0.0254 |
| GAS PROD./TRANSM. | 2.2336 | 0.0000 | 270.3933 | 0.0000 | 0.0000 | 0.0000 | 278.1339 |
| GAS FLARING/VENTING | 1.0353 | 58080.0495 | 611.7652 | 0.0000 | 4224.0036 | 28.9883 | 672.9418 |
| *Sub-total* | *4.5272* | *58080.0495* | *882.1816* | *0.0000* | *4224.0036* | *28.9883* | *951.1011* |
| COAL MINING | | | | | | | |
| SURFACE | 0.1706 | 0.0000 | 2.8852 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| UNDERGROUND | 0.5118 | 0.0000 | 133.1625 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| COAL PROCESSING | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| *Sub-total* | *0.6824* | *0.0000* | *136.0477* | *0.0000* | *0.0000* | *0.0000* | *0.0000* |
| GASOLINE STOR/DIS.TR. SYSTEM | | | | | | | |
| REFINERY | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| MAJOR MARKETERS | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| SERVICE STATIONS | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| TRANSPORT VESSELS | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| *Sub-total* | *0.0000* | *0.0000* | *0.0000* | *0.0000* | *0.0000* | *0.0000* | *0.0000* |
| ***TOTAL*** | ***5.2095*** | ***58080.0495*** | ***1018.2292*** | ***0.0000*** | ***4224.0036*** | ***28.9883*** | ***951.1011*** |
| **GRAND TOTAL** | **2183.3934** | **115182.1314** | **1476.2073** | **7.4707** | **13125.5330** | **501.8894** | **1864.2609** |

| NATIONAL GHG INVENTORY: 1994 | | PRODUCTION ACTIVITY | | 1994 EMISSIONS (Gg) | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| SUMMARY OF NATIONAL EMISSIONS | | | | CO2 | CH4 | N20 | C0 | NOX | NMVOC |
| SECTOR/SUB-SECTOR | | UNIT | VALUE | | | | | | |
| PROCESS INDUSTRIES | | | | | | | | | |
| IRON & STEEL | | | | | | | | | |
| | BILLETS | kt | 42.213 | 0.000 | 0.038 | 0.000 | 0.004 | 0.004 | 0.030 |
| | ROLLED PRODUCTS | kt | 10.138 | 0.000 | 0.009 | 0.000 | 0.000 | 0.000 | 0.007 |
| | ***Sub-total*** | ***kt*** | ***52.351*** | ***0.000*** | ***0.047*** | ***0.000*** | ***0.004*** | ***0.004*** | ***0.037*** |
| NON-FERROUS METALS | | | | | | | | | |
| | ***PRIMARY ALUMINIUM*** | ***kt*** | ***0*** | ***0*** | ***0*** | ***0*** | ***0*** | ***0*** | ***0*** |
| INORGANIC CHEMICALS | | | | | | | | | |
| | AMMONIA | kt | 244.719 | 260.087 | 0.000 | 0.000 | 0.000 | 0.196 | 0.000 |
| | UREA | kt | 329.127 | 0.000 | 0.000 | 0.000 | 0.000 | 0.263 | 0.000 |
| | OTHER(S) | kt | 0 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | ***Sub-total*** | ***kt*** | ***573.846*** | ***260.087*** | ***0.000*** | ***0.000*** | ***0.000*** | ***0.459*** | ***0.000*** |
| ORGANIC COMPOUNDS | | ***kt*** | ***0*** | ***0*** | ***0*** | ***0*** | ***0*** | ***0*** | ***0*** |
| NON-METALLIC MINERALS | | | | | | | | | |
| | CEMENT | kt | 3086.000 | 1496.401 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | LIME | kt | 5.594 | 4.392 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | OTHER | kt | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | ***Sub-total*** | ***kt*** | ***3091.594*** | ***1500.79325*** | ***0*** | ***0*** | ***0*** | ***0*** | ***0*** |
| OTHER (ISIC) | | | | | | | | | |
| | PAINT PRODUCTION | m3 | 20990 | 0 | 0.000 | 0.000 | 0.000 | 0.000 | 274.969 |
| f | BEER PRODUCTION | HL | 23970125 | 0 | 28764.150 | 0.000 | 0.000 | 0.000 | 0.000 |
| | SOFTDRINKS | HL | 13219072 | 0 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | BREAD PRODUCTION | kt | 479.281 | 0 | 0.000 | 0.000 | 0.000 | 0.000 | 3.067 |
| | COTTON TEXTILE PRODUCTION | Million m2 | 379.51 | 0 | 0.000 | 0.000 | 0.000 | 0.000 | 48.957 |
| | SYNTHETIC TEXTILES PRODUCTION | Million m2 | 308.627 | 0 | 0.000 | 0.000 | 0.000 | 0.000 | 39.813 |
| | ***Sub-total*** | | | ***0*** | ***28764.150*** | ***0.000*** | ***0.000*** | ***0.000*** | ***366.806*** |
| **TOTAL: INDUSTRY** | | | | **1760.881** | **28764.197** | **0.000** | **0.004** | **0.463** | **366.843** |

| NATIONAL GHG INVENTORY: 1994<br>SUMMARY OF NATIONAL EMISSIONS<br>SECTOR/SUB-SECTOR | PRODUCTS USE ACTIVITY<br>UNIT | <br>VALUE | 1994 EMISSIONS<br>CO2<br>(Gg-CO2) | <br>CH4<br>(Gg-CH4) | <br>N20<br>(Gg-N2O) | <br>C0<br>(Gg-CO) | <br>NOX<br>(Gg-NOX) | <br>NMVOC<br>(Gg NMVOC) |
|---|---|---|---|---|---|---|---|---|
| SOLVENTS & OTHER PRODUCTS USE | | | | | | | | |
| PAINT APPLICATION | m3 | 20990 | 0 | 0.000 | 0.000 | 0.000 | 0.000 | 0.405 |
| DEGREASING & DRY-CLEANING | 0 | 0 | 0 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Paper Printing | 0 | 0 | 0 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Other | | | | | | | | |
| **TOTAL** | | | **0** | **0.000** | **0.000** | **0.000** | **0.000** | **0.405** |

| NATIONAL GHG INVENTORY: 1994 | | AGRICULTURAL ACTIVITY | | 1994 EMISSIONS | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| SUMMARY OF NATIONAL EMISSIONS | | | | CO2 | CH4 | N20 | C0 | NOX | NMVOC |
| SECTOR/SUB-SECTOR | | UNIT | VALUE | (Gg-CO2) | (Gg-CH4) | (Gg-N2O) | (Gg-CO) | (Gg-NOX) | (Gg NMVOC) |
| AGRICULTURE | | | | | | | | | |
| LIVESTOCK | | | | | | | | | |
| | Enteric Fermentation | 1000 HEAD | 254334 | 121.000 | 1181.375 | 1181.375 | 1181.375 | 1181.375 | 1181.375 |
| | Manure Management | 1000 HEAD | 254334 | 7.150 | 61.863 | 61.863 | 61.863 | 61.863 | 61.863 |
| | ***Sub-total*** | ***10^3 Head*** | ***508668*** | ***128.150*** | ***1243.238*** | ***1243.238*** | ***1243.238*** | ***1243.238*** | ***1243.238*** |
| Rice Cultivation | | ***(Mha-Days)*** | ***228.557*** | ***0.00*** | ***1085.65*** | ***0.00*** | ***0.00*** | ***0.00*** | ***0.00*** |
| Savannah Burning | | | | | | | | | |
| | Derived | kha | 7571 | 0.00 | 13.202 | 0.408 | 346.561 | 14.762 | 0.000 |
| | Guinea | kha | 40000 | 0.00 | 95.995 | 2.970 | 2519.856 | 107.338 | 0.000 |
| | Sudan | kha | 34220 | 0.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | Sahel | kha | 3150 | 0.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | ***Sub-total*** | ***kha*** | ***84941*** | ***0*** | ***109.197*** | ***3.378*** | ***2866.417*** | ***122.101*** | ***0.000*** |
| Field Burning of Agric. Wastes | | ***kt crop*** | ***61626.66*** | ***0.000*** | ***34.299*** | ***0.718*** | ***720.289*** | ***25.936*** | ***0.000*** |
| Agricultural Soils | | | | | | | | | |
| TOTAL: AGRICULTURE | | | | 128.150 | 2472.380 | 1247.334 | 4829.944 | 1391.274 | 1243.238 |

| NATIONAL GHG INVENTORY: 1994 | LAND USE CHANGE | | 1994 EMISSIONS | | | | | |
|---|---|---|---|---|---|---|---|---|
| SUMMARY OF NATIONAL EMISSIONS | ACTIVITY | | CO2 | CH4 | N20 | C0 | NOX | NMVOC |
| SECTOR/SUB-SECTOR | UNIT | VALUE | (Gg-CO2) | (Gg-CH4) | (Gg-N2O) | (Gg-CO) | (Gg-NOX) | (Gg NMVOC) |
| LAND USE CHANGE | | | | | | | | |
| Annual Forest Growths | | | | | | | | |
| Tropical Plantations | kha | 409 | -6903.600 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Tropical Other Forests | kha | 16133 | -25031.356 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| ***Sub-total*** | ***kha*** | ***16542.3647*** | ***-31934.956*** | ***0.000*** | ***0.000*** | ***0.000*** | ***0.000*** | ***0.000*** |
| Other Ecosystem Growths | | | | | | | | |
| Non-Forest Trees | ***/10^3 trees*** | ***200*** | ***-4785.00*** | ***0.00*** | ***0.00*** | ***0.00*** | ***0.00*** | ***0.00*** |
| Biomass Harvests | ***kt dm*** | ***55298.66*** | ***91242.79*** | ***0.00*** | ***0.00*** | ***0.00*** | ***0.00*** | ***0.00*** |
| Forest Conversions | | | | | | | | |
| Aboveground Biomass | | | | | | | | |
| On-site Burning | kha | 380.00 | 4242.76 | 18.51 | 0.13 | 162.00 | 4.60 | 0.00 |
| Off-site Burning | kha | 380.00 | 6110.80 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Decay | kha | 380.00 | 10697.78 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Sub-total* | *kha* | *1140* | *21051.34* | *18.51* | *0.13* | *162.00* | *4.60* | *0.00* |
| Soil Disturbance | | | | | | | | |
| Trop. Moist Forests | kha | 298.00 | 27481.67 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Trop. Dry, Woody Sav. | kha | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Grassland | kha | 34 | 1558.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Sub-total* | *kha* | *332* | *29040.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| ***Sub-total: Forest Conversions*** | | ***1140*** | ***21051.3435*** | ***18.51*** | ***0.13*** | ***162.00*** | ***4.60*** | ***0.00*** |
| Abandonment of Managed Lands (AML): > 20yrs | | | | | | | | |
| Tropical Forests | | | | | | | | |
| Moist | kha | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Seasonal | kha | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Dry | kha | 12.00 | -32.45 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Sub-total* | *kha* | *12* | *-32.45* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| Grassland | | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* | *0.00* |
| ***Sub-total: AML*** | | ***12.00*** | ***-32.45*** | ***0.00*** | ***0.00*** | ***0.00*** | ***0.00*** | ***0.00*** |
| **TOTAL: LAND USE CHANGE** | | | | | | | | |
| Gross Uptake | | | -36752.41 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Gross Emissions | | | 112294.13 | 18.51 | 0.13 | 162.00 | 4.60 | 0.00 |
| **Net Emissions** | | | **75541.73** | **18.51** | **0.13** | **162.00** | **4.60** | **0.00** |

| NATIONAL GHG INVENTORY: 1994 | LAND USE CHANGE | | 1994 EMISSIONS | | | | | |
|---|---|---|---|---|---|---|---|---|
| SUMMARY OF NATIONAL EMISSIONS | ACTIVITY | | $CO_2$ | $CH_4$ | N20 | C0 | NOX | NMVOC |
| SECTOR/SUB-SECTOR | UNIT | VALUE | (Gg-$CO_2$) | (Gg-$CH_4$) | (Gg-$N_2O$) | (Gg-CO) | (Gg-NOX) | (Gg NMVOC) |
| WASTE MANAGEMENT | | | | | | | | |
| Municipal Solid Wastes (MSW) | | | | | | | | |
| Landfills | kt MSW | 222 | 0 | 17 | 0 | 0 | 0 | 0 |
| Open Dumps | kt MSW | 5080 | 0 | 178 | 0 | 0 | 0 | 0 |
| Open Burning | kt MSW | 16157 | 0 | 18 | 0 | 171 | 3 | 0 |
| Incineration | kt MSW | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| ***Sub-total: MSW*** | ***kt MSW*** | ***21459*** | ***0*** | ***213*** | ***0*** | ***171*** | ***3*** | 0 |
| Waste Water Treatement | | | | | | | | |
| *All Municipal (D&C)* | *Gg BOD5* | *229* | *0.00* | *5.03* | *0.00* | *0.00* | *0.00* | *0.00* |
| Industrial | | | | | | | | |
| Iron/Steel | Gg BOD5 | 56000 | 0.00 | 1232.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Non-Ferrous Metals | Gg BOD5 | 8850 | 0.00 | 194.70 | 0.00 | 0.00 | 0.00 | 0.00 |
| Fertilizer | Gg BOD5 | 4500 | 0.00 | 99.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Food & Bev. | Gg BOD5 | 15143 | 0.00 | 333.14 | 0.00 | 0.00 | 0.00 | 0.00 |
| Paper & Pulp | Gg BOD5 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Refin./Petrochem. | Gg BOD5 | 32800 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Textiles | Gg BOD5 | 84 | 0.00 | 1.85 | 0.00 | 0.00 | 0.00 | 0.00 |
| Rubber | Gg BOD5 | 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Other | Gg BOD5 | 608 | 0.00 | 13.38 | 0.00 | 0.00 | 0.00 | 0.00 |
| *Subtotal* | *Gg BOD5* | *117985* | *0.00* | *1874.07* | *0.00* | *0.00* | *0.00* | *0.00* |
| ***Sub-total: WWT*** | ***Gg BOD5*** | ***139444*** | ***0.00*** | ***2086.67*** | ***0.25*** | ***171.20*** | ***3.29*** | ***0.00*** |
| **TOTAL: WASTE MANAGEMENT** | | | **0.00** | **2299.27** | **0.51** | **342.39** | **6.59** | **0.00** |

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