Contents of NIC Report

FOREWORD

By Honourable Solomon Ekuma Berewa
Vice-President of the Republic of Sierra Leone.

On behalf of the Government and people of the Republic of Sierra Leone it is my great pleasure to present this Initial National Communications Report of Sierra Leone to the United Framework Convention of Climate Change (UNFCCC)

This report on the Initial national Communications of Sierra Leone was prepared by Greenhouse Gas Inventory, Vulnerability and Mitigation Analysis teams in collaboration with Secretariat of the CCP and the UNDP. The team comprised local experts drawn from the University, Government Departments and Ministries as indicated in the Project Documentation.

As is evident in the report, key sectors such as Energy, Agriculture, Industries, Landuse, Landuse Change and Forestry, and Waste Management and Coastal Management have been addressed and have come up with positive results for the development of climate change.

The groups were ably assisted by Mr. Bubu Pateh Jallow the International Consultant, of the Republic of Gambia and the Local Consultant professor Ogunlade R Davidson of the University of Sierra Leone whose input were invaluable in the training of the team members and the preparation of this report.

This report is also a synthesis of the many sensitization workshops and conferences organized by the climate change project secretariat. The draft report has been reviewed by imminent scientists both locally and internationally and their comments are contained therein.

The report will serve a useful purpose to the Government decision policy-makers and universities and other relevant stakeholders working generally on climate change issues in the country. This report will serve as a partial fulfillment of the country's obligations to the UNFCCC as clearly stated in Article 4 and in accordance with Article 12 of the Convention. THE Mitigation and Adaptation measures recommended in this report will require both local and international support for their implantations.

With the preparation of this report Sierra Leone will be in the position to establish an Institution responsible for climate Change activities locally and internationally.

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ACKNOWLEGEMENTS

In compliance with Article 4.1, 4.2 and in accordance with Article 12 of the United Nations Framework Convention on Climate Change (UNFCCC), the Project SIL/02/G32 entitled "Enabling Sierra Leone's capacity to fulfill its obligations to the United Nations Framework Convention on Climate Change (UNFCCC)", was established in February 2003 with the objective of building Institutional and Technical capacities in the country and to prepare a National Communications for the country.

In order to successfully implement the project, three (3) Technical expert teams were established, i.e. GHG Inventory, Vulnerability and Adaptation and Mitigation Analysis Study teams. Implementation started with the GHG programme followed by the other two programmers.

National Communications Report apparently addresses key themes such as National Circumstances, National Inventory of Greenhouse Gas Emissions, Mitigation of Greenhouse Gas Emissions, Vulnerability (Impacts and Adaptation) and also cross-cutting issues. Hopefully, this report will serve as a reference material for all Climate Change stakeholders and practitioners. It also highlights the main Greenhouse Gases in the country such as carbon dioxide, methane and nitrous oxide.

May I through this medium on behalf of the Climate Change Project Secretariat in the Meteorological Department, Ministry of Transport and Communications congratulate the leaders and members of the GHG Inventory, Mitigation Analysis Study and Vulnerability and Adaptation teams, the Local and International Consultants for the production of such admirable report.

I wish to register my sincere gratitude and that of the Secretariat of the Climate Change Project to the UNFCCC/GEF/UNDP and other agencies that contributed both morally and financially to the successful completion of this report. Not to mention names would be very unfair to all those who have contributed significantly to the preparation of the report. Credit must go to the following individuals, Mr. Bengt Ljunggren and Ms. Lorna French of the UNDP, Dr. Raymond Johnson leader of the GHG team, Dr. Sahr A. Aruna Leader of the Mitigation Analysis Study team, Mr. Momodu Alrashid Bah leader of the Vulnerability and Adaptation team, Mr. Bubu Pateh Jallow, International Consultant of the Gambia, Professor Ogunlade Robert Davidson Local Consultant and Chairman of the writing team which prepared the INC report, the reviewers (local and international) of the various sectors of the report. Ms. Sabaina Paila, Project Secretary and all members of the Climate Change Project Secretariat (CCPSL)

Special thanks go to the general manager and Staff of the Sierra Leone Airport authority for their moral and financial assistance to the Climate Change Project.

Prepared by

Jerry T O Pratt
Project Coordinator

ACRONYMS AND ABBREVIATION USED IN NIC REPORT

AML	**-**	**Abandonment of Managed Lands**
CO_2	**-**	**Carbon Dioxide**
CEF	**-**	**Carbon Emission Factors**
CFC	**-**	**Chloro Florocarbon**
CFWB	**-**	**Change in Forest and other Woody Biomass**
CH_4	**-**	**Methane**
CO	**-**	**Carbon Monoxide**
COP	**-**	**Conference of Parties**
CSO	**-**	**Central Statistics Office**
EF	**-**	**Emission Factor**
EI	**-**	**Energy Industries**
EJ	**-**	**Exajoule**
FAO	**-**	**Food and Agricultural Organization**
FGC	**-**	**Forest and Grasslands Conversion**
GDP	**-**	**Gross Domestic Product**
GEF	**-**	**Global Environmental Facility**
Gg	**-**	**Gigagrams**
GHG	**-**	**Greenhouse Gases**
H_2O	**-**	**Water Vapour**
HCFC	**-**	**Hydro-Chlorofluorocarbon**
HFO	**-**	**Heavy Energy Oil**
IEA	**-**	**Intergovernmental Panel on Climate Change**
Km	**-**	**Kilometre**
LUCUCF	**-**	**Landuse, Landuse Change and Forestry**
MAFAFS	**-**	**Ministry of Agriculture, Forestry and Food Security**
MCI	**-**	**Manufacturing and Construction Industries**
MM	**-**	**Milimeters**
MT	**-**	**metric Tonne**
MP	**-**	**Metal Production**
NO_x	**-**	**Nitrogen Oxide**
N_2O	**-**	**Nitrous Oxide**
NEPAD	**-**	**New Partnership for Africans Development**
NGO	**-**	**Non-Governmental Organization**
NMVOC	**-**	**Non-Methane Volatile Organic Compound**
NPA	**-**	**National Power Authority**
O_3	**-**	**Ozone**
OECD	**-**	**Organization for Economic Cooperation and Development**
%	**-**	**Percentage**
S&T	**-**	**Science and Technology**
SO_2	**-**	**Sulphur Dioxide**
SF_6	**-**	**Sulphur Hflexafloride**
SWDS	**-**	**Solid Wastes Disposal Sites**
Tg	**-**	**Teragram**

UN	**-**	**United Nations**
UNDP	**-**	**United Nations Development Programme**
UNEP	**-**	**United Nations Environmental Programme**
UNFCCC	**-**	**United Nations Framework Convention on Climate Change**
VMT	**-**	**Vehicle Miles Traveled**

EXECUTIVE SUMMARY OF NIC

NATIONAL CIRCUMSTANCES

Sierra Leone is located in the southern-Western part of the bulge of West Africa. It lies between latitudes 7 and 10^0 N of the equator and between longitude 10 and 13N of the Greenwich Meridian. The country has a surface area of about 71,700 square kilometers (28000 square miles) with a population of about 5 million growing at 2.5% per annum. Approximately 80-90% of the population is in the rural areas. The vast majority of the population subsists in poverty and most of it is malnourished as a result of the 10 years civil conflict. Life expectancy at birth is extremely low (less than 40 years). Infant mortality is among the highest in the world.

School enrolment ratios are now moderate and the illiteracy rate is about 80%. Sierra Leone's social diversity is reflected in the different ethnic groups and local languages such as Mende, Temne, Limba, Creole, Lokko, Fulah, Mandingo etc.. There is no religious extremism as Muslims and Christians co-exist peacefully in the country.

The climate of Sierra Leone is wet tropical, marked by distinct wet and dry seasons. The wet season is from May to October and the dry season November to April. The wet season is related to the flow from the southwest of the tropical maritime monsoon which is a mass of moisture – laden air that originates over the south-Atlantic ocean.

The dry season is caused by the hot dusty air of the Harmattan trade winds that develop over the Saharan region in the circulation around the high pressure cells.

The mean annual rainfall over the country is about 3000mm. the southern and coastal areas receive from 3000 to 5000mm. The rains fall steadily in the wet season with the heaviest in the months of July and August. Apart from the two seasons there is a sub season known as the Harmattan.

The temperatures are consistently high throughout the country, roughly averaging about 28^0C. The humidity, like the temperature is usually high as a result of the heavy rains coupled with high temperature and the maritime influences. Humidity rises up to 93% in the Wet Season and decreases inland to about 47% as the rainfall declines. There is little variation in the day length due to the near equatorial location, but sunshine hours are affected during the wet season.

The major economic activities undertaken in the country are Agriculture and mining. Agriculture provides employment for about 85% of the population and contributes more than 30% of the Gross Domestic product (GDP) and 16% of the total export earnings. Fuelwood is the main source of energy for 90% of the population for domestic cooking. It is also used for non-domestic purposes in Agro-based industries such as tobacco and fish smoking in many coastal villages.

Mining industry is one of the most important in terms of employment, and contribution to the national economy. The minerals mined include; Diamonds, Bauxites, Rutiles, Gold etc. Mining has a lot of potentials as a large income generating sector but its impact on other land use activities has been extensive over the years. Studies have revealed that extensive damage is being caused to the ecosystem due to improper environmental management in the mining sector. Both large and artisanal mining operations have resulted in extensive land devastation, removal of the top soil cover, thereby rendering the land unsuitable for farming or other viable economic activities. Water air quality changes and siltation in tidal creeks/river systems affect maritime life and also drinking water resources of the communities living down stream. When mining is carried out in hilly areas and slopes, severe erosion takes place and flooding may result. In certain instances, the activities of the miners divert surface drainage.

Greenhouse Gas flows

From the report on the gas flows in Sierra Leone it is evident that in 1990 360Gg CO_2 were emitted into the atmosphere while 303,058 Gg CO_2 were removed from the atmosphere for the period by various social activities.

Emissions of 360Gg CO_2 were due to emissions of 355Gg from energy industries (ET), 151 Gg from Manufacturing and Construction Industries (MCI) and 6Gg from metal products (MP).

Land use Change and Forestry category was responsible for the net CO_2 removal of over 300,000 Gg and this net removal is due to the emissions of 86,357 Gg due to Conversion of Forest and Grasslands (FGC) into other land use types and removals of other woody biomass (CFWB) and 329,106 CO_2 due to abandonment of managed lands (AML). Thus Sierra Leone is a net sink of CO_2. Other gases emitted into the atmosphere are Nitrogen Oxides (NO_x), Carbon monoxide (CO), and non-methane volatile organic compounds (NMVOC).

A total of 6,108 Gg CO was emitted in the atmosphere in 1990. Of this, 82% (4,893 Gg CO) came from the Agricultural sector and about 18% from the land use change and forestry sector. Burning of savannahs is responsible for 80% (4,884 Gg CO) of the CO emissions in the country. NMVOC emissions were registered in the Industrial processes. About 390 Gg were emitted in 1990 in the process of production of metals.

It is evident that emissions of methane are more important than the other GHGs based on comparison of their global warming potentials. Methane emitted is equivalent to $1.2x10^{15}$ tons $C0_2$ equivalent ($TC0_2E$) and represents 100% of the total emissions in Sierra Leone. The bulk of these emissions come from rice cultivation.

Mitigation measures for Greenhouse Gases

Climate Change Mitigation is not a stand-alone problem. It will both affect and be affected by socio-economic policies and by choices involving development, sustainability

and equity. Policies to limit net emissions can best promote sustainable development if they are consistent with broader societal objectives. Some mitigation options can even promote benefits far beyond immediate climate change concerns such as reducing health problems, increasing local employment, minimizing air pollution, protecting and enhancing forest and water sheds, minimizing certain subsidies and taxes and accelerating the development and diffusion of energy-efficient technologies.

As a mitigation assessment approach for Sierra Leone, a scoping workshop was conducted which, involved collecting data and information through stakeholder consultations. As a result, the following options were screened for further analysis:

i) Transport Sector

- Lead-Free petrol
- Mass transportation (road and water) for passengers and cargo.
- Creation of pay parking lots
- Enforcement of regular maintenance regulations for vehicles
- Improve the water transport system
- Regulate cost of duty to improve transport (tax incentives)
- Regulation/policies on fuel use and consumptions

ii) Energy/industrial Sector

- Hydro electric power
- Switching and promotion for renewable energy (solar energy and LPG)
- Use of other fuels such as ethanol, oxygen etc.
- Development of alternative energy sources such as Bio-fuels (from corn, sugarcanes, Rice Husk etc.)

iii) Agricultural Sector

- Water management in rice cultivation and maintenance of soils.
- Low amount of organic matter
- Use of rice-straw, compost, biogas residues
- Mineral fertilizers
- Fallow incorporation and mulching

iv) Forestry

- Forestry protection, conservation and increase
- Reforestation, afforestation and Agroforestry
- Urban and Community Forestry.

v) Waste Management Sector

- Waste incineration
- Composting
- Recycling.

The methodology used to arrive at the mitigation option was the "Mitigation Option Weighting" method based on the following criteria. Mitigation benefits, financial viability, implementation/organizational viability, technological viability, size, acceptability and political willingness.

Climate Change and Socio-Economic Scenarios

Climate data for the period 1961 to 1990 were used to construct the climate change scenarios for Sierra Leone. Data were sourced from the following meteorological stations; Lungi, Bonthe, Kabala, Njala and Bo. The parameters used for the study were precipitation (Rainfall) temperature, solar radiation, evaporation etc. It was evident from the study that the coastal areas experienced the heaviest rainfall in the form of Torrential rains. The study period (1961-1990) shows an average annual rainfall of about 2746mm which varied from 3659mm at Bonthe in the south to 2618mm at Kabala in the North. The following software such as the GCM, HADCM, UKTR, ECHAM models were used to develop the climate change scenarios for Sierra Leone. The average for 1961-1990 is about 26.7°C. This average is expected to increase by about 7-9 percent by the year 2100.

Projection from the 1961-1990 using the ECHAM4 and HDCM2 models for the rainfall values at 2100 are similar to the current climate rainfall amount, whiles the CSIRO-TR and UKTR models show a decrease in rainfall by about 3-10% below the current monthly and annual values. Based on the GCM outputs, solar radiation is expected to decrease by 12% under the HADCM2, by 9% under the UKTR model, and under the CSIRO-TR and ECHAM models by 5%. In Sierra Leone, based on the last reference MAGICC/SCENGEN models, $C0_2$ concentration of about 350 parts per million (PPM) was determined in 1990. Double $C0_2$ concentration levels of about 580ppm are likely to be achieved by 2025 and about 700ppm by 2100. Sea level rise (SLR) scenarios adopted in this study are 0.2m as baseline and 0.5m, 1,0m and 2.0m by 2100.

Impacts of Climate Change induced Sea Level

The main limiting factor for making accurate assessment of the Vulnerability of the coastal sea level rise has been the lack of data of the topography of the coastal area to the desired accuracy (i.e. to allow the delineation of the appropriate contour line). Some sections of the coast particularly the urban centres of the capital, Freetown and coastal towns of Kambia, Bonthe Sherbro Island do not have these data. As much as possible data was derived from limited information on the survey beach marks and surveys of roads within the coastal areas. The elimination of the area outside the risk zone was assisted by the availability of maps showing the 30m contour.

Shoreline Recession

Climate Change is expected to impact Sierra Leone's sandy beaches in two ways: -

(1) The rise in sea levels expected from Climate Change would accelerate the rate of recession of sandy shores.
(2) Increases in littoral transport capacity arising from increases in the intensity and duration of storms.

Also, sea level rise can affect coastal structures such as the jetties along the coastline.

Flooding and inundation affect some coastal segments of the Freetown peninsular (i.e. bays, estuaries and beaches). Sea level rise have the effect of augmenting a decrease in the quality and quantity of ground water resources otherwise caused by man's activities. The estimated population along the coastal areas at risk for 1m rise of sea level is about 2,315,860.

If no action is taken on sea level rise, a total of 26.4km square is estimated to be lost and areas such as the northern at southern areas are vulnerable. Potential adaptation measures to address management of the coastal zone in Sierra Leone are: -

- Establishment of coastal management on coastal erosion in Sierra Leone.
- Delineation of flood and erosion hazardous areas.
- Improvement of the quality of topographic data for the coastal zone.
- Monitoring of the coast
- Sand and Gravel mining
- Education and Research

Impacts of Climate Change on Fisheries

In assessing the impacts of climate change on the productivity in Sierra Leone, the effects of temperature on annual productivity of riverine fisheries resources are evaluated on the basis of the average stream width of 250 meters for the Rokel River, the biogenic capacity of the stream, the annual water temperature, the alkalinity/acidity of the water, and the type of fish population present in the river.

Productivity of the riverine fisheries of the Rokel River is projected to increase under all climate change model scenarios. The estimated productivity of the Rokel River under the current (1961-1990) climate is 228 tons per kilometer (tons/km) reach of the river.

All the climate change model scenarios projected an increase in the productivity of the river. The highest increase in productivity is projected by the HADLEY 2 model scenario and it ranges from 3% (i.e. 236 tons per Km) increase by 2025 to about 8% (i.e. 248 tons/km) increase by 2100. The projections based on CSIRA model is lowest of all the models considered for this study. The projected productivity under the CSIRA varies from about 2% (i.e. 234 ton/km) increase in 2025 to about 6% (i.e. 243 tons/km) increase in 2100. Commercial shrimp yield was estimated for current climate for the average period 1961 to 1990 and for simulated climate change to 2100 based on the model output for the GCM models (Hardly 2, UKMOTR, CSIRA and ECHAM 4). The stabilized commercial shrimp yield (SCSY) under current climate with annual temperature of about 26.7°c is 71.5kg/ha. Simulation based on the warming of the atmosphere by 2075 to about 28.7° C under the HADLEY2, 28.3°C under the UKMOTR, 28.1°C under CSIRA and 28.4°C under the ECHAM4 models shows increases from current climate.

The proposed adaptation measures for the fisheries sector are: -

- Promotion of effective formulation and implementation of the fisheries strategic management plan.
- Effective protection of spawning sites and fishing nursery areas.
- Promotion of research development.
- Promotion of monitoring control and surveillance of fishing grounds and fish stocks for sustainable exploitation.
- Promotion of climate change related education and awareness programmes.
- Provision of financial resources and institutional capacity.
- Closed season this option could be adopted when the fishering is under threat of either over exploration or adverse effect of climate change. This option could allow for the restoration of either the degraded habitat or recovering of the fisheries.

Impact of Climate change on Vegetation Cover

Under current climate, the land in Sierra Leone has the potential land cover of about 6% **tropical wet forest**, 49% **tropical moist forest**, 21% **sub-tropical wet forest**, and 23% **sub-tropical moist forest**. The overall indications from the Holdrige Life Zone classification analysis are that under an equilibrium climate, the potential land cover of Sierra Leone as projected by the GCM outputs used in this study predicted 66% (HADC), 55% (UKTR), 66% (CSIRO) and 81% (ECHAM) **tropical dry forest** and 30% (HADC), 55% (UKTR), 26% (CSIRO) and 13% (ECHAM) **tropical very dry forest** categories as a result of the projected decrease in precipitation ((figure 2) and associated increase in bio-temperature (Figure 3) by year 2100.

Basically, as a result of climate change, 60% of the country will be under **tropical dry forest**, 24% under **tropical very dry forest**, and 12% cover under **sub-tropical moist forest** particularly in the South and East of the Country. This is the reverse of the current situation and indicates a northward shift in the vegetation i.e. from **tropical rain forest** to **tropical dry forest.**

In respect of the Forest Gap simulation scheme, Figure 6 shows the total Biomass produced under the various climatic scenarios and indicates that there is an overall gradual increase in total biomass production in the following five models used in ascending order of magnitude: CURR, CSIR, UKTR, ECHAM, and HADC.

Figure 7 similarly predicts the same trend for the Basal area Production but with a wider difference of $450M^2$/ha between CURR and CSIRO. HADC continues to dominate the total basal area production.

Species distribution per size classes for each specific year is shown in Table 3. Hannoa klieneana is by far the fastest growing species attaining the 6^{th} diameter class (over 60cm diameter) in 25 years. The slowest growth was exhibited by seven species (Chorolphora, Cordia, Daniella, Gmelina, Khaya, Nauclea and Parkia) out of the twelve species used in the simulation.

Potential adaptation measures will include silvicultural interventions such as appropriate management, for example, adjusting planting and harvesting dates, switching to more drought-resistant species, refining and liberation thinning.

Impacts of Climate Change on Water Resources .

In this study, the vulnerability and adaptation of water resources to climate change in Sierra Leone is assessed by simulating the hydroclimatic cycle using the monthly, spatially lumped and one dimensional water balance model, WATBAL. The runoff model was executed to generate 100 monthly flow sequences assuming (i) no increase in global temperature, dT/dt = 0, and (ii) a warming trend dT/dt. The flow is described as Low Flow (LF) when it is one standard deviation lower than the average flow, described as Normal Flow (NF), and is described as High Flow (HF) when it is one standard deviation higher than the average flow.

The model was run with the values for LF, NF, and HF as input in combination with the climate change scenarios developed from the GCM outputs. The results indicate that with the projected climate change, flow of the Rokel River Basin will increase by about 1% to 7% by 2100. However, the United Kingdom Meteorological Office Transient Model (UKTR) predicts a decrease of about 5% to 6%.

The adaptation measures proposed for the water resources sector include: -

a) The efficient management of water resources aimed at reducing demand and increasing the supply base. The reduction in water demand can be achieved through the identification and adoption of positive attitudes that would lead to the use of less water, and recycling and reuse of water. Also, efficient water use can be facilitated through education, voluntary compliance, pricing policies, rationing of water or the imposition of water conservation measures.

b) Improved planning and coordination of the use of the river basin, which may provide solutions to problems of water quality and supply. Planning can also help to address the impacts of population, economic growth, and changes in the supply of and demand for water. The cost of developing contingency plans is small in comparison with the potential benefits.

c) Effective monitoring and management of the watershed is considered crucial most, as climate change is likely to affect the frequency of floods and draughts. Monitoring systems will assist in coping with theses changes and will be of immense benefit without climate change.

Research and systematic Observations

In order to achieve the goals and targets of the International Community on Research and systematic Observations, effort should be made to address these issues of Research and Observations. As indicated in the study research in Sierra Leone is not properly addressed. Only a few national institutions in the country are involved in research activities such as the Meteorological Department in the Ministry of Transport and

Communications, Department of Environment in the Ministry of Agriculture, Forest and Food Security and Environment, Ministry of Health, Njala University and Fourah Bay College. Research is on the way to reorient most of the present policies, particularly those related to finance and natural resources management, in the direction of sustainable economic and environmental development and management. This in no small measure will help to mainstreaming climate change concept into development programmes of Sierra Leone.

Climate and Climate Change studies and assessments are highly dependent on reliable meteorological, hydrological and environmental data and information. Hence the need for representative network of systematic observations i.e. ground based data, satellite and communications networks. To achieve this, government as a priority should improve without delay the current conditions of service of its workers thereby attracting qualified personnel into the service.

Priority activities for the improvement of systematic observations of Sierra Leone includes: -

- Strengthening of the climate data base of all institutions in the country, provide up to date computer facilities and train experts in the input and storage of climate related data.
- Provide automatic recording equipment and instruments for continuous recording of meteorological, hydrological and climatological elements and phenomena.
- Rehabilitation and expansion of meteorological stations for the collection and monitoring of all categories of data.
- Capacity building in Human Resource in the meteorological department should be addressed in order to meet the present and future challenges.
- Education and sensitization of the public on climate change issues.
- Strengthening of the national climate change committee (NCCC) to be able to advise the Government on climate change matters appropriately.
- Intensification of research on climate change in Sierra Leone.
- Collaboration with the national and international institutions in the field of research in climate change.

Education, Training and Public Awareness

The public needs to be adequately informed about issues relating to climate change. This can be achieved through education in both the formal and informal sectors of the Educational System of the country. At present, climate change is not fully addressed as an isolated component in our educational system, rather it is treated as subsections in subjects like Geography, Environmental Physics and some aspects under energy studies. We are hopeful that the Ministry of education and all other sectors in the national Economy will design the curricula to reflect issues relating to climate change. The mitigation and Adaptation measures identified in all sectors considered in this National

Communication should be incorporated in the school curricula at both lower, basic and tertiary levels.

It is pertinent to note that during the implementation of the various studies incorporated in the National Communication, sensitization and public awareness campaigns were carried out by the project throughout the country targeting grassroots people, high level government officials, Ministers, NGO's, CBS's, farmers, teachers, students etc.

CHAPTER ONE

NATIONAL CIRCUMSTANCES
SIERRA LEONE

1.0 GENERAL DEVELOPMENT CONTEXT

Sierra Leone got independence from Britain on April 27, 1961 and attained its Republican status in April 19, 1971. As the country was greatly deficient in public infrastructure when it became independent, major plans were made for rapid development, based on its abundant unexploited natural resource endowment, including a wide variety of rich mineral, agricultural, forest and marine wealth. Despite some improvements were achieved by the end of the first decade, but a combination of global factors such as the oil price crises and fluctuating commodity prices, and poor economic response policies the country started showing signs of economic decline. Since the mid-1980s, the country has suffered dramatic economic decline and political instability. It went through five military coups, 1967-1991), and a brutal armed conflict that lasted for just over ten years (March 1991-January 2002).

Sierra Leone's political instability can be traced from a wide variety of internal and external factors. The rising inequality between the majority poor and a small rich group, poor governance of major public institutions, mismanagement of public financial resources and relative neglect of rural communities are some of the internal factors. The worsening terms of trade for the country's limited export commodities, increasing imports as well as adverse social and other developments in the world economy are the external factors that have compounded the country's problems.

On the economic front, annual growth averaged about 4 percent and 3.5 % in the 1960s and 1970s respectively. Growth slowed dramatically to an average of 1.5 % in the 1980s, largely on account of misguided economic policies and economic mismanagement. In the late 1970s and early 1980s, the government embarked on a major public expenditure in hosting the OAU Summit, which affected the development budget as the public and private borrowing increased. As a result, in the late 1980s, Government introduced a series of macroeconomic and structural reforms on the advise of the multi-lateral institutions (reduction of the budget deficit, liberalization of the exchange rate, abolition of price controls and exchange restrictions), but the results fail to improve the situation. The civil war in the 1990s worsens the situation and the economy plunged at an average of – 4.5 % per annum between 1990 and 2000. However, recent trends indicate that some stability in the economy has returned. Since 2000, the economy has been growing between 5.8 and 6.8% per annum, mainly due to reconstruction and more prudent economic policies.

1.1 GEOGRAPHY, CLIMATE AND DEMOGRAPHY

1.1.1 Location of Sierra Leone:

Sierra Leone has an area of 72,325 km^2 between latitudes $6^0$55' and $10^0$00' North and between longitudes $10^0$14' and $13^0$17' West. Sierra Leone is bordered in the northeast by the Republic of Guinea, in the south and southeast by the Republic of Liberia and in the west by the North Atlantic Ocean (Fig.1.1).

The country is divided into four (5) main geographical regions: the coastline, interior lowland plains, interior plateau, the mountains, and Freetown Pennisula. The coastline of Sierra Leone is part of the general coastline of the West and Central Africa region, which is a low plain, sandy and surf beaten. The general coastline orientation is North-west-south-east and is strongly determined by the local structural and lithological framework. Four broad coastal geomorphic types are recognized in this region which is also typical of the Sierra Leone coast: -

- Drowned coasts in the northern area;
- Sand bar or lagoon coasts along the North of the Gulf of Guinea;
- Deltas associated with most rivers (e.g. Niger Delta) usually with mangrove swamps;
- Coasts with sand spits (and tombolos) formed by accumulation of longshore transported sand in bays and estuaries.

The drainage system consists of a series of rivers from North to south including the Great Scarcies, Little Scarcies, Rokel, Jong, Sewa, Moa and Mano rivers. The interior lowland plains extend form coastal terraces in the West to the East of the country occupying about 43% of the land area. The interior plateau is made up of granite that runs from the northern part of the country to southeast. They seldom rise above 700m and are comprised of alluvial iron stone gravel in the southeastern region while the north end is comprised of weathered outcrops of granite rocks. The higher mountains are found in the North and East of the country, Loma Mountains and Tingi Hills respectively. The highest peak in the Loma Mountains is the Bintumani and rises to 1945 metres. The Sankan Biriwah of the Tingi Hills rises to 1885 metres. The Freetown peninsula is made up of dissected mountainous Peaks with Sugar Loaf and Picket Hills being the highest.

Figure 1.1: Physical Map of Sierra Leone

1.1.2 Climate of Sierra Leone

The mean long-term wind regime over Sierra Leone is influenced by the distribution of atmospheric pressure over the tropical zone of the Atlantic Ocean in spring, and in autumn respectively due to two major atmospheric high-pressure systems: the St. Helena or South Atlantic Maximum and the Azores or North Atlantic Maximum. The equatorial atmospheric depression between these two high-pressure systems exerts a less prominent influence on the wind regime over Sierra Leone.

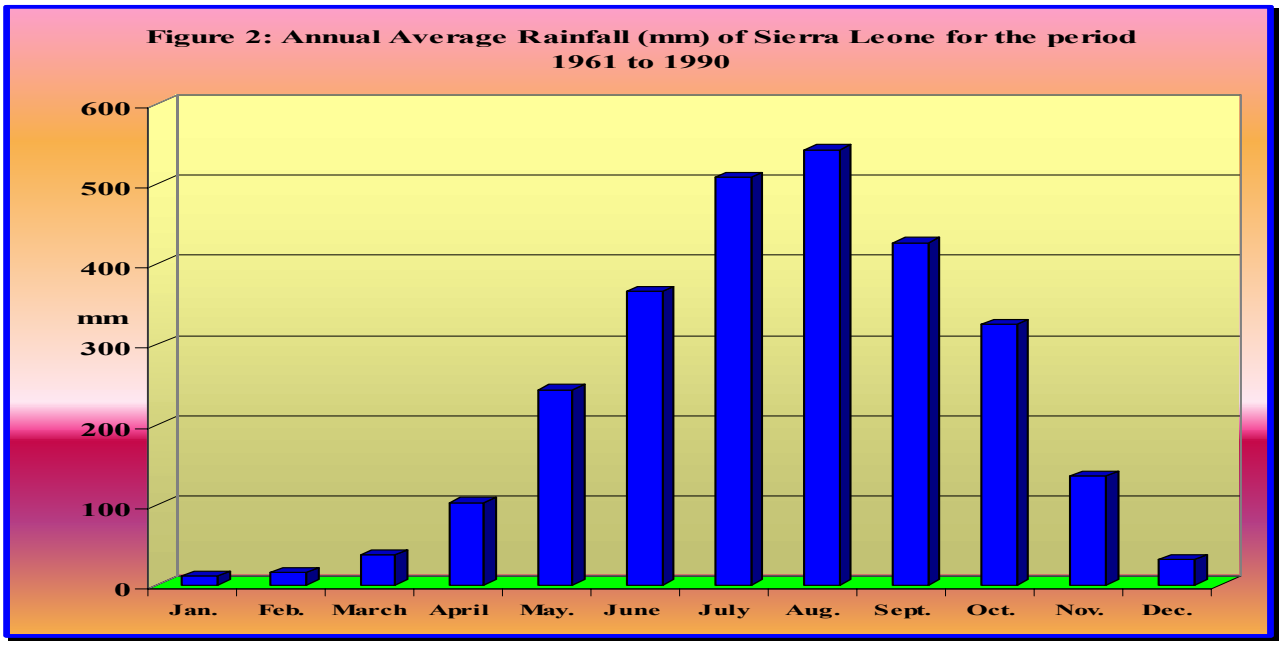
Local changes in atmospheric pressure resulting from temperature differences between land and the adjacent ocean as well as to orographic and land cover differences exert local changes in wind patterns on a diurnal and other short-term periods.

Sierra Leone has a tropical climate with two distinct seasons. The dry season (December to April) is dominated by winds from the Northeast (i.e. the North–east trades), and the rainy season (May to November), the Southwest monsoon dominates. Both seasons may have some variations in their commencement and duration. The Northeast trades otherwise known as the Harmattan are relatively cool and humid. In May to November, the winds are unstable in terms of direction and from June to October South-westerly winds dominate. During the rainy season, clouds of vertical development of 8-10% general prevail everyday. These are usually accompanied by rainfall. The highest observed cloudiness from the area 6-7 and are closely related to the influence of the equatorial monsoons blowing from June to November. The cloud amount decreases to 3-5 a month during the months of December to April.

The highest amount of rainfall occurs during the rainy season, which lasts from May to November. The heaviest rains occur in July and August (Fig 1.3). The mean monthly

amount of rainfall reaches its maximum in July and August, when the average number of rainy days is 27.

Figure 1.2: Average Monthly Rainfall Distribution in Sierra Leone for 30 year Period, 1961 - 1990



The mean long-term air temperature regime shows an average monthly temperature of between 26-28^{0}C from June to October, with a maximum temperature of 32^{0}C. Temperatures of up to 36^{0}C have also been recorded especially during the month of March. A minimum temperature of 20^{0}C has also been recorded. Air humidity according to monthly means can be as high as 80-90% during dry season and decreased to 70-80% during the rest of the year. The mean monthly occurrence of mist is approximately 1%. The visibility is obstructed by haze, the frequency of occurrence of which increases from 25% to 40% during the period from December to May. Its frequency from June to September is 3-5%. From December to February (Northern Winter), mist occurrence in the area increase to almost 2% a month.

1.1.3 Population & Demography

Sierra Leone has a population of 4,976,871 based on the 2004 national census. Growth of Sierra Leone's population has been positive although a decline is recorded from 2.3 percent between 1974 and 1985 to 1.8 % in the nineteen year period between 1985 and 2004.

At national level the sex ratios over the years have revealed a dominance of females. Results of the 2004 census indicate that the percentage of females reached its highest of 2.9 percent since the first national census in 1963. This then suggests that the male population accounted for 47.1 %.

The urban population has grown from about 31.0 % in 1974 to an estimated 39 percent by 2003 (UNFPA 2005), suggesting that slightly over sixty percent of the population still live in the rural areas. Fertility has experienced only slight decline overtime. The current estimate of the Crude Birth Rate is 42 births per thousand populations. The current Total Fertility Rate (TFR) of 6.1 children per woman, based on the 2004 census returns, little declined since 1974, when the TFR was 6.5 children. Government has viewed fertility levels as high and unacceptable since the eighties.

With respect to mortality, all indices point to an unsatisfactory situation. With a Crude Death Rate of about 20 percent thousand, Sierra Leone remains one of the Sub-Saharan countries with the highest death rate. With an Under 5 Mortality Rate 297 for males and 271 for females, the country records the highest rate in Africa. These rates are even higher than the average for the least developed countries (160 for males and 149 for females). This shows decline overtime. For example, the Crude Birth Rate is estimated to have declined from 36 per thousand in 150 to its present level of 20 deaths per 100 persons. Life Expectancy is still low. Results of the 2004 census suggest an overall of 48.4 years. This however reflects increase overtime.

1.1.4 Vegetation Cover and Land Use

Sierra Leone has six (6) major ecosystems: Forest, Montane, Savanna, Agricultural, Wetland and Freshwater and coastal and marine. Each of these ecosystems is characterized by certain dominant vegetation and wildlife.

Deforestation accounts to a large extent for the environmental degradation in the country. The traditional farming practice of shifting cultivation, with declining fallow periods, have over the years left vast areas of land deforested in much of the country. It is estimated that 600,000 hectares of forested lands (or 8% of total arable uplands) have been cleared for farming. The problem is further exacerbated by the high dependence of the population on fuel wood as the main source of energy for cooking and a lesser extent for cottage industry. While uplands continue to be the principal source of fuel wood and construction materials, mangroves along the coastal areas are being increasingly exploited for fuel wood, boat construction, and rice cultivation. This has led to increased exposure to storms and destruction of natural breeding grounds for marine and estuarine fish and other organisms.

In the northern region of Sierra Leone where 60% of the cattle and small ruminant population is concentrated, over 8,300 sq km of land has been left bare due to overgrazing. There are no attempts at any form of range and pasture management; bush fires continue to affect about 200,000 hectares of savannah woodlands annually. Thus, overgrazing and annual bush fires have caused an apparent ecological change from savannah woodland to grassland in the cattle rearing areas.

Mining activities, particularly in the eastern and southern regions, have also left vast areas deforested and degraded. It is estimated that between 80,000 and 120,000 hectares

have been mined in different parts of the country with minimal efforts at reclamation. The uncontrolled exploitation of mineral resources, coupled with the very few mitigating policies and conservation programmes over the years, and poor enforcement of those existing has resulted in devastating environmental consequences.

Table 1.1: The relative area of the various vegetation types are as follows:

Vegetation/Land-use type	Area km^2	%	Dominant land-use
Closed high forest	3,652	5	Forest Reserve, Timber
Secondary Forest	2,610	3.6	Timber, firewood, coffee, cocoa
Forest Regrowth	37,744	52.2	Fallow with arable crops in mixed stands, fire wood
Savanna woodland	6,226	8.6	Grazing, Bush fallow with arable crops in mixed stands
Mixed tree savanna	7,320	10.0	-do-
Lophira tree savanna	2,646	3.7	Grazing
Coastal woodland	501	0.7	Bush fallow, arable crop in mixed farms
Coastal tree savanna	564	.8	None
Upland grassland	2,552	3.5	Bush fallow with arable crops
Montane grassland	40	0.1	Grazing
Rock outcrop	500	0.7	None
Mangrove swamp forests	1,716	2.4	Paddy rice cultivated
Fringing swamp forest	288	0.4	-do-
Raphia swamp forest	355	0.5	-do-
Swamp/riverine grassland	1,819	2.5	Bush fallow, rice some arable crop
Swamp cultivation	2,039	2.8	Paddy rice some water controlled
Upland crops	1,640	-	Arable crops, orchards, scattered crop, plantations
Oil palm plantation	63	0.1	Oil palm
Rubber plantation	21	-	Rubber
Forest Plantation	25	-	Timber/Firewood
Source: FAO/LRS, 1980			

1.1.5 THE ECONOMIC TRENDS

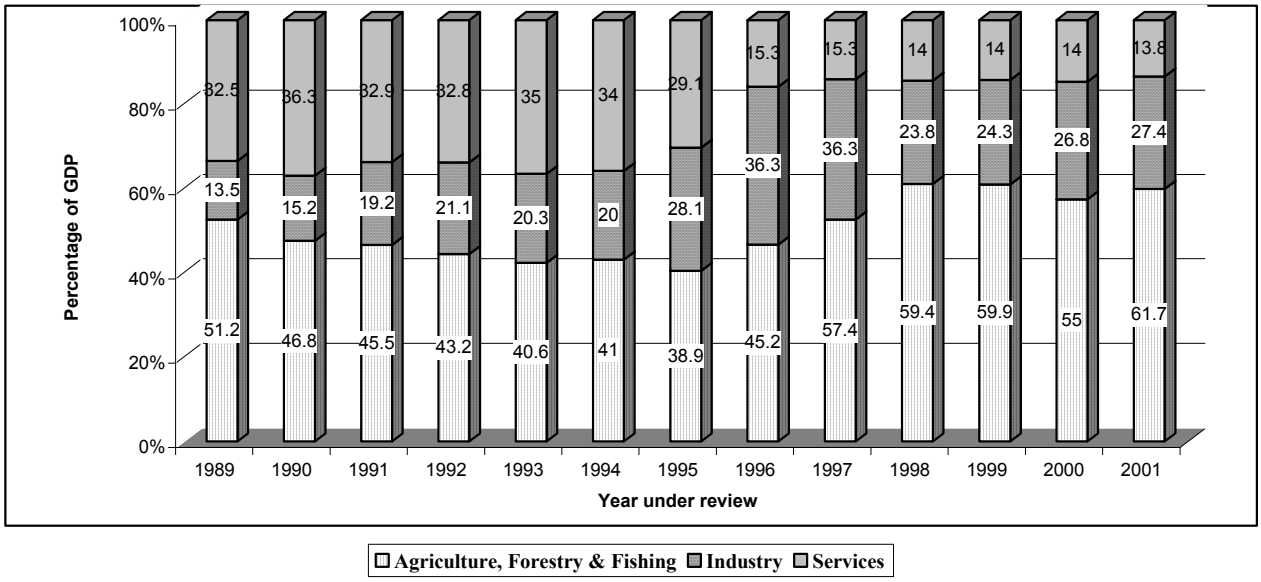
Sierra Leone is a small open economy that has suffered prolonged deterioration and an accompanying low standard of living of the vast majority of the populace despite its significant resource endowments. Past policies of successive governments since the 1970s have failed to address the long term challenges of the country's economy and the standard of living of the majority has been largely marginal.

Agriculture and its associated activities is the dominant sector of the economy, about 40% of the GDP and sustain about two-thirds of the population, but mostly at a bare subsistence level. The mining sector, which is largely export oriented is the next largest productive resource in the economy and provides about 20 percent of GDP. The potential of both the agricultural and mining sectors are yet to be fully exploited. Policies are needed for exploiting and utilizing the resources in these sectors for the benefit of most people. The manufacturing sector is small with mostly import-substituting industries that

employ about 2 percent of the labour force. The service sector accounts on average for about 15 percent of GDP. This sector comprises mainly transport, communications, insurance, finance and government services. The respective shares of these sectors to the national economy are shown in figure 1.2 below.

Fig. 1.3

Figure 2. Percentage of GDP by activity : 1989 - 2001

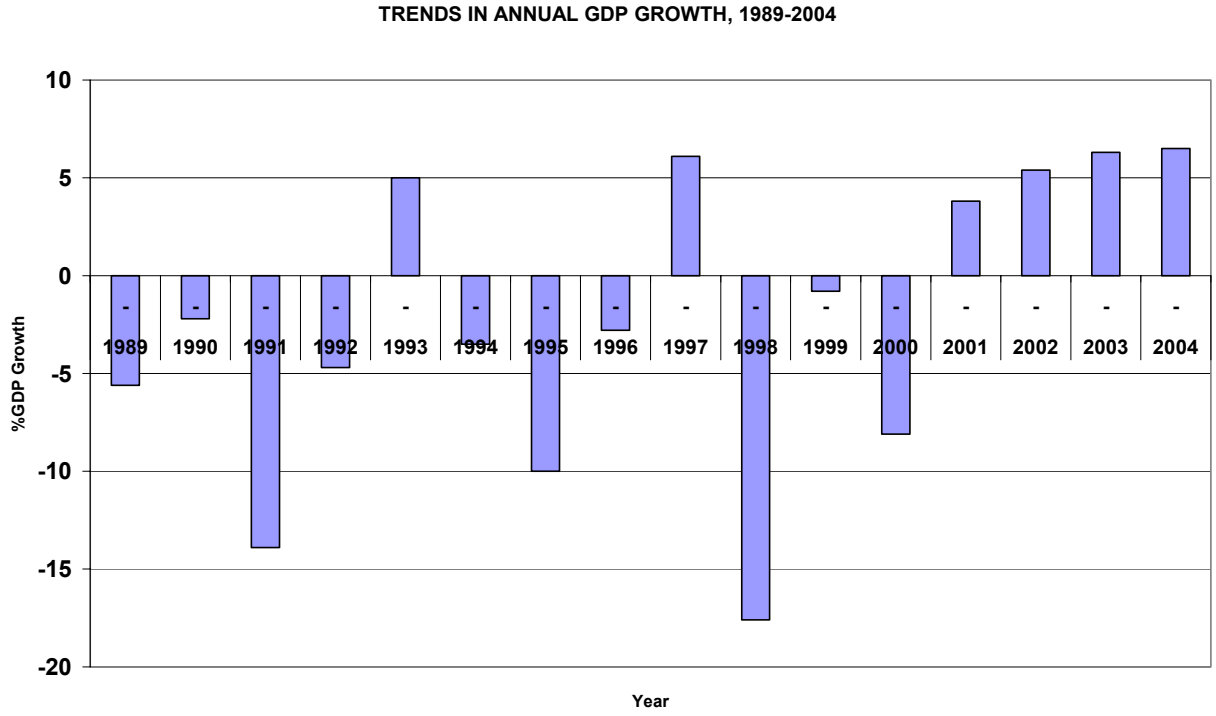


Generally, the average annual growth rate of GDP has been declining until recently as shown in figure 1.3. The moderate economic gains achieved by Sierra Leone between 1966 and 1970 with average annual growth rates of around 4% declined to 2.1% between 1971 and 1980, and to a further decline of average annual rate of 0.07% between 1981 and 1989. This decline in the economy can be attributed to a combination of factors such as weak internal management policies, poor performance of the economic recovery programmes and weak export prices in the face of higher import prices. The impact of the Structural Adjustment Programme (trade liberalization, stabilization of the exchange rate, removal of subsidies on petroleum products and staple foods) as advocated by the World Bank/IMF on the overall economy has been mixed. As a result, any gains that may have been achieved by these policies were reversed by escalating prices on the staple food. Strategies such as planned privatization of public enterprises and restructuring of the civil service for more efficient services are on-going, but signs of any positive impact are yet to be identified. Overall benefits of this programme are yet to be realized by majority of the citizens. This situation got worsened by the rebel war which led to devastation of the economy and the social infrastructure of the country. The production in the agricultural, mining and industrial sector was badly disrupted. As output and exports declined so was the increase in external debt reaching an estimated US$ 1.2 billion in the year 2000.

The weak economic performance is fully reflected in the country's GDP per capita. It drooped from US$380 in 1980 to US$237 in 1990 and US$142 in 2000. The negative annual growth rates of -13.9% in 1990/91 and -17.6% in 1998 clearly illustrate the

economic impacts of the war. However, there has been a steady rise in growth rates from 2001 to 2004. The growth rates increased from 3.0% in 2001 to 5.4% in 2002 and this trend continued to 6.3% in 2003 with a growth of 6.5% in 2004, and expected to exceed 7.5% in 2006. This steady rise reflects the continuing recovery in agriculture and expansion in the manufacturing, construction and services sectors of the economy. This improvement has reflected in the increase in GDP per capita rising from US$142 in 2000 to US$160 in 2002, and to US$210 in 2004.

Fig. 1.4



1.2 SITUATIONAL ANALYSIS IN RELEVANT SECTORS

1.2.1. ENERGY PRODUCTION AND USE

Sierra Leone is reasonably well endowed with renewable energy resources, namely hydro, solar and biomass, but very little fossil fuels. Exploration for crude oil has been going on for sometime now in the South west of the country, and recently licences were given to four exploration companies, but no official records yet of success. Some lignite reserves that are estimated about a million tonnes have been found in the western area. Hydro sources are mainly along a network of rivers and tributaries that have a potential estimated above 1,200 MW. Solar energy is in abundance being a tropical country, but wind speeds are mostly between 2-5 m/s and only in limited areas and limited periods. Apart from the large forest areas in the country, agricultural and crop residues are estimated to about 2 million tonnes of oil equivalent available annually. Most of these resources are yet to be exploited.

Since the petroleum refinery was shut down in the mid 1980s, Sierra Leone imports all of its petroleum product requirements to satisfy its modern energy needs especially for electricity production and for the transport sector. Electricity is mainly produced from oil-fired thermal power plants. Hydro power forms less than 10% of all electricity produced. Currently, the country faces difficulties with electricity supplies as electricity generation capacity is grossly inadequate and load shedding is common as well as management problems. As a result only about 10% of the population has access to electricity.

Sierra Leone's energy use is characterized by the dominance of traditional fuels-firewood and charcoal in the domestic sector largely for cooking. Traditional fuels represent over 80% of primary energy consumption in the domestic sector. Biomass (firewood and charcoal) constitutes over 80% of total primary energy consumption. The major areas of production have become heavily exploited. As much as 30% of the wood produced is converted to charcoal. In terms of volume, charcoal forms only about 10% of wood resources used for energy production.

Table 1.2: Energy use patterns of the poor and non poor

Activity/facility	% of poor utilizing facility	% of non poor utilizing facility
Kerosene	89	69
Fuelwood	99	78
Charcoal	1	15
Electricity	2	29

Source: Sierra Leone Integrated Household Survey – Consumption Aggregates and Poverty Estimates, Statistics Sierra Leone

Apart from the high wastage of useful energy related to the dominant use of firewood and charcoal, it has serious adverse environmental problems including those relating to health and safety aspects. Also, a more challenging aspect is the security of its supply base. Due to increase use of these fuels as a result of increase incidence of poverty the demand continues to grow especially in urban towns with no signs of declining trend. Another noticeable trend is the substantial increase in the supply of charcoal to the urban areas from the rural areas. Charcoal burning seems to be an attractive option for entry by the refugees of the 10 year rebel war and similar refugees from neighbouring countries. As a result, the supply of charcoal along certain rural axis increased substantially. With no short of demand, the supply continues to reduce. Due to the limited resource base, this feature has led to major deforestation of forest lands. This trend must be checked for the future sustainable development of the country. Alternatives to these cooking fuels are very important especially for the urban towns that provide the market for these fuels.

1.2.2 AGRICULTURE

Agriculture including livestock and fishing is the largest employer in the country, 75% of the population, and the greatest contributor to the GDP (45%). However, surveys done by the government indicated that farmers are the poorest in the country, especially the subsistence food crop farmers. The sector has many challenges which can be summarized as follows:

- Low capital investments and weak support for R&D work, technology generation and poor extension services
- Absence of viable technology based inputs
- Weak credit and micro-finance systems to support purchase of inputs
- Poor transport networks for agricultural produce
- Low participation of farmers in policy-making and other decision making processes
- Institutional weaknesses along with poor human capacities

Fisheries that contributes about 9.4% to the GDP is the most economic activity along the coastline, and is the largest single source of animal protein in the country. However, the fisheries sub-sector was badly affected by the civil war and this made people along the coastline to be among the poorest of the country.

Food insecurity is one of the problems in Sierra Leone, both in terms of food access and poor quality of food intake. In 2002, FAO estimate shows that out of 580,000 metric tons required by the country, only 46% of the cereal consumption (especially of rice, the staple food) was met by local production, the rest was from imports and food aid.

However, after 1999, there has been a visible increasing trend in food production as shown in table 1. The major constraints of agricultural production and productivity still remain, including shortage of quality seeds, pesticides, fertilizers and modern implements; post-harvest losses; and a poor marketing system.

Table 1.3: Food Production Trends from 1999 to 2003 (Thousand metric tons)

Crop	1999	2000	2001	2002	2003
Rice	248	298	311	422	445
Sweet Potato	20	28	21	25	28
Groundnut	29	15	49	98	34
Cassava	240	241	314	400	479

Source: FAO Statistics

1.2.3 FORESTRY

Sierra Leone is essentially a forestry country, but with the different forest types. It is estimated that forestry contributes about 2-4% to the GDP of which one-fourth is attributed to artisanal wood processing. Imports of wood based products are relatively small and erratic, and constitute mostly of plywood, high quality veneers and some sawn

coniferous timbers. Export of logs were initiated by SILETI in the late 1970s but has recently been prohibited by government because of its contribution to deforestation.

6.3million ha (87% of land area) is classified as forest lands (UNDP/FAO – LRS 1980). The forested area comprises of bush re-growth from shifting cultivation system (60% of the total), is distributed as shown in table 2. 5% (365,200ha) are the government Forest Estate that is made up of gazetted Forest Reserves, proposed reserves not yet legally gazetted, protected forests on chiefdom lands, and Game Reserves and National Parks

Table 1.4: Forest Resource Areas

Forest type	Area '000ha	%
Closed high forest	365	5.8
Secondary forests	261	4.1
Forest regrowth	3,774	59.9
Savanna woodland	1,619	25.6
Mangrove and Associated forest	286	4.5
Plantations (Forest Trees)	4.0	0.1
Total	**6,309**	**100**
Source: FAO/TFAP, 1990		

The major forest types based on aerial photographs are.

- **Closed high forest:** has a closed canopy and trees are over 30m tall. Its potential is not fully known since areas of degraded forest are included in this category.
- **Secondary forest:** has a closed canopy with trees 10-30m tall most of it consists of re-growth often from farming.
- **Forest re-growth:** is by far the largest type of forest in Sierra Leone and is the outcome of the prevailing shifting cultivation system thus it can be considered primarily as fallow land which stays uncultivated from 5 to 8 years. The rate of deforestation of closed high forest is increasing particularly in the Northern Province and less in the Southern and Eastern Provinces. The re-growth vegetation is commercially and socially important since it provides the bulk of the fuel-wood requirement for the urban and rural population of the country.
- **Savannah woodland:** consists mainly of areas with a crown cover of 20-50%. There are very few savannas with a crown cover above 60%. Their productive potential is limited.
- **Mangrove Swamp forests:** contain mostly stunted shrubs and some trees up to 10-20m tall. There are quite significant areas of mangrove forests left although most of the usable wood have been exploited for fuel-wood/fish smoking during the last three or four decades.

A national forest policy exist within the National Development Plan (1974/95 – 1978/79), though not implemented for variety of economic and political reasons. The relevant aspects for the Forestry Sector are follows:

- Acquisition, management and protection of a forest estate, including the development of plantations, sufficient to ensure the supply of sawn timber poles and fuel-wood and to maintain the quality of the environment.
- Development and expansion of the saw-milling industry in both the Government and private sectors to ensure maximum production from the natural forests and plantations.
- Establishment of wood using industries to ensure maximum utilization of the timber produced by the forests.
- Conduct of forest research and forest training programmes to the extent necessary to sustain the foregoing requirements.
- Preservation and conservation of the country's wildlife resources.

The goals to be achieved are to increase the area under forest from 4.3% to 10% by reservation of an additional 1,600 square miles, to increase the area under plantations by 25,000 acres, to finance and reorganize the Forest Industries Corporation (FIC) and to ensure adequate control over timber concessions and to strengthen the Forest Department at all level.

For decades forestry has been neglected and its role in land use and economic development has been largely overlooked. The situation has further deteriorated in recent years, and in effect no forest management has been exercised, partly due to the archaic and inadequate forest law but mainly due to inadequate funding.

1.2.4 EDUCATION

The Government of Sierra Leone has long prioritized education in its programme but have struggled with providing the means to bring quality learning to all school-aged children. Even before the war ended, in 2002, the government began efforts to increase school enrolment. In 1999, the government undertook the payment of school fees in all government owned and assisted primary schools; waived national examination fees; an in 2003, basic education was made compulsory.

As part of its push to meet Millennium Development goal of ensuring quality education for all by 2015, the government has renewed its focus on education of girls. From 2003 the government provides full support to girls successful in the National Primary School Examination (NPSE) for Junior Secondary School (JSS) in the Northern and Eastern Provinces, two priority regions for boosting the enrolment and retention o girls. By 2007, JSS education for all girls will be free. Estimates that primary school enrolment now exceeds one million and to accommodate the influx of students, and to provide access to learning in remote areas, two programmes were instituted, Complementary Rapid Education for Primary School (CREPS) and Non-Formal Primary Education (NFPE)/Community Movement for Education (CoME). Basic Education for children is now compulsory in Sierra Leone according to the Education Act of 2003. However, there are many challenges facing the sector..

Prior to the conflict in the country, there were considerable regional disparities in the country's education system and the fighting only served to widen the gaps with the northern and eastern provinces falling further behind. School enrolment in the Western Area is estimated to be 75 percent, while in the Northern Province, 25 percent. The student-teacher ratio, a relationship that greatly affects the quality of education, is estimated at 23:1 in the Western Area an 82:1 in the Eastern Province. The North province suffered greatly during the war, especially its educational system that was already inadequate before the conflict.

Within the under-performing northern and eastern provinces, the northern District of Koinadugu has the lowest access to education in the country. Also there is gender disparity. Countrywide girls make up 45 percent of enrolled students; in Koinadugu that percentage shrinks to 32 percent. From enrolment and retention, to the student-teacher ratio, to gender disparity, the district's educational needs are great.

1.2.5 HEALTH

Sierra Leone has poor health indictors. The situation was worsened by a decade of protracted civil war from 1991 to 2001 which led to virtual collapse of social services and economic activities in most parts of the country. As a result, it has found itself among the countries with the worst UNDP development index indicators. The under-five child mortality rate and the maternal mortality ratio have stagnated and remain unacceptably high at 286 per 1000 live-births3 and 1,800 per 100,000 live-births and 1,800 per 100,000 live-births respectively. After cessation of hostilities in 2002, the government and other agencies embarked on series of national recovery and reconstruction initiatives. These have steadily restored functional government machinery and social services in all districts; and the mode of operations have changed from national recovery to development with the completion of the government's poverty programme (PRSP) in 2004.

A recent survey by the government show that the major challenges of the sector were the general lack of relevant documentation such as annual reports, difficulties meeting key stakeholders, transport difficulties and the limited time for the assignment which required extensive travel across the whole country and meeting a wide range of stakeholders. Life expectancy has dropped from 42 years in 1990 to 34.5 years in 2001. The provisional results of the 2005 Multiple Indicator Cluster Survey showed that the infant and under-five child mortality rates have not changed from the 2000. The results show unacceptable high levels of 170 and 286 per 1000 live-births respectively.

This compares unfavourably with the West and Central African countries average of 109 and 191 infant and infant and under-five mortality rates respectively. The maternal mortality is also among the highest in the world and is estimated at 1,800 per 100,000 live-births. The nutritional status of the population is equally poor. Moderate and severe stunting prevalence in under-fives increased from 34% and 16% in 2000 to 40% and 20% in 2005 respectively. Iodine deficiency disorders are still a public health problem even though there has been significant improvement of goiter and iodine deficiency prevalence rates from 25% and 97% in 1992 to 3% and 33.5% in 2003 respectively. The 1998

micronutrient survey reported 40% of vitamin A deficiency prevalence among children below five years; and 86% anaemia among pregnant women. The 2005 VAM also reported anaemia prevalence of 74% and 68% among children 6 months to 59 months in rural and urban areas respectively.

The poor health and nutrition indicators of the country can be attributed to a high disease burden. Malaria (35.1%), aqcute respiratory infection (21.7%) and watery & bloody diarrhea (8.1%) are the top most causes of outpatient attendance, together accounting for about 65%. The health facility records is an underestimation when compared to the two week prevalence rates reported in the 2005 VAM report. These three diseases together with malnutrition account for about 75% of under – five consultations comparable to reports of th Lancet series. Although the under-five is about 17-20% of the population they make up 49% of consultations at PHUs. Malaria is hyperendemic/holo-endemic in the country, and affects the whole population, but children under five years and pregnant women are most vulnerable with high morbidity and mortality. Malaria, diarrhea and acute respiratory infections account for 33%, 29% and 14% of the under-five mortality respectively.

The country also experiences from time to time outbreaks of the following epidemic prone diseases: cholera, yellow fever, shigellosis, lassa fever, measles, meningitis, typhoid fever and anthrax. Additionally, the country is not spared of the HIV/AIDS pandemic. Though the national population based sero-prevalence of 1.53%, factors such as high prevalence of sexually transmitted infections (STIs), poverty, ignorance and a youthful population can easily fuel the pandemic.

1.2.6 WATER SUPPLY

The water supply in Sierra Leone (Freetown and the inland settlements) requires very urgent attention. Guma Valley Water Company is incapable of meeting the water supply requirement of the city whilst SALWACO and the Water Supply Division of the Ministry of Energy and Power also incapable of supplying inland settlements and other rural areas.

Water supply to Freetown and its environs is by the Guma Valley Water Company, which was established in 1961 to serve the then population of 800,000 people. Due to Urban migration as a consequence of the civil conflict, water demand in the city of Freetown now far exceeds the supply. This is responsible for water shortage affecting many parts of the city. In addition, frequent power shortages have exacerbated the situation, as water cannot be lifted to the high well areas where power is needed to pump the water. To cope with the current water demand and achieve wider equity in water supply, the Guma Valley Water Company has introduced nighttime rationing in many areas including settlements of the Peninsula Road. From Juba westwards and parts of Kissy and Wellington.

Water supply is constrained by the rapid uncontrolled and uncoordinated planning of expansion of the city without utility services and the damage and deliberate removal of water meters from supply lines thereby depriving Guma Valley Water Company of much needed revenue. Also the unwillingness of unconnected consumers to pay for water for

use of stand posts. Loss of catchment areas due to deforestation, misuse of company facilities such as cutting and disconnecting supply lines by squatters and unconnected individuals are causing much loss of water.

Recently, the government adopted an improvement strategy which is to use Universal metering that was commenced in 1993 and is 75% complete with the hope to complete by the end of 2006. This project suffered several setbacks mainly during the war years 1992 – 2000 when many meters were removed. Also public standposts were erected to provide water for unconnected customers who would pay a minimal monthly fee using a card system but the programme collapsed in 2003 and efforts to resuscitate it have still not yielded the required dividend. In the long term, the company intends to build another dam, the Orugu dam

The Sierra Leone Water Company (SLAWACO) is responsible for Water Supply to the Townships of Bo, Kenema, Makeni and Lungi, Bo, Kenema, Makeni and Lungi. Reasonable water supplies are now operating on daily basis with increased coverage to consumers in selected areas such as Kenema. The Company is investing in economic water sources for supply water to urban provincial communities. They are also actively working with the Decentralization Secretariat to transfer water supply responsibilities to the local authorities. A general National Water Policy prepared by SLWACO with the assistance of the United Nations Economic Commission for Africa (UNECA) is being finalized.

1.2.7 WASTE MANAGEMENT

In Sierra Leone, waste management is mainly conducted in Freetown the capital and located in Western area. Hence, most of the discussion will be restricted to data obtained from the Ministry of Health and Sanitation on activities in Freetown. No data exist on waste management for both the rural and the provincial areas, about 90% of the country. However, Freetown, is the
the most densely populated area in the country, and is the sit of government, commercial and economic centre of the country, also hosts the harbour; the entry point of all imported goods and exit point of most exports in the country.

Wastes, is defined in Sierra Leone as “finished products that have been used and disposed of”. It is categorized into two groups; decomposable wastes and non-decomposable wastes. Non-decomposable wastes comprise sludge and lubricant oils, plastics and galvanized rubber, glass and metals/tins/scrapes, etc. Decomposable wastes comprise garbage from food, vegetables, other garden wastes and water wastes. Majority of the wastes generated in Sierra Leone are; food and garden wastes in the form of vegetables and fruits, plastics in the form of carrier bags, bottles and packets are major waste due to imported and locally produced items packed in plastics, paper (combustible waste) imported and locally generated items packed in cartoons, wrapped in papers, Wood waste in the form of sawdust, woodcuttings and shavings is another type of waste that is generated extensively by the timber industry, sewage (toxic and non-toxic) and solid

wastes (human wastes). and sludge wastes are generated from power stations in the country.

Generally waste is collected from markets places, offices and business centres, are collected in $20m^3$ containers placed at designated points, whilst for homes and small scale businesses, wastes are collected in smaller containers and deposited at designated points as well. Human wastes, septic/septic tanks are collected and deposited in designated points while those from traditional houses use dug up holes or deposited at designated sites using buckets. There are collection points for liquid wastes. They are usually emptied into the drainage systems by roads, streams or rivers or the sea. The sludge from power stations is usually collected and stored in selected places before disposal. Agricultural wastes from harvesting are normally collected in heaps at the location in farms and poultry and animal wastes are collected and dumped in designated sites.

Disposal of collected wastes is through four methods; Incineration, Landfills and Open-dumps, Composting and Recycling. Landfills and Open dumps are the most common methods used. In Freetown, wastes are disposed of in two authorized locations, but due to increase in population in Freetown, other unauthorized open dump sites have been created at locations where open lands and streams exist, especially in densely populated areas. Human wastes are collected from septic/septic tanks using specialized septic vehicles and disposed off at the Kingtom landfill site, and those from pits, are buried or emptied at the sea. The incineration of combustible wastes is done mostly during the dry season. Those incinerated are burning of garbage wastes that is done both in homes and unauthorized open dump sites and burning of wood-shavings and Sawdust. Composting is done mostly on food and garden wastes. This is common in areas where vegetable farming is the main economic activity. Recycling is done mostly on non-decomposable items. The informal sector plays a very important role in this area. Pots, agricultural tools, tin lamps and bushings for cars are some of the items that are produced from recycling.

1.2.8 HUMAN DEVELOMENT AND POVERTY

Generally, poverty increased in the country during the economy decline, and became more pervasive and intensified during the 1990s, partly due to the war. About 82 percent of the population lived below the poverty line; Sierra Leone had one of the most skewed income distributions in the world, with a Gini Index of 66. Since 1996, Sierra Leone has been ranked among one of the least developed in the UNDP Human Development Index, and in 2005 was ranked second to the bottom. Unfortunately, the poverty situation got worsened by the rising incidence of typhoid, malaria and communicable diseases, including tuberculosis.

The social and economic impacts of the 10-year civil conflict (1991-2002) were devastating. The brutal attacks by the Rebels, the Revolutionary United Front (RUF) that began in March 1991 and backed by cross sections of the national armed forces left a trail of human tragedy. An estimated 20,000 people killed and thousands more injured. Over 2 million people displaced; 500,000 fled to neighbouring countries. There was a mass exodus of skilled professionals out of the country, leaving most of the country drained of

skilled manpower. The damages extended to significant loss of property and destruction of public and productive infrastructure. Mining and agricultural activities, the lifeline of the country, were essentially brought to a halt. Farms were ravaged or abandoned, while the livestock population was almost entirely wiped out.

However, significant progress has been made in stabilizing the economy and removing many of the structural impediments to growth, despite fundamental disruptions from the rebel war. On the overall, implementation of macroeconomic and structural adjustment programme has not brought the expected benefits in terms of sustained growth and human development. The fundamental aspects of the programme and their implementation that stressed stabilization and macroeconomic balance without adequate attention to the productive capacity of the nation or improvement of human conditions, especially of the poor did very little to improve the overall social and economic situation of the country. However, the country has embarked on a recovery programme since 2000.

1.2.9 Poverty Reduction Strategy in Sierra Leone

Government formulated a poverty reduction strategy to cope with the destruction of the country. It started with an Interim Poverty Reduction Strategy Paper (IPRSP) that was finalised in June 2001. The paper identified actions that address the challenges for transition from war to peace through a responsive poverty reduction programme and pro-poor economic growth. The IPRSP was implemented in two phases. The first phase (2001-2002), placed emphasis on restoring national security and good governance, re-launching the economy, and providing basic social services to the most vulnerable groups. The next phase (2003-2004) focused on good governance, revival of the economy, and social sector development. The emphasis was on measures: (a) to maintain economic stability; (b) to enhance the population's capacity to undertake income-generating activities, raising productivity and employment; (c) to secure the resources to fight poverty and deliver quality public services; and (d) to rebuild security, governance, justice, and human rights. The IPRSP provided the basis for a Poverty Reduction Strategy Paper (PRSP).

The National Recovery Strategy (NRS) was launched in October 2002 on the basis of district assessments and local recovery plans. The NRS focused on (a) the consolidation of state authority and peace building: (b) promotion of reconciliation and enforcement of human rights; (c) facilitating resettlement and reintegration and rebuilding communities; (d) facilitating access to previously inaccessible areas and expediting service delivery; and (e) stimulating economic recovery.

Both the IPRSP and the NRS were successfully implemented during 2001-2004 with the support of the international funding agencies and considerable progress was made in restoring security and consolidating peace. A National Social Action Programme, implemented by the National Commission for Social Action (NaCSA), was launched with intention to rebuild the social and economic capital at community level.

The Poverty Reduction Strategy paper (PRSP) was prepared by extensive national consultations of ministers, parliamentarians, local authorities, NGOs, civil society, the

private sector, development partners, beneficiary groups, and general citizens. The PRSP proposes sectoral policies and institutional reforms to achieve economic growth, providing food security, job opportunities, basic social services and effective social safety nets for both the short term and the long term in three pillars that are closely tied to the Millenuim Development Goals (MDGs). Pillar one is promoting good governance, security and peace. Pillar two is pro-poor sustainable growth for food security and job creation and pillar three is human development.

In addition, the PRSP also considers a number of short-term challenges that need to be met immediately. These challenges include:

- the impact of the spread of HIV/AIDS and other diseases such as malaria, typhoid and wide-ranging communicable diseases;
- the need to ensure affordable shelter for those households that are still deprived of it;
- the process of re-integration;
- and the need of labor-intensive approaches to sector programmes, especially public works, mining and agriculture.

Recognizing the importance of Science and Technology (S&T) in overall socio-economic development, the government is currently engaged in promoting a co-coordinated and coherent approach for advancing S&T in Sierra Leone. There is now a strong commitment to develop a strategy for the development of S&T activities that will be geared towards the improvement of the quality of life of its people. In order to facilitate the process, a plan of action has been put in place and includes the development of a Science and Technology Policy and the establishment of the necessary institutions such as the national S&T Secretariat and Council.

Energy and power supplies have been consistently erratic and unsatisfactory over the years. The country depends on two main sources for electric power generation. Diesel fuel generating plants account for about 90% of total electricity generation, while hydroelectricity accounts for the rest. The electricity sector is operated by one state-owned enterprise, the National Power Authority (NPA), that performs the four separate activities of generation, transmission, distribution and supply. The existing systems are old and inefficient, resulting in substantial losses of generated energy, estimated 30%. Electricity generation, which stood at around a peak of 196 GW hours in 1984, declined drastically to around 25-30 GW hours in 2000. Poor power supplies have increased the use of alternative generation from small petrol/diesel driven generators, with significant cost overheads for both individuals and private sector enterprises.

Sierra Leone has high potential for generating hydropower. The long overdue Bumbuna Hydro Electric Project when completed will generate sufficient power initially to supply Freetown and the North and later other parts of the country. There is a mini-hydro at Dodo in the East that provides electricity to the provincial headquarter towns of Kenema and Bo.

1.3 RECENTS POLICIES IN RELEVANT SECTORS

As previously mentioned, Sierra Leone went through a civil war that ended in 2002. Since then, the country has embarked on several programmes that have significant impact on the relevant sectors to GHG emissions. A successful multi-party democratic election was held in 2002, and both internal and external security was strengthened. The socio-economic situation has been improved and this was recorded by a recent meeting of the UN Security Council. Over 500 schools, vocational and technical institutions have been reconstructed along with greatly improved provision of learning materials and teacher training. Also, Universal free Primary education was adopted for the first years of schooling along with increased thrust on vocational and technical education. Also, over 1000 homes have been reconstructed in rural areas.

1.3.1 ECONOMY

The economy of the country has grown rapidly since 2002 and the real output growth between 2000 and 2004 averaged at about 13.6% per annum resulting in the national output from US$634 m in 2000 to US$1.1 billion in 2004. The GDP growth increased and the projected growth is estimated to grow by 7.5% in 2006, and annual inflation drop down to 11%. Despite the increase in government revenue but still depend on 50% donor support.

Exports, especially diamonds grew significantly, but imports still remain high, mainly due to construction materials for government programmes. The country has now qualified for the debt relief under the enhanced HIPC initiative and government intend to use such proceeds on the social investments, especially education and health. Also, the country has undergone wide ranging structural and institutional reforms to achieve efficient management of the economy and provision of essential services for the population. Government is putting a effort to effect their PRSP programmes to address poverty in the country.

1.3.2 AGRICULTURE AND FORESTRY

The need for a broader forest policy related to land use and agriculture was recognized in the 1986 Green Revolution Programme which identified the forestry's roles as:-

- To conserve and develop forest areas so as to protect the soil and water resources and maintain micro-climate stability for a sustainable agricultural production programme.
- To employ forest vegetation to replenish soil fertility on a sustainable basis.
- To increase significantly the production of forest products which contribute directly to food supply and also benefit the rural population in cash terms.

Forest policy, by the nature of the resource involved, is necessarily long term, but to make such policy effective requires the identification and funding of short term priorities associated with long term development benefits. The main short term priorities are:

- Conservation of the forest estate, by instituting sound silvi-cultural management (including control of forestry logging and protection).

- Development of pilot programme in improved agro-forestry cropping systems.
- Development of pilot firewood plantations.
- To manage and sustain a comprehensive research programme to provide sound technical basis for improved agro-forestry systems, to work on fuel-wood species and other species important to the national economy.
- Develop a data base for forest areas to allow the planning of management systems
- Assistance to and coordination of other agencies working in these priority areas.

The longer term approach would continue these priorities, expand successful programme to include increased priorities and programmes for:-

- A fuller conservation programme co-coordinating wildlife and ecology
- Development of mainly forestry watershed management systems in selected catchments
- Development of industrial plantations and investment scale programmes in agro-forestry and fuel-wood.
- Expansion of forest training to match capability to increasing responsibility.

1.3.3 HEALTH

The national health policy is based on the Primary Health Car concept. Following the implementation of several pilot primary health care initiatives, including the Bamako Initiatives, a broad based health sector policy was developed in 1993 and revised in 2002. The policy has Primary Health Car as the main thrust. It has five (5) objectives, nine (9) key components and ten (10) priority areas. The implementation of the policy is facilitated by technical policies. Ten (10) technical policies have been completed and are in use. A reproductive health policy is currently being developed. There is however, no specific policy on child health, although the other policies contain elements on child survival and maternal health.

These policies reflect adequately on the government PRSP document, and international and regional initiatives such as the Millennium Development Goals, Roll Back Malaria, CRC, CEDAW, Cairo Declaration, the Beijing Platform of Action, and NEPAD health objectives.

The Health sector has being revived through the reconstruction of hospitals and health centres, provision of equipment and re-opening of the major referral hospital in the capital. Also, Primary health programmes were revitalized. These moves have assisted in getting the infant mortality rate to drop to 170 per 1000 births.

1.3.4 WASTE

World Bank Power and Water Project

The Project for the study and implementation of the Rural Water Supply and Sanitation (RWSS) for Bombali, Tonkolili, Bo and Kenema districts funded by the government and IDA (World Bank) by GKW Consultants at SALWACO. The project aims at providing and rehabilitating wells, gravity schemes, VIP Latrines, and other rural water supply and sanitation facilities in the rural areas of the district named.

African Development Bank

The study for the Rural Water Supply and Sanitation Initiative by the Government and African Development Bank (ADB) has started with the evaluation of bids by Consultants. Fieldwork is expected to start soon as the evaluation proves leading to appointment of the successful bidder is completed.

1.4 LONG-TERM DEVELOPMENT CHALLENGES: VISION 2025

Government's poverty strategy is also set within the overall vision of the country's longer-term activity based on the desire to create a better future for Sierra Leone – a future that is characterized by the virtuous circle of peace, stability and wealth creation. As the country has experienced an unprecedented social, economic and political decline over the last three decades, it has become increasingly important to tackle certain critical challenges on its development agenda. The overall thrust of these challenges is the imperative of embarking on an extensive economic recovery programme for sustained growth and human development, in a peaceful and stable environment.

Sierra Leone's Vision 2025, which was developed through consensus, aptly summarises the development principles, which Sierra Leoneans agreed must guide their development efforts for the foreseeable future. The strategic areas of focus chosen which must become the basis for plans and policies for Sierra Leone are to:

- Attain a competitive private sector-led economic development with effective indigenous participations;
- Create a high quality of life for all Sierra Leoneans;
- Build a well-educated and enlightened society;
- Create a tolerant, stable, secure and well-managed society based on democratic values;
- Ensure sustainable exploitation and effective utilization of our natural resources while maintaining a health environment; and
- Become a science and technology driven nation.

They represent the core strategic issues that must provide the objectives for all plans, policies and programmes that aim to contribute to the development of Sierra Leone.

CHAPTER TWO

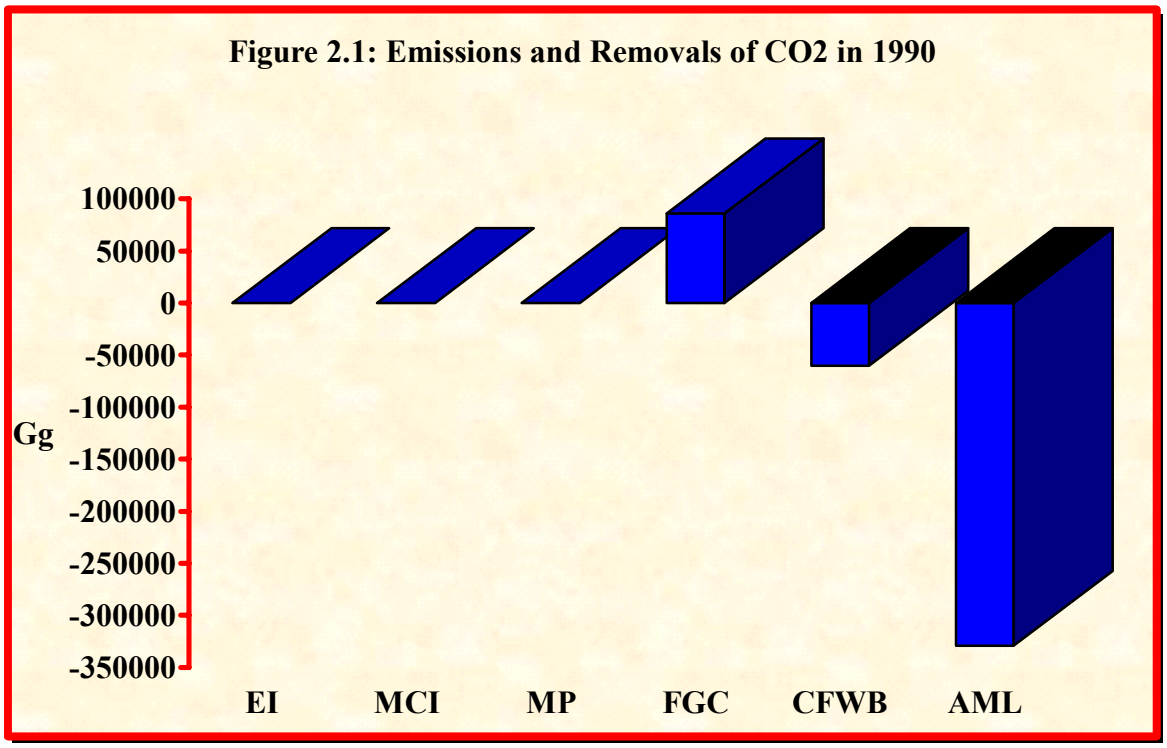
SUMMARY OF GREENHOUSE GAS FLOWS IN SIERRA LEONE

2.1: Emissions and Removals of Greenhouse Gases in 1990

2.1.1: Carbon Dioxide (CO_2):

In 1990, a total of 360 Gg CO_2 were emitted into the atmosphere while 303,058 Gg CO_2 were removed from the atmosphere. Thus, Sierra Leone is a net sink of CO_2 removing over 300,000 Gg CO_2 from the atmosphere in 1990.

Emissions of 360 Gg CO_2 were due to emissions of 355 Gg from Energy Industries (EI), 151 Gg from the Manufacturing and Construction Industries (MCI) and 6 Gg from Metal Products (MP). Land Use Change and Forestry category was responsible for the net CO_2 removal of over 300,000 Gg and this net removal is due to the emissions of 86,357 Gg due to conversion of forest and grasslands (FGC) into other land use types and removals of 60,309 Gg due to changes in forest and other woody biomass (CFWB) and 329,106 Gg CO_2 due to abandonment of managed lands (AML). These emissions are illustrated in Figure 2.1 below.



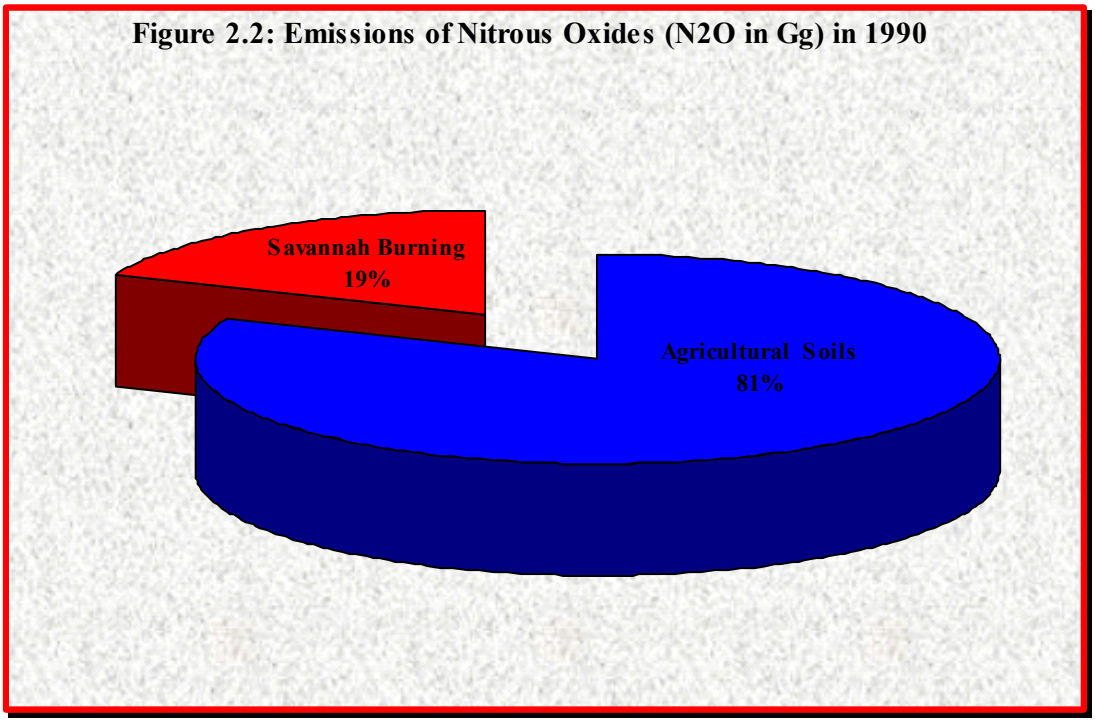
2.1.2: Methane (CH_4):

A total of over 48,203 Tg CH_4 were emitted in 1990. CH_4 represented the largest emitted GHG in 1990. Rice Cultivation under Agriculture was the biggest emitter (≈ 100%). Other activities that have contributed to CH_4 emissions from 1990 were management of domestic livestock (17.47 Gg CH_4), burning of savannahs (186 Gg CH_4), burning of agricultural residues (4.7 Gg CH_4), conversion of forests and grassland to other landuse types (128,591 Gg CH_4), solid waste disposal (0.18 Gg CH_4) and wastewater handling (0.65 Gg CH_4). The combined contribution of these other activities towards the emissions of CH_4 in 1990 was less than 1%.

2.1.3: Nitrous Oxide (N_2O):

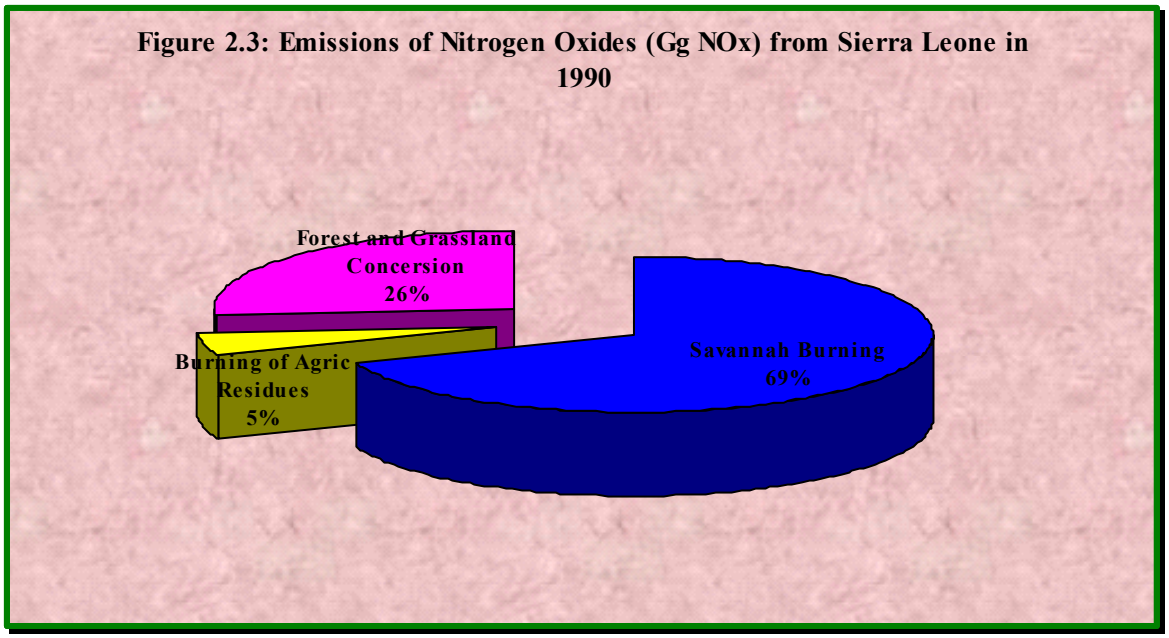
Thirteen (13) Gigagrams of Nitrous Oxides (13 Gg N_2O) were emitted in 1990. From Figure 2.2 below, 81% of the emissions come from application of fertilizers in fields and 19% of the emissions are due to burning of savannahs.

Figure 2.2: Emissions of Nitrous Oxides (N2O in Gg) in 1990



2.1.4: Nitrogen Oxides (NOx)

A total of 121 Gigagrams of Nitrogen Oxides (121 Gg NOx) were emitted in 1990. From Figure 2.3, about 69% of these emissions were due to the burning of savannahs, 26% due to the conversion of forests and grasslands to other land-use types, and 5% due to the burning of agricultural residues.



2.1.5: Carbon Monoxide (CO)

From Table 2.1, a total of 6,108 Gg CO were emitted in 1990. From Figure 2.4, about 82% of these emissions (4,893 Gg CO) came from the Agriculture sector and about 18% from the Land Use Change and Forestry sector.

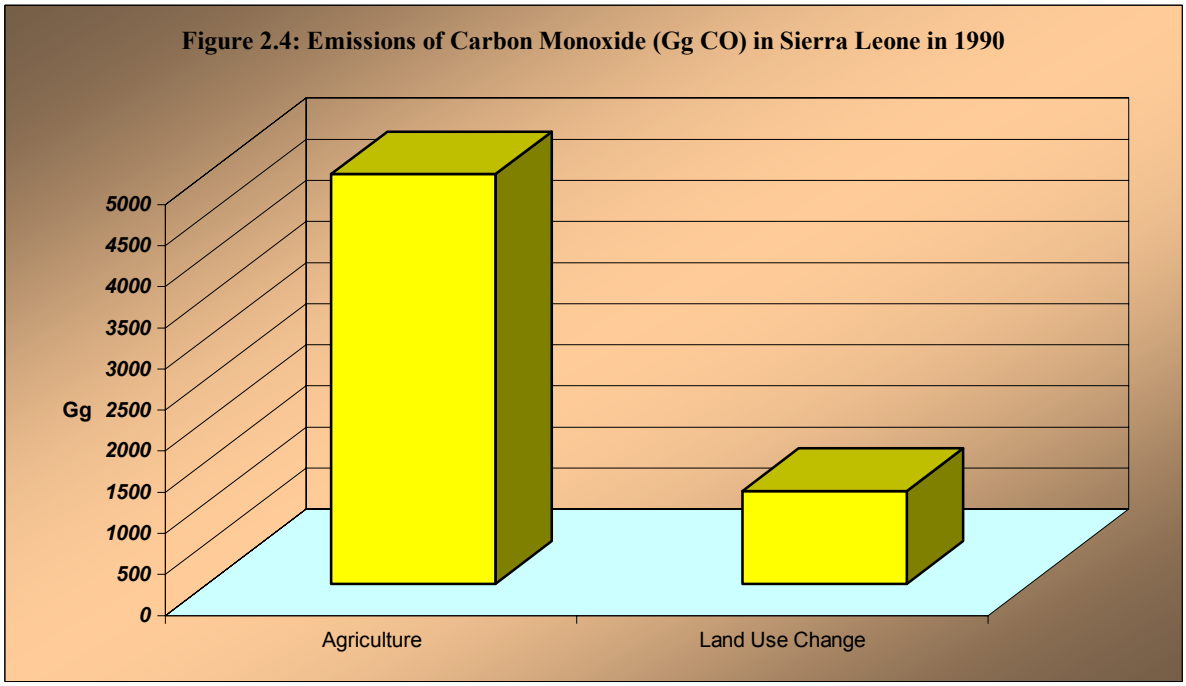
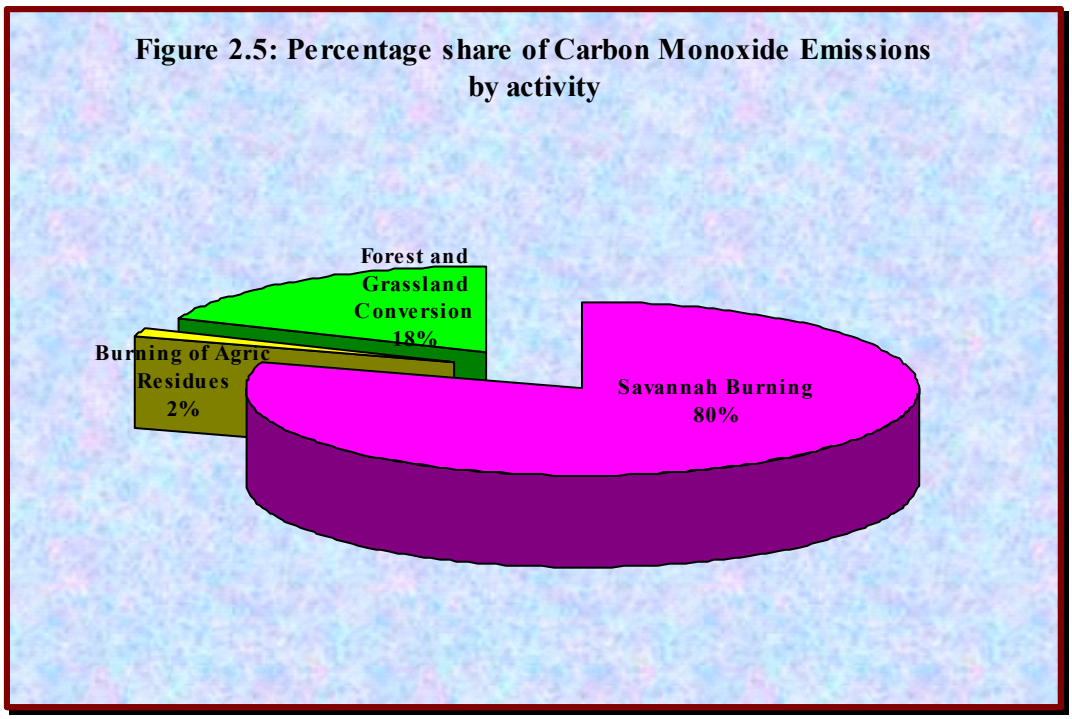


Figure 2.5 shows the distribution of the carbon emissions by activity within the agriculture and land-use change categories. Burning of savannahs is responsible for 80% (4,884 Gg CO) of the CO emissions.



2.1.6: Non-Methane Volatile Organic Compounds (NMVOC)

NMVOC emissions were registered only in the industrial processes category of emission sources. About 390 Gg of NMVOC were emitted in 1990 and this was due to the production of metals.

2.2: Trend of GHG emissions and removals from 1990 to 1995

Tables 2.1 to 2.6 and Figures 2.6 to 2.11 show emissions or removals of GHGs and their trends from 1990 to 1995. What is evident is the peak in emissions or removals in 1992 for all gases except NMVOC. NMVOC has an increase in emissions throughout the period from 1990 to 1995.

Emissions of CH_4 are constant at about 48 Petagram (Pg) from 1990 to 1992 and thereafter drop drastically to less than 1 Teragram (Tg) for the period 1993 to 1995.

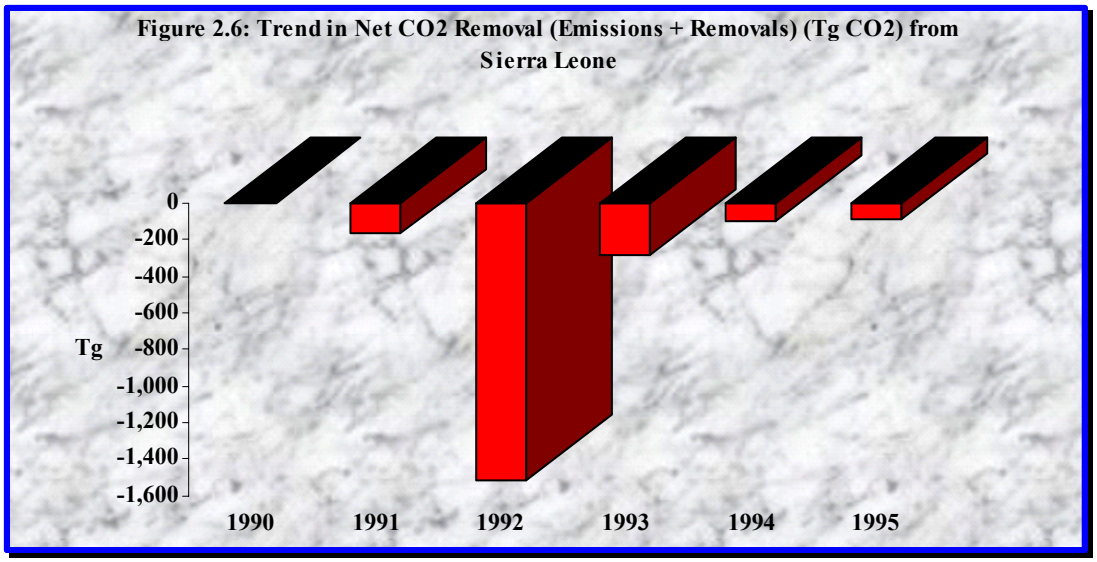


Figure 2.6: Trend in Net CO2 Removal (Emissions + Removals) (Tg CO2) from Sierra Leone
Tg
0
-200
-400
-600
-800
-1,000
-1,200
-1,400
-1,600
1990
1991
1992
1993
1994
1995

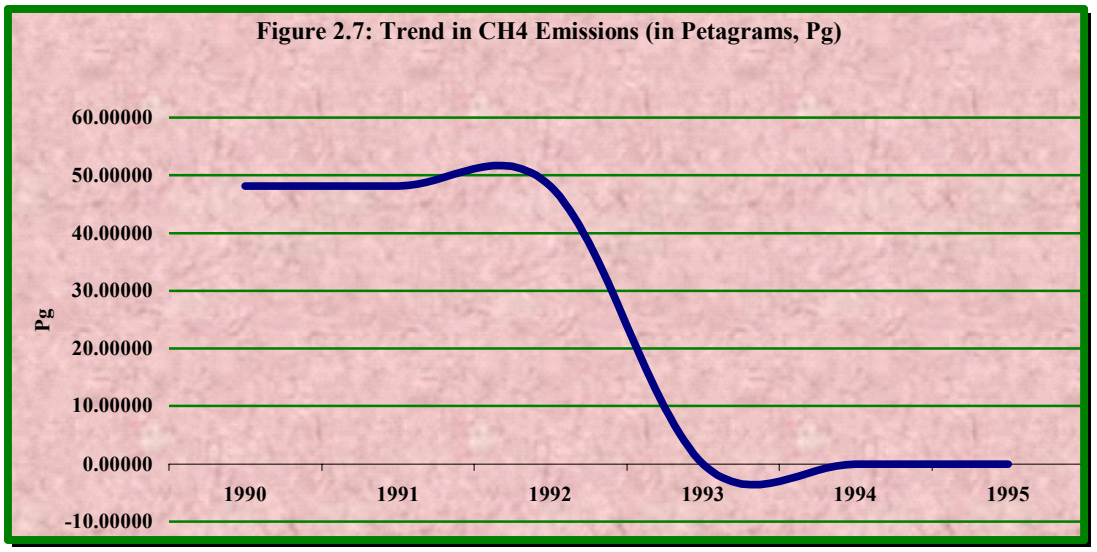


Figure 2.7: Trend in CH4 Emissions (in Petagrams, Pg)
Pg
60.00000
50.00000
40.00000
30.00000
20.00000
10.00000
0.00000
-10.00000
1990
1991
1992
1993
1994
1995

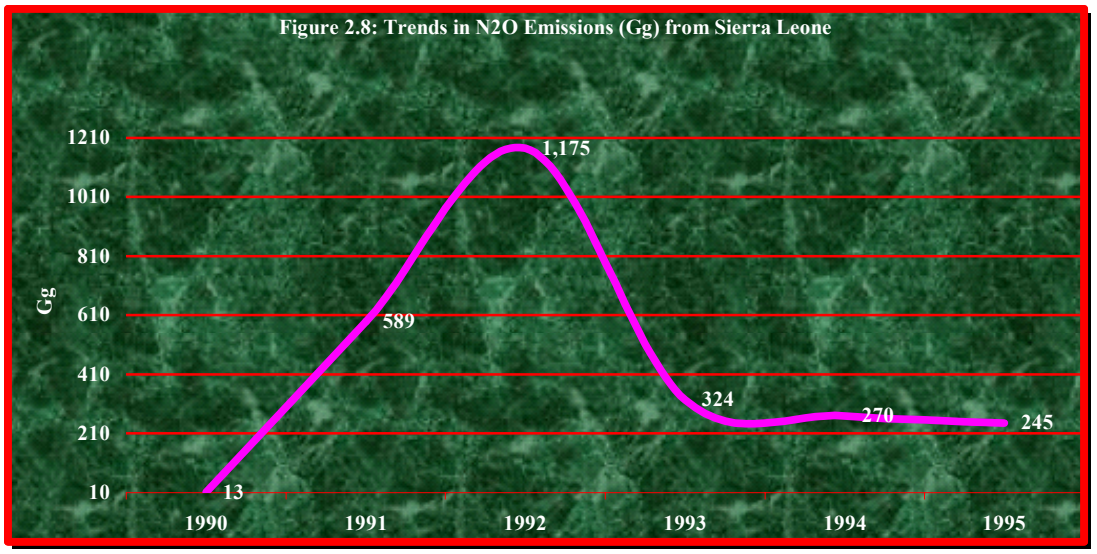


Figure 2.8: Trends in N2O Emissions (Gg) from Sierra Leone
Gg
1210
1010
810
610
410
210
10
13
589
1,175
324
270
245
1990
1991
1992
1993
1994
1995

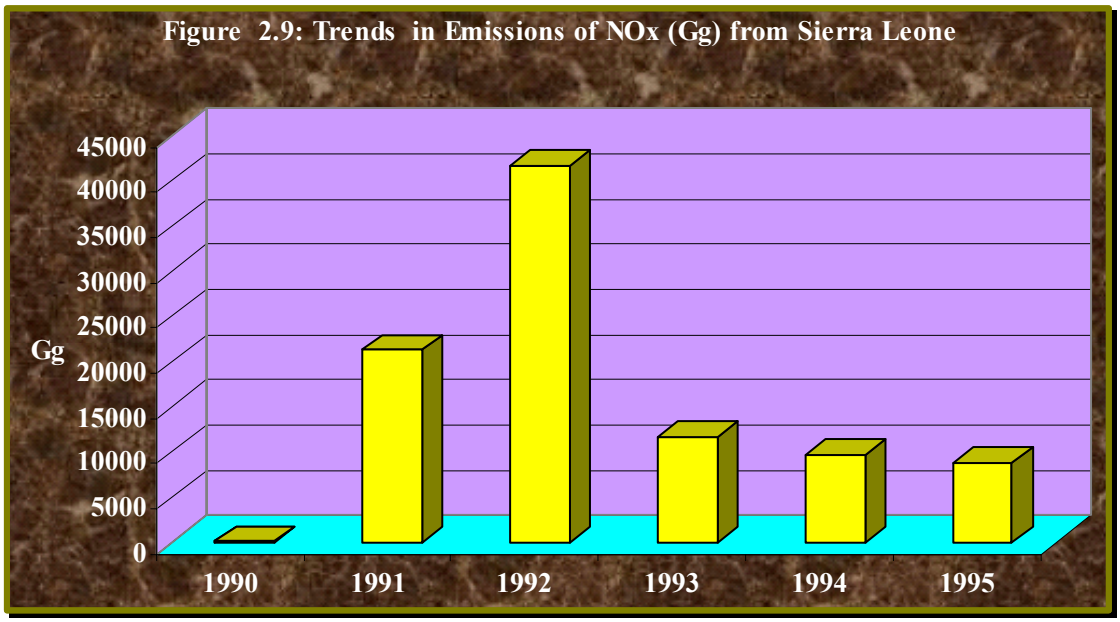


Figure 2.9: Trends in Emissions of NOx (Gg) from Sierra Leone
Gg
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
1990
1991
1992
1993
1994
1995

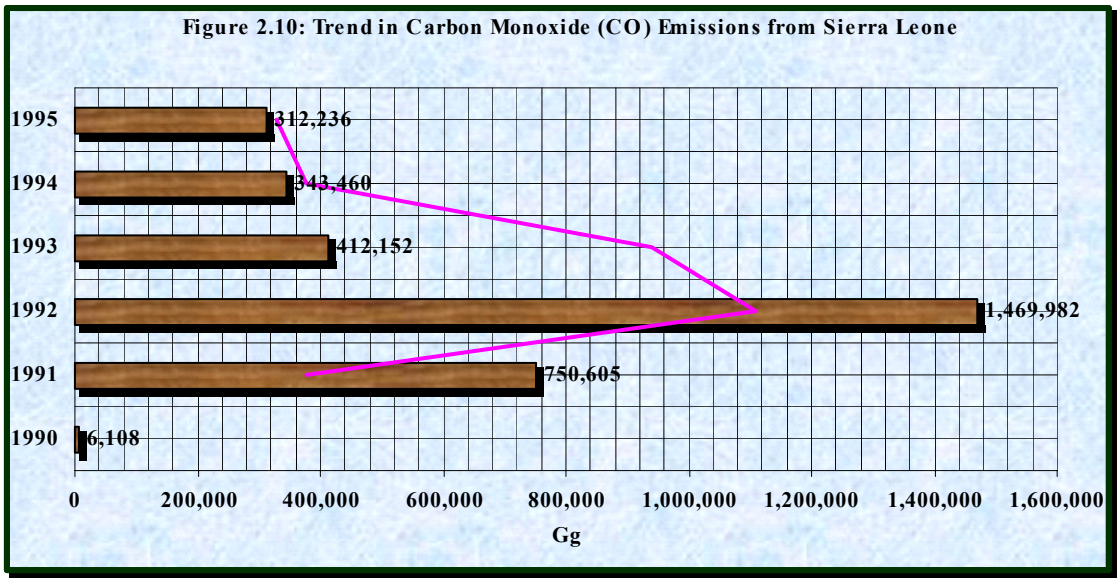


Figure 2.10: Trend in Carbon Monoxide (CO) Emissions from Sierra Leone
1995
1994
1993
1992
1991
1990
312,236
343,460
412,152
1,469,982
750,605
6,108
0
200,000
400,000
600,000
800,000
1,000,000
1,200,000
1,400,000
1,600,000
Gg

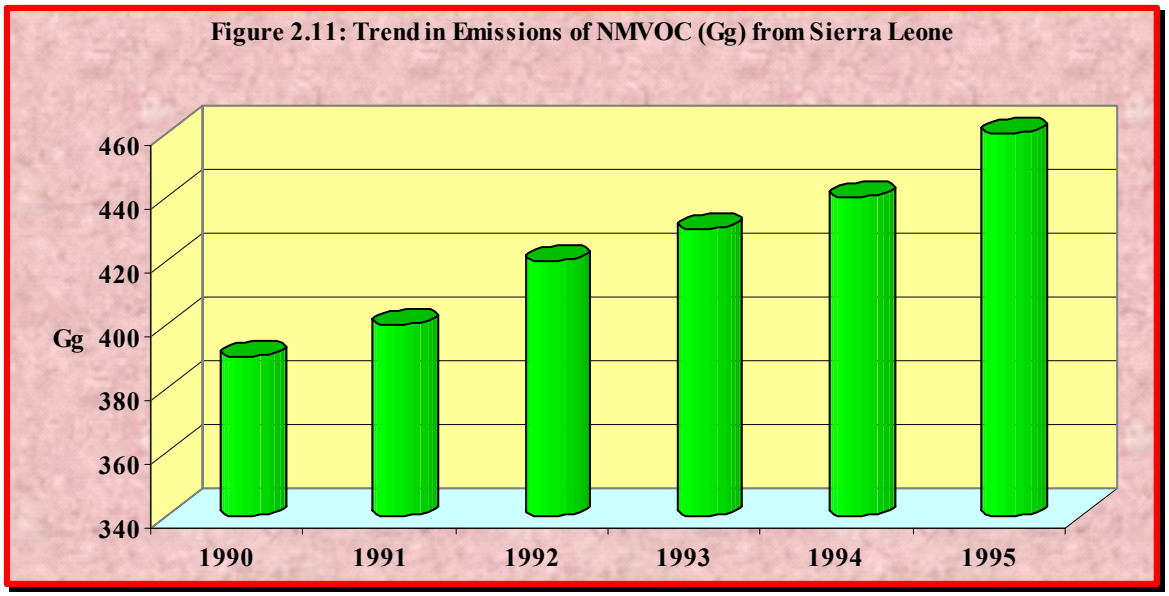


Figure 2.11: Trend in Emissions of NMVOC (Gg) from Sierra Leone
Gg
460
440
420
400
380
360
340
1990
1991
1992
1993
1994
1995

Table 2.1: Summary of the 1990 National Greenhouse Gas Inventory of Sierra Leone
(Gg)

Greenhouse Gas Source and Sink Categories	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Total National Emissions and Removals in 1990	**360**	**-303,058**	**48,203,200,338**	**13**	**121**	**6,108**	**390**	**0**
1 Energy	**355**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
A Fuel Combustion (Sectoral Approach)	*355*		*0*	*0*	*0*	*0*	*0*	
i. Energy Industries	*204*		*0*	*0*	*0*	*0*	*0*	
ii. Manufacturing Industries and Construction	*151*		*0*	*0*	*0*	*0*	*0*	
2 Industrial Processes	**6**	**0**	**0**	**0**	**0**	**0**	**390**	**0**
i. Mineral Products	*6*					*0*	*390*	*0*
3 Solvent and Other Product Use	**NOT ESTIMATED DUE TO LACK OF METHODOLOGY**							
4 Agriculture			**48,203,200,208**	**12.22328**	**88.830**	**4,983**		
i. Enteric Fermentation			*16.39300*					
ii. Manure Management			*1.083000*	*0.1198306*				
iii. Rice Cultivation			*48,203,200,000*					
iv. Agricultural Soils				*10*				
v. Prescribed Burning of Savannas			*186.066*	*2.3026*	*83.221122*	*4,884*		
vi. Field Burning of Agricultural Residues			*4.703122*	*0*	*5.509*	*99*		
5 Land-Use Change & Forestry	**0**	**-303,058**	**128.591**	**0.88407**	**31.9527**	**1,125**		
i. Changes in Forest and Other Woody Biomass Stocks	*0*	*-60,309*						
ii. Forest and Grassland Conversion	*86,357*		*128.59135*	*0.8840656*	*31.95266*	*1,125*		
iii. Abandonment of Managed Lands		*-329,106*						
6 Waste			**0.82590**	**0.000089**	**0.000000**	**0**	**0**	**0**
i. Solid Waste Disposal on Land			*0.1776610*					
ii. Wastewater Handling			*0.6482400*	*0*				
7 Other (please specify)								

Table 2.2: Summary of the 1991 National Greenhouse Gas Inventory of Sierra Leone (Gg)								
Greenhouse Gas Source and Sink Categories	**CO_2 Emissions**	**CO_2 Removals**	**CH_4**	**N_2O**	**NO_x**	**CO**	**NMVOC**	**SO_2**
Total National Emissions and Removals in 1991	**230**	**-169,388,409**	**48,203,306,551**	**589**	**21,302**	**750,605**	**400**	**0**
1 Energy	**229**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fuel Combustion (Sectoral Approach)	229		0	0	0	0	0	
i. Energy Industries	229		0	0	0	0	0	
2 Industrial Processes	**1**	**0**	**0**	**0**	**0**	**0**	**400**	**0**
i. Mineral Products	1					0	400	0
3 Solvent and Other Product Use	***NOT ESTIMATED DUE TO LACK OF METHODOLOGY***							
4 Agriculture			**48,203,200,036**	**0**	**0**	**488**		
i. Enteric Fermentation			17					
ii. Manure Management			1	0				
iii. Rice Cultivation			48,203,200,000					
iv. Agricultural Soils				0				
v. Prescribed Burning of Savannas			19	0	0	488		
vi. Field Burning of Agricultural Residues			0	0	0	0		
5 Land-Use Change & Forestry	**0**	**-169,388,409**	**85,728**	**589**	**21,302**	**750,116**		
i. Changes in Forest and Other Woody Biomass Stocks	0	-21,879,848						
ii. Forest and Grassland Conversion	68,737,930		85,728	589	21,302	750,116		
iii. Abandonment of Managed Lands		-216,246,491						
6 Waste			**20,787**	**0**	**0**	**0**	**0**	**0**
i. Solid Waste Disposal on Land			20,786					
ii. Wastewater Handling			1	0				
7 Other (please specify)								

Table 2.3: Summary Report for1992 National Greenhouse Gas Inventory of Sierra Leone (Gg)								
Greenhouse Gas Source and Sink Categories	**CO_2 Emissions**	**CO_2 Removals**	**CH_4**	**N_2O**	**NO_x**	**CO**	**NMVOC**	**SO_2**
Total National Emissions and Removals in 1992	**2**	**-1,515,341,413**	**48,203,392,328**	**1,175**	**41,744**	**1,469,982**	**420**	
1 Energy								
Fuel Combustion (Sectoral Approach)								
i. Energy Industries								
ii. Manufacturing Industries and Construction								
2 Industrial Processes	**2**						**420**	
i. Mineral Products	2						420	
3 Solvent and Other Product Use	**NO ESTIMATES DUE TO LACK OF ACTIVITY DATA**							
4 Agriculture			**48,203,200,010**	**20**	**0**	**0**		
i. Enteric Fermentation			10					
ii. Manure Management			1	20				
iii. Rice Cultivation			48,203,200,000					
iv. Agricultural Soils								
v. Prescribed Burning of Savannas								
vi. Field Burning of Agricultural Residues								
vii. Other (please specify)								
5 Land-Use Change & Forestry	**0**	**-1,515,341,413**	**167,998**	**1,155**	**41,744**	**1,469,982**		
i. Changes in Forest and Other Woody Biomass Stocks		-47,789,724						
ii. Forest and Grassland Conversion	77,035,247		167,998	1,155	41,744	1,469,982		
iii. Abandonment of Managed Lands		-1,544,586,937						
6 Waste			**24,320**					
i. Solid Waste Disposal on Land			24,320					
ii. Wastewater Handling								
7 Other (please specify)								

Table 2.4: Summary Report for 1993 National Greenhouse Gas Inventory of Sierra Leone (Gg)								
Greenhouse Gas Source and Sink Categories	**CO_2 Emissions**	**CO_2 Removals**	**CH_4**	**N_2O**	**NO_x**	**CO**	**NMVOC**	**SO_2**
Total National Emissions and Removals in 1993	**2**	**-281,515,951**	**75,866**	**324**	**11,704**	**412,152**	**430**	**0**
1 Energy	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fuel Combustion (Sectoral Approach)	0		0	0	0	0	0	
i. Energy Industries	0		0	0	0	0	0	
ii. Manufacturing Industries and Construction	0		0	0	0	0	0	
iii. Transport	0		0	0	0	0	0	
2 Industrial Processes	**2**	**0**	**0**	**0**	**0**	**0**	**430**	**0**
i. Mineral Products	2					0	430	0
3 Solvent and Other Product Use	**NOT ESTIMATED DUE TO LACK OF METHODOLOGY**							
4 Agriculture			**17**	**0**	**0**	**0**		
i. Enteric Fermentation			16					
ii. Manure Management			1	0				
iii. Rice Cultivation			0					
iv. Agricultural Soils				0				
v. Prescribed Burning of Savannas			0	0	0	0		
vi. Field Burning of Agricultural Residues			0	0	0	0		
5 Land-Use Change & Forestry	**0**	**-281,515,951**	**47,103**	**324**	**11,704**	**412,152**		
i. Changes in Forest and Other Woody Biomass Stocks	0	-177,563,354						
ii. Forest and Grassland Conversion	14,869,431		47,103	324	11,704	412,152		
iii. Abandonment of Managed Lands		-118,822,028						
6 Waste			**28,746**	**0**	**0**	**0**	**0**	**0**
i. Solid Waste Disposal on Land			28,454					
ii. Wastewater Handling			292	0				
7 Other (please specify)								

Table 2.5: Summary Report for 1994 National Greenhouse Gas Inventory of Sierra Leone

(Gg)

Greenhouse Gas Source and Sink Categories	CO_2 Emissions	CO_2 Removals	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Total National Emissions and Removals in 1994	**11**	**-96,076,137**	**72,854**	**270**	**9,754**	**343,460**	**440**	**0**
1 Energy	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fuel Combustion (Sectoral Approach)	0		0	0	0	0	0	
i. Energy Industries	0		0	0	0	0	0	
ii. Manufacturing Industries and Construction	0		0	0	0	0	0	
iii. Transport	0		0	0	0	0	0	
2 Industrial Processes	**11**	**0**	**0**	**0**	**0**	**0**	**440**	**0**
i. Mineral Products	11					0	440	0
3 Solvent and Other Product Use	**NOT ESTIMATED DUE TO LACK OF METHODOLOGY**							
4 Agriculture			**17**	**0**	**0**	**0**		
i. Enteric Fermentation			16					
ii. Manure Management			1	0				
iii. Rice Cultivation			0					
iv. Agricultural Soils				0				
v. Prescribed Burning of Savannas			0	0	0	0		
vi. Field Burning of Agricultural Residues			0	0	0	0		
vii. Other (please specify)			0	0				
5 Land-Use Change & Forestry	**0**	**-96,076,137**	**39,253**	**270**	**9,754**	**343,460**		
i. Changes in Forest and Other Woody Biomass Stocks	0	-15,105,895						
ii. Forest and Grassland Conversion	18,051,918		39,253	270	9,754	343,460		
iii. Abandonment of Managed Lands		-99,022,160						
6 Waste			**33,584**	**0**	**0**	**0**	**0**	**0**
i. Solid Waste Disposal on Land			33,292					
ii. Wastewater Handling			292	0				
7 Other (please specify)								

Table 2.6: Summary Report for 1995 National Greenhouse Gas Inventory (Gg)								
Greenhouse Gas Source and Sink Categories	**CO_2 Emissions**	**CO_2 Removals**	**CH_4**	**N_2O**	**NO_x**	**CO**	**NMVOC**	**SO_2**
Total National Emissions and Removals in 1995	**24**	**-86,167,407**	**102,509**	**245**	**8,867**	**312,236**	**460**	**0**
1 Energy	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Fuel Combustion (Sectoral Approach)	0		0	0	0	0	0	
Energy Industries	0		0	0	0	0	0	
Manufacturing Industries and Construction	0		0	0	0	0	0	
Transport	0		0	0	0	0	0	
2 Industrial Processes	**24**	**0**	**0**	**0**	**0**	**0**	**460**	**0**
Mineral Products	24					0	460	0
3 Solvent and Other Product Use	**NOT ESTIMATED DUE TO LACK OF METHODLOGY**							
4 Agriculture			**17**	**0**	**0**	**0**		
Enteric Fermentation			16					
Manure Management			1	0				
Rice Cultivation			0					
Agricultural Soils				0				
Prescribed Burning of Savannas			0	0	0	0		
Field Burning of Agricultural Residues			0	0	0	0		
Other (please specify)			0	0				
5 Land-Use Change & Forestry	**0**	**-86,167,407**	**35,684**	**245**	**8,867**	**312,236**		
changes in Forest and Other Woody Biomass Stocks	0	-12,582,929						
B Forest and Grassland Conversion	16,440,862		35,684	245	8,867	312,236		
C Abandonment of Managed Lands		-90,025,340						
6 Waste			**66,808**	**0**	**0**	**0**	**0**	**0**
A Solid Waste Disposal on Land			66,412					
B Wastewater Handling			396	0				
7 Other (please specify)								

2.3: Total Emissions and Removals

Table 2.8 shows the total emissions and removals of GHGs in 1990. Emissions of CH_4 are more important than all the other gas based on comparison using the Global Warming Potential (see Figure 2.12). CH_4 emitted is equivalent to $1.2*10^{15}$ Tons CO_2 equivalent (TCO2E) and represents 100% of the total emissions from Sierra Leone. The bulk of these emissions come from rice cultivation.

Table 2.7: Synthesis of the 1990 Greenhouse Gas Inventory of Sierra Leone

	Gigagrams (Gg)				
	Carbon Monoxide	Carbon Dioxide	Methane	Nitrogen Oxide	Nitrous Oxide
	CO	CO_2	CH_4	NOx	N_2O
1: ENERGY					
Energy Industries		204.00			
Manufacturing Industries and Construction		151.00			
Sub-total module 1	***0.00***	***355.00***	***0.00***	***0.00***	***0.00***
2: INDUSTRIAL PROCESSES					
Mineral Products	6.00				
Sub-total module 2	***6.00***	***0.00***	***0.00***	***0.00***	***0.00***
4: AGRICULTURE					
Domestic Animals and Animal Manure			0.00		
Rice Production			48,203,200,000.00		
Savanna Burning	4,884.00		186.07	83.221122	2.3026
Field Burning of Agricultural Residues	99.00		4.70	5.509	
Sub-total module 4	***4,983.00***		***48,203,200,190.77***	***88.73***	***2.30***
5: LAND USE CHANGE & FORESTRY					
Changes in Forest and Other Woody Biomass Stocks		-60,309			
Forest and Grassland Conversion	1,125	86,357	128.59135	31.95266	0.8840656
Abandonment of Managed Lands		-329,106			
Sub-total module 5	***1,125.00***	***-303,058.00***	***128.59***	***31.95***	***0.88***
6: WASTE					
Solid Waste Disposal on Land			0.177661		
Wastewater Handling			0.64824		
Sub-total module 6			***0.83***		
TOTAL	**6,108.00**	**-**	**48,203,200,320.1**	**120.68**	**3.19**

		302,703.00	**9**		
Global Warming Potential (GWP), 100 years integration		**1.00**	**24.50**		**320.00**
1000 TCO_2E		**-302,703.00**	**1,180,978,407,844.6**		**1,019.73**
%		**0**	**100**		**0**

CHAPTER THREE

ASSESSMENT OF GREENHOUSE GAS MITIGATION OPTIONS FOR SIERRA LEONE

3.1 Mitigation Assessment Approach

The term mitigation simply refers to human interventions through appropriate policy options and actions to reduce sources (and potential sources) or enhance sinks of GHGs, eg, forests, oceans and natural systems that can absorb CO_2 from the atmosphere. Mitigation assessment typically focuses on long-term opportunities for reducing GHG emissions or enhancing carbon sinks. The primary users of the assessment are policy-makers and decision makers.

Some degree of climate change is now inevitable due to past emissions. One essential strategy for responding to this is mitigation, which is based on action to limit the net emissions of GHGs. This net emission is defined as emissions minus removals by sinks. Limiting emissions will slow and eventually reverse the rise in the atmospheric concentrations of GHGs.

3.1.1 Desk review of literature and Stakeholder consultations

The first approach to mitigation assessment was to conduct a scoping workshop, which involved collecting data and information through stakeholder consultations and desk review of literature on mitigation options of GHGs the outcome of which was the development of a comprehensive list of mitigation options, which were then screened for further analysis:

(i) Transport Sector:

- Lead-free petrol, Mass transportation (road and water) for passengers and cargo, creation of pay parking lots, Enforcement of regular maintenance regulations for vehicles, Improve the water transport system, Regulate cost of duty to improve transport (tax incentives), Regulations / policies on fuel use and consumptions.

(ii) Energy / Industrial Sector

- Hydro Electric Power (HEP), Switching and promotion fo renewable energy (Solar Energy & LPG), Use of other fuels such as Ethanol, Oxygen, Development of alternative energy sources such as Bio-fuels (from corn, sugarcane, rice husk etc).

(iii) Agricultural sector

- Water management in rice cultivation and maintenance of soils, Low amount of organic matter, Use of rice-straw, compost, and biogas residues, Mineral fertilizers, Fallow incorporation and mulching.

(iv) Forestry sector

- Forest protection, conservation and increase efficiency in forest management.
- Reforestation, afforestation and agroforestry, Urban and community forestry.

(v) Waste management sector

- Waste incineration, Composting, Recycling, Landfills and Open-dumps.

The method for mitigation assessment used is the "Mitigation Option Weighting" method, which is based on the following criteria:

- **Mitigation benefits, Financial Viability, Implementation/Organizational viability, Technological viability, Size, Acceptability,** and **Political Willingness.**

For the different activities considered for which fossil fuels and fuel-wood are the sources of energy, the following mitigation options were considered and weighted (Table 3.1).

Table 3.1: Mitigation Options and their weightings

Activity	Mitigation Option	Weighting
Electricity	Steam generators using Nut shell	21.8
Cooking	Efficient Biomass stove using Rice husk	18.7
	Efficient Biomass stove using Wood shavings & saw dust	16.1
Road and River Transportation	Mass transportation - Railway	20.5
	Mass transportation – Bus	18.7
	Mass transportation – Water (Boats or Ferry)	18.7

3.2 In-depth Analysis of options and projects

3.2.1 Energy/Industrial sectors

Sierra Leone, like most Least Developed Countries (LDCs), depends mainly on fossil fuel (petrol, diesel, Liquid Petroleum Gas-LPG, kerosene and Marine Fuel Oil-MFO) and fuel-wood (wood and charcoal) for its source of energy. Petrol, diesel and MFO are the main sources of energy that are used in the transportation and electricity sectors. Figure 3.1 shows the quantity of fossil fuel imported into the country between 2000 and 2004. Figure 3.2 shows the extrapolated annual fuel-wood consumptions between 1985 and 2004. It can be clearly seen that there is a steady increase in the consumptions of fuel-wood over the stated period.

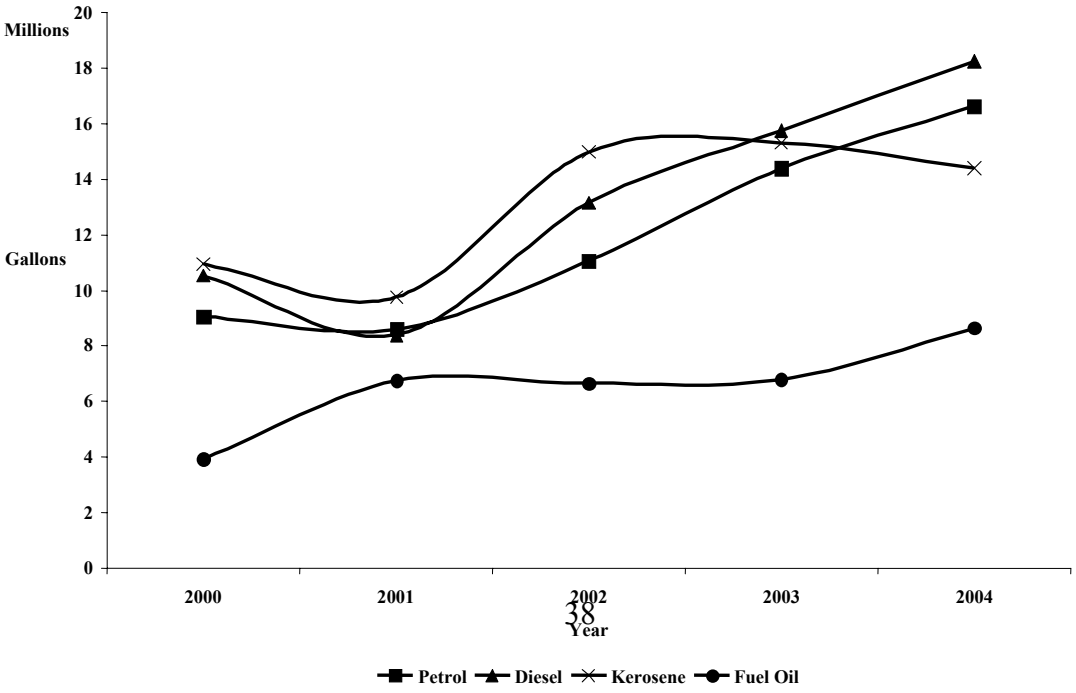


Fig 3.1: Fuel imported into Sierra Leone from 2000-2004 (Sierra Leone Petroleum Unit)

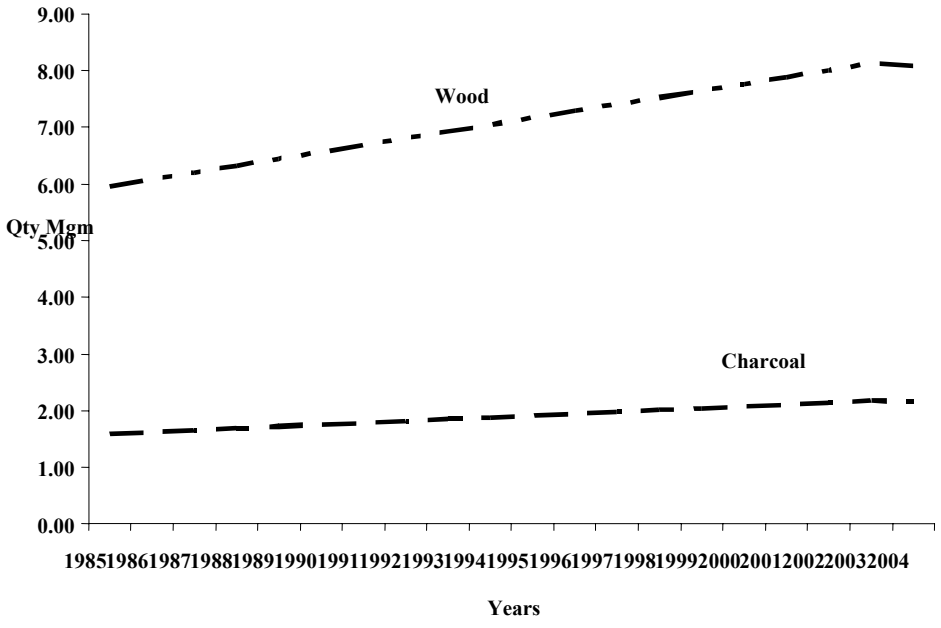


Fig 3.2 Extrapolated annual fuel-wood consumption in Sierra Leone (1985-2004)

3.3 Energy sources for domestic cooking

In Sierra Leone, fuel-wood and kerosene account for about 96.8% and 2.7% respectively as the main sources of energy used for domestic cooking. Figure 3 shows the sources of energy that households use for domestic cooking.

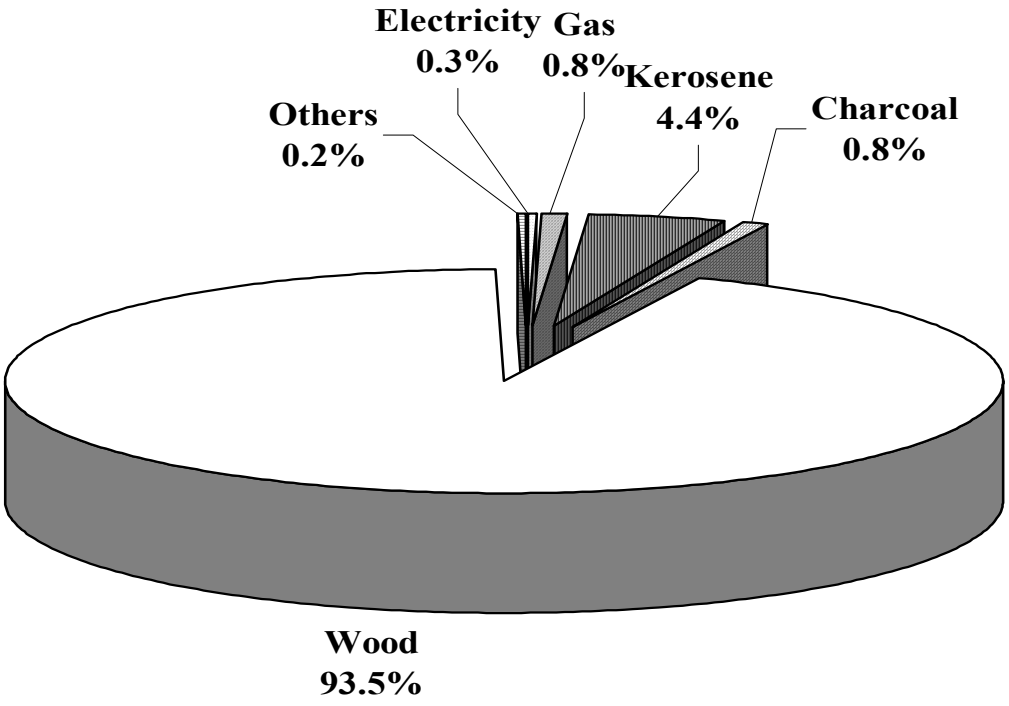


Fig 3.3 Percentage of households by principal source of fuel for cooking (CSO, 1995)

3.4 National Power Generation

In Sierra Leone, the National Power Authority (NPA) and the Bo-Kenema Power Station (BKPS) are the two government utilities responsible for generating electricity for both industrial and domestic consumptions. NPA provides electricity for the Western Area whilst BKPS provides for Bo, the Provincial Headquarter of the Southern Province and Kenema the provincial Headquarter of the Eastern Province. For the rest of the country, individuals or private institutions provide their own electricity supply using personal generators.

3.4.1 National Power Authority (NPA)

NPA uses the generators located at Kingtom to generate electricity using diesel and MFO as its main sources of energy. BKPS uses both hydro (Dodo hydro located in Kenema) and generators (located in Bo) to generate its electricity using diesel and MFO. The hydro is used for six months in the year and the generators for the remaining six months. Figure 4 shows the sources of energy used by households in Sierra Leone for lighting.

NPA has 7 generators housed at its Kingtom Power Station, whilse BKPS has 3. Data on the quantity of fossil fuel used annually by these institutions are not readily available. Figure 6 shows the annual MFO consumptions of NPA from 1996 to 2002. The shape of the graph in figure 6 relates to the quantity of MFO consumed when all or some of the four main generators are in full operation. Due to frequent power failures in the Western Area, households seek for alternative sources of light.

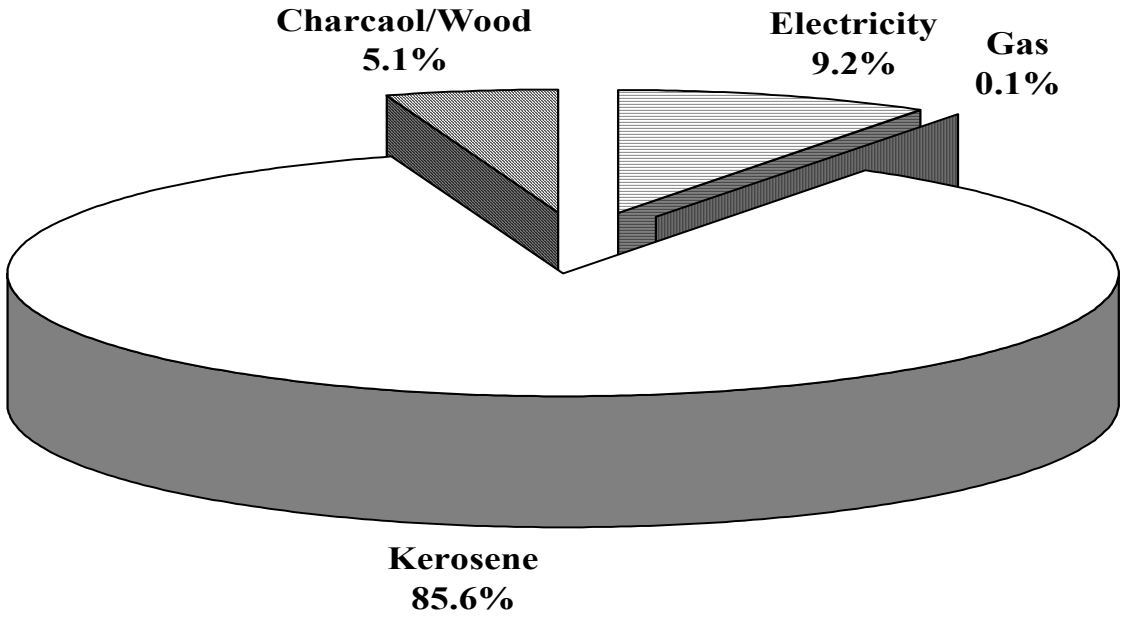
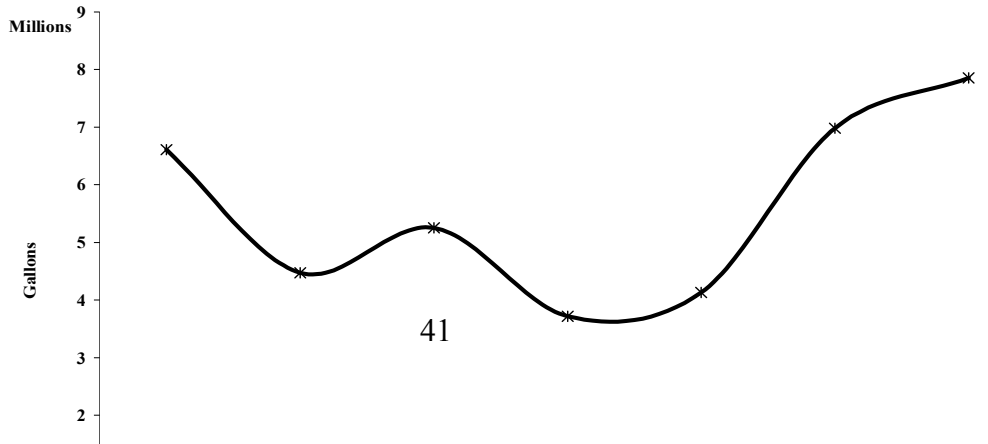


Fig. 3.4 Percentage of households by principal source of fuel for lighting. (CSO, 1995)



3.4.2 Private Sector Generators

In 2002, the prices of low capacity generators fell resulting in the mass ownership of generators by all categories of people. Between 1996 and 2002, the total registered private generating capacity in the Western area was 73.23MW (Conteh, 2003). The present capacity is higher than this value due to non official registration of some generators. These generators use petrol or diesel , but unfortunately no reliable data exist on them.

The Rutile Mining Company, the Sierra Leone Brewery, the Sierra Leone Cement factory, Shankerdas, UN institutions etc, are examples of institutions that generate the electrical power they require for their operations. Their generators rated in Mega-watts use MFOs and diesel as their main sources of energy. The Sierra Leone Brewery has 2-500kVA generators whilst the Sierra Leone Cement factory has a number of generators with capacity totaling 6MW.

3.5 Transport Sector

The transportation sector of Sierra Leone is characterized by on-road vehicles that ply the roads and outboard motors that ply the river estuaries. The fossil fuel vehicles that ply the roads are categorized as; private cars, taxis, light vans, Lorries, "Poda-Poda"/Buses and motorcycles. Figure 3.5 shows the number of vehicles authorized to ply the roads each year and Figure 8 shows the distribution of on-road vehicles that plied the roads in 2004.

From figure 3.5, we see that from 1990-1994, there was a steady increase in the number of vehicles plying the roads each year. In 1995, the first decrease in the number of vehicles was recorded, with 1997 recording the lowest due to a military coup and an embargo on the country for fuel. The increase in number of vehicles in 1998 was as a result of the return of the democratic government. This brought about some amount of confidence but was again disrupted with the second invasion of the country by the RUF/SLA in 1999. From 2000, there was a steady increase in the number of vehicles plying the roads.

No data exist on the consumption rates of motor vehicular transport in the country. These graphs were obtained from calculated fuel consumptions per day for the various groups of authorized on-road vehicles that ply the roads.

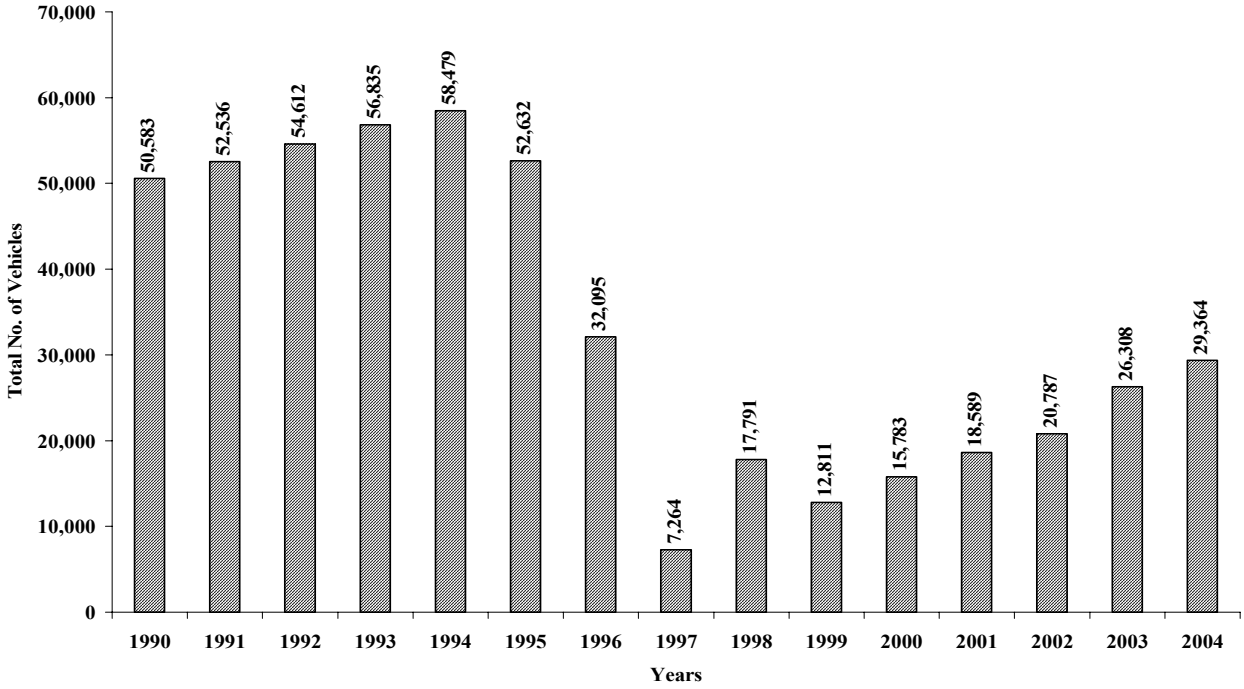


Fig. 3.5: Total Number of Vehicles Plying the Roads of Sierra Leone 1990-2004 (Planning section, SLRTA, 2004)

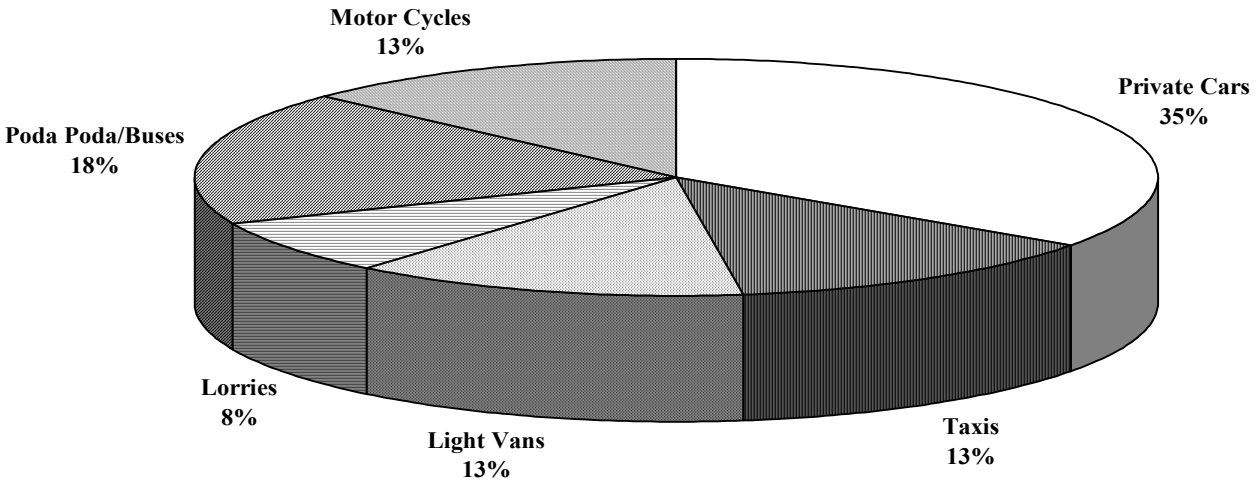


Fig. 3.6: Percentage distribution of vehicles that plied the roads from 1990-2004

3.5.1 Emissions from On-road Transport vehicles

Emissions of CO_2 and other GHGs from vehicular transports are based on; Age and mileage, driving profile of vehicle, type of fuel vehicle is using and consumption rate, class of vehicle, technology type, hot exhaust emissions and cold-start emissions.

It is assumed that emissions of CO and NOx from on-road vehicles increases by 60% over 80,000 km, whilst emissions of NMVOCs increase by 30% over the same mileage (DETR, 1996). Based on the average annual mileage of cars, 80,000 km corresponds to a time period of 6.15 years.

The drive cycle over a journey is the key factor which determines the amount of pollutant an on-road vehicle emits. Key parameters affecting emissions are the acceleration, deceleration, steady speed and idling characteristics of the journey. Other factors are load on the engine such as the road gradient and vehicle weight. However, work has shown that for modelling vehicle emissions for an inventory covering a road network on a national scale, it is sufficient to calculate emissions from emission factors in g/km related to the average speed of the vehicle in the drive cycle (Zachariadis and Samaras, 1997). Note that strictly on a per-litre-of-fuel-consumed basis, diesel emits more CO_2 than petrol.

The category and type of on-road vehicles can also determine the level of emission. On-road vehicles considered are as follows:

- Cars (Petrol and Diesel), Light Goods Vehicles (Petrol and Diesel) (Gross Vehicle Weight (GVW) 3.5 tonnes), Heavy Goods Vehicles-Lorries (GVW > 3.5 tonnes), Buses and coaches and Motorcycles.

Figure 3.6 shows the classifications and percentage distribution of on-road vehicles for 2004. This distribution pattern is the same for all the years under consideration.

Table 3.2: Emissions from Petrol and Diesel Combustion (gm/L fuel)[1]

Vehicle Type	CO_2	CH_4	N_2O
Car - Gasoline	2360	0.56	0.028
Car - Diesel	2730	0.1	0.2
Light-Duty Diesel Trucks (LDDT)	2730	0.08	0.2
Heavy-Duty Diesel Vehicles (HDDV)	2730	0.15	0.08
Heavy-Duty Gasoline Vehicles (HDGV)	2360	0.49	0.08
Motorcycles	2360	1.42	0.046

[1] Environment Canada - Greenhouse Gas Emissions 1990-2000

Table 3.2 shows the emission characteristics of petrol and diesel combustions for on-road vehicles. Using standardized calculations, the estimated amount of CO_2 and SO_2 emitted into the atmosphere by on-road vehicles in Sierra Leone in 1990 is shown in Table 3.3. Similar calculations were done to obtain cumulative emissions for ten years starting 1990 (Table 3.4).

Table 3.3: Petrol and Diesel on-road vehicles emissions				
Source	**CO_2 gm/L**	**CH_4 gm/L**	**N_2O gm/L**	**SO_2 kg/m-ton**
Petrol	189,961,170,787.20	45,075,532.05	2,253,776.60	41,728.00
Diesel	67,187,281,051.80	2,461,072.57	4,922,145.13	12,758.49
Total	**257,148,451,839**	**47,536,604.62**	**7,175,921.73**	**54,486.49**

Table 3.4: Cumulative Emissions by Petrol and Diesel on-road vehicles 1990 – 2000				
Source	**CO_2 gm/L**	**CH_4 gm/L**	**N_2O gm/L**	**SO_2 kg/m-ton**
Petrol	1,605,106,298,736.00	380,872,681.06	19,043,634.05	352,587.21
Diesel	620,738,924,960.70	22,737,689.56	45,475,379.12	134,139.21
Total	**2,225,845,223,696.70**	**403,610,370.62**	**64,519,013.17**	**486,726.42**

3.6 Emissions from Stoves

In most LDCs, large quantities of biomass are burnt in small inefficient stoves that emit non-CO_2 GHGs and suspended particulates. Wood fuel used for cooking accounts for 40% of the global emissions of CO_2 and other GHGs into the atmosphere that enhance global warming.

In Sierra Leone, the three-rock stove/open fire stove, metal stove commonly called "Coal pot" and the kerosene stoves are the three kinds of stoves used. The three-stone stove is used by 90% of households. This stove and the "coal pot" stove have the following drawbacks: dispersion of the flames and heat during windy conditions, lost through lack of proper control over the fire, exposure to heat and smoke as well as fire hazard, as such are very inefficient. Tables 3.5a and 3.5b show the emissions from fuel wood combustion. Table 3.6 shows emissions from wood and charcoal for the periods 1990-2000 respectively.

Table 3.5a: Emissions from Wood-fuel Combustion (gm/kg fuel)[2]		
Emitted Gases	**Open fire stove - Wood**	**Metal stove - Charcoal**
Total-SP	7.7	2.4
SO_2		0.07
NO_x		
CO	10-180	250-380

[2] Power of the Stove, Karekezi, S and N. Murimi, Stove Images, 1995

Kerosene though considered relatively clean does emit CO_2 and other GHGs as the stove gets older. In Sierra Leone, most of the kerosene stoves are imported from China and India. These stoves start malfunctioning within a very short time, emitting CO and SP. The emission from kerosene stoves could not be calculated as there are no consumption data on kerosene for cooking. Table 3.7 shows the emission characteristics for kerosene when used for cooking.

Table 3.5b: Emissions from Wood-fuel Combustion (gm/kg fuel)[3]			
Source	**CO_2**	**CH_4**	**N_2O**
Wood Fuel/Wood Waste	950	0.05	0.02
Accidental Forest Fires	1630	3	1.75
Conventional Stoves	1500	15	0.16
Conventional Fireplaces and Inserts	1500	15	0.16
Other Wood-Burning Equipment	1500	15	0.16

Table 3.6: Emissions from Wood and Charcoal (gm/kg fuel) from 1990-2000				
Source	**CO_2**	**CH_4**	**N_20**	**SO_2**
Wood	118,214,130.24	1,182,141.30	12,609.51	
Charcoal	34,355,287.83	63,230.59	36,884.51	1,475.38
Total	152,569,418.06	1,245,371.89	49,494.02	1,475.38

Table 3.7: Emissions from Kerosene Combustion (gm/L fuel)[4]			
Kerosene	**CO_2**	**CH_4**	**SO_2**
Electric Utilities	2550	0.006	0.031
Industry	2550	0.006	0.031
Producer Consumption	2550	0.006	0.031
Residential etc.	2550	0.026	0.006
Other Small Combustion	2550	0.026	0.031

3.7 GHG Emission from Electricity Generation

The global electricity supply sector accounts for almost 2,100MtC/yr or 37.5% of total carbon emissions. Because a limited number of centralized and large emitters are easier to control than millions of vehicle emitters or small boilers, the electricity sector is the prime target for GHG emissions control.

For this sector, only emissions from NPA are considered as no reliable data are available on fossil fuel consumption rates for the other institutions that generate their own electricity.

Table 3.8 shows the emission characteristics of heavy marine fuel oil and Table 3.9 the emissions from NPA generators.

8 Environment Canada – Greenhouse Gas Emissions 1990 - 2000

[4] Environment Canada - Greenhouse Gas Emissions 1990-2000

Table 3.8: Emissions from Heavy/Marine Combustion (gm/L fuel)[5]			
Heavy Fuel Oil	**CO_2**	**CH_4**	**N_2O**
Electric Utilities	3090	0.034	0.064
Industry	3090	0.12	0.064
Producer Consumption	3090	0.12	0.064
Residential etc.	3090	0.057	0.064

From Table 3.9, we see that though NPA is not in operation for most part of the year, emissions from electricity generation contribute significantly to global warming. It must be emphasized that the emissions calculated do not take into cognisance the ages of the generators, the quality/grade of the marine fuel oil nor the emissions of the caterpillar generators.

Table 3.9 Emissions from NPA generator at Kingtom Power Station (gm/L fuel) 1996-2000				
Years	**Annual MFO Consumption (kg)**	**CO_2**	**CH_4**	**N_2O**
1996	1,152,751,744*	92,870,748,462.18	1,021,878.79	1,923,536.54
1997	779,497,643*	62,799,757,108.77	691,000.56	1,300,706.94
1998	915,946,107*	73,792,645,251.56	811,957.91	1,528,391.36
1999	648,607,757*	52,254,692,447.44	574,970.73	1,082,297.84
2000	720,065,523*	58,011,644,257.97	638,315.83	1,201,535.67
Total		**339,729,487,527.91**	**3,738,123.81**	**7,036,468.35**
**Annual fuel consumption (Conteh, 2003)*				

Emissions from kerosene lamps were not calculated as there is no reliable data on the type of kerosene lamps in use and quantity consumed per day for lighting.
On the whole, comparing the emissions from the various combustion activities; fuel-wood and fossil fuel, for cooking, on-road-transportation and electricity generation, it can be seen that Sierra Leone does contribute to global warming (Table 3.10), though less significantly.

Table 3.10: Amount of GHGs emissions in Sierra Leone (fuel-wood; kg/metric-Tonnes, Kg/L fossil fuel)				
Source	**CO_2**	**CH_4**	**N_2O**	**SO_2**
Fuel wood	152,569.42	1,245.32	49.29	1,475.38
Fossil fuel-On-road transport	2,225,845,223.70	403,610.37	64,514.01	486,726.42
*Electricity	339,729,487.53	3,738.12	7,036.47	
Total	**2,565,727,280.64**	**408,593.81**	**71,599.78**	**488,201.80**

[5] Environment Canada - Greenhouse Gas Emissions 1990-2000

**Only NPA fossil fuel Consumption (1996-2000)*

3.8 Mitigation Assessments

Sierra Leone being a signatory to UNFCCC, is now looking at mitigation options that will enable her to reduce emissions, as over 90% of the energy it utilizes is from fossil fuel and biomass.

Sierra Leone has over 20 hydro potential sites of which the Bumbuna dam is the only one that has been tapped. This dam, which is near completion, has a capacity of 50MW. This was considered as the most viable mitigation option for the electricity sector. If five of these hydro potentials including Bumbuna are utilized, it will result in an almost zero emission from the electricity sector.

Projection of the amount of emissions from electricity sector cannot be quantified as there are:

1. No data available on the number of private generators or their fuel consumption patterns.
2. NPA fuel consumption is subjected to the functioning of the generators which are old and are at most times not functioning.

Notwithstanding, the commissioning of the Bumbuna dam will reduce emissions from electricity sector significantly and the payback period will be short considering the amount of money that is spent on purchasing both MFOs and diesel, reduced dependent on private generators which in turn becomes savings for individuals or institutions owning these generators in terms of fuel and maintenance cost.

For areas that the Bumbuna dam will not supply electricity, use of palm nut shells as fuel for thermal generators for electricity was also viewed as a viable mitigation option. These shells are being produced in huge quantities during the harvesting period of the palm oil in the Provinces. This can be used as source of fuel as they have high calorific value. Though this option results in reducing emissions, it can be controlled as it is from a single source. Its benefits are that rural communities will have electricity and have the opportunity of using electric stoves. This will result in fuel wood savings, less time spent collecting wood, and forest preservation and income generation through the selling of the nuts since these nuts are annually produced in large quantities in the provinces.

The use of efficient biomass stoves was given as a mitigation option for cooking. This is an option that is viable as the Jiko stove called the “wonder stove” is now available at a cost of US$6 (Six US dollars). This stove uses charcoal as source of energy. In Kenya, the Jiko stove industry has created 50% more jobs in the stove sector compared to the traditional metal stove (Burn, 1985). This stove when compared to both the “3-stone fire place stove” and metal stove is highly efficient and burns less fuel thus producing less emissions.

Benefits of using efficient stoves can be quantified in terms of firewood saved, forest area that does not need to be replanted, and savings in income used in purchasing fuel and most important of all, improved health for women and children.

Use of efficient stoves has the advantage of reducing women's time input, because less firewood is needed, as such less time is spent gathering firewood/less money spent in buying wood. This results in spending half the time that would have been spent gathering wood for the 3-stone fire stove/ savings of up to half the amount spent on buying the wood. In terms of consumption, between 40% and 60% less wood is used when compared to the 3-stone fire stove.

Figure 3.9 shows the difference in annual consumptions when the 3-stone fire stove and metal stove are used for cooking as against an efficient stove like the Jiko stove. Wood-1 and Charcoal-1 show the normal annual consumption trend and Wood-2 and Charcoal-2 the trend. The assumption made for this scenario is that there is a 50% and 55% savings made in wood and charcoal respectively.

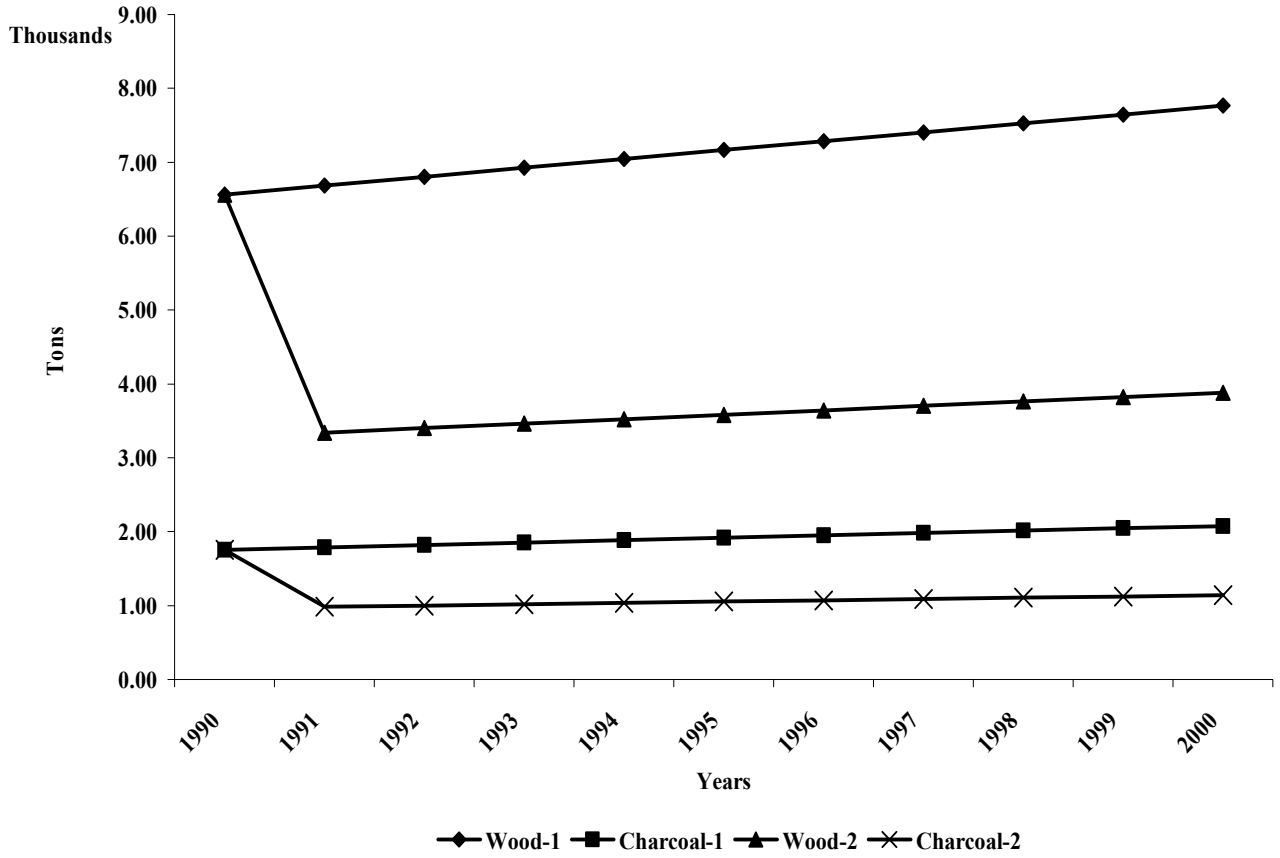


Fig. 3.9 Savings in fuel-wood consumption when Efficient stove is used. (1990-2000)

The economic savings realized with the use of efficient stoves is significant with regards to emissions.

In Sierra Leone, 70% of the on-road vehicles are found in the Western Area. Also, 16% of the population resides in the Western area. As such use of buses and poda-poda for mass transportation will be a viable mitigation option when looking at it from the angle of emission per vehicle per person. Not withstanding, it must be realized that the sizes of mass transport vary in terms of the number of passengers it can carry. Scenario-one looked at reducing cars in the percentages indicated; Private cars-40%, Taxis-25% and

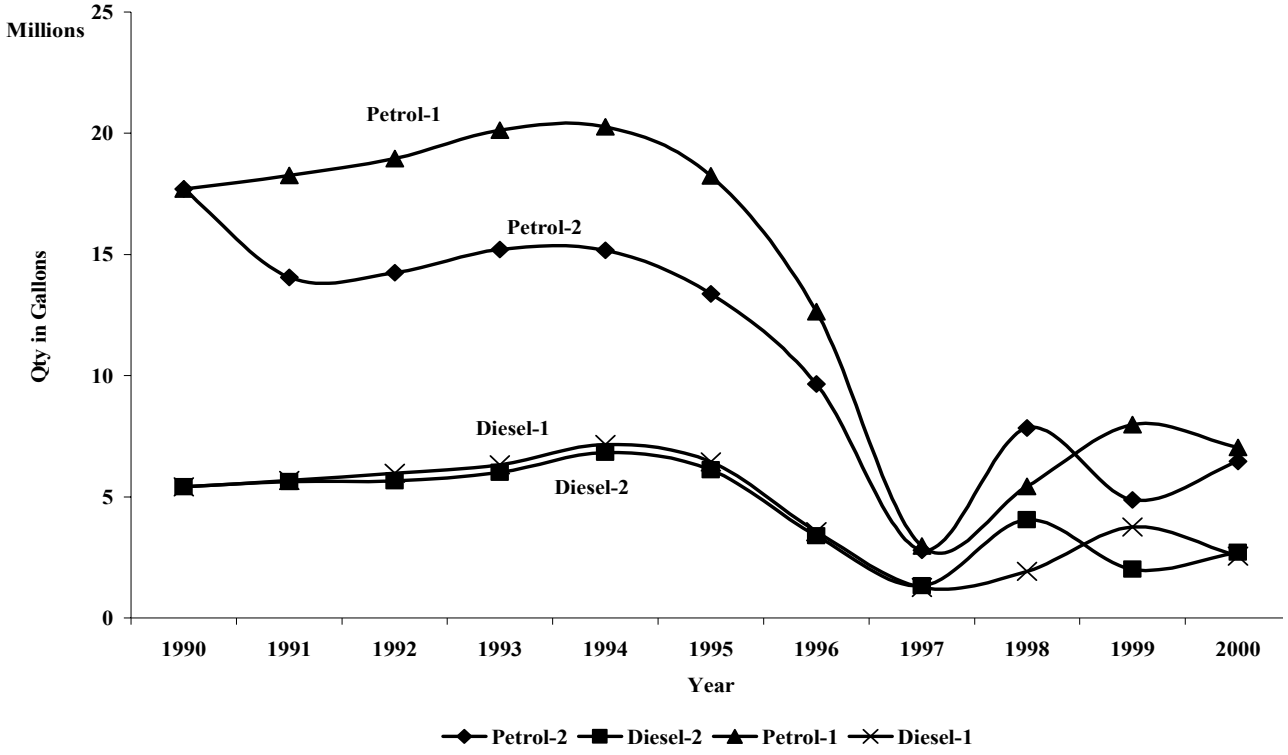


Fig.3.10 Savings in Petrol and Diesel consumptions, with increase in Mass Transportation-Bus/Poda-Poda (1990-2000)

increase Buses/Poda-podas by 140%.

Figure 3.10 shows the two curves; Petrol-1 and Diesel-1 being the assumed annual consumptions and Petrol-2 and Diesel-2 the scenario situation.

Table 3.12: GHG Emission reduction using efficient stoves (kg/metric-tonnes)				
Source	**CO_2**	**CH_4**	**N_20**	**SO_2**
Wood-1	118,214,130.24	1,182,141.30	12,609.51	
Wood-2	64,029,476.67	640,294.77	6,829.81	
Charcoal-1	34,355,287.83	63,230.59	36,884.51	1,475.38
Charcoal-2	20,182,813.04	37,146.28	21,668.66	866.75
Reduction	68,357,128.36	567,930.85	20,995.54	608.63
% Reduction	**45%**	**46%**	**42%**	**41%**

Table 3.12 shows the quantity and percentage reductions realized in scenario-one. This option will attract private investment as bus/poda-poda is a financially viable venture in Sierra Leone. But this has to be accompanied by tax disincentive for users of private cars. Furthermore tax should be levied on owners of cars above ten years old.

The use of boats as a means of mass transportation within the Western area is also a viable mitigation option in the context of mass transportation. The Western area is located on the coast and so is a significant part of the country. Also, use of boats and Ferry is not a new venture in the country, as such using them for short runs within the western area will contribute immensely in reducing GHG emissions. Scenarios on the type of boats that ply the coast cannot be conducted as no data exist on their consumption patterns.

Table 3.13: GHG Emission reduction for scenario-one (kg/Litre)

	CO_2	CH_4	N_2O
Petrol-2	286,451,089	67,971	3,399
Diesel-2	115,871,242	27,495	1,375
Petrol-1	353,081,016	83,782	4,189
Diesel-1	118,039,919	28,009	1,400
Reduction	68,798,604	16,325	816
% Reduction	**15%**	**15%**	**15%**

3.9 MITIGATION OPTIONS IN THE WASTE SECTOR

3.9.1 Waste Generation

In Sierra Leone, waste management analysis is only conducted in the Freetown municipality, located in Western area. As such, much of the data presented is this work is based solely on data provided for this area by the Ministry of Health and Sanitation. No data exist on waste management for both the rural and the provincial areas, which is about 90% of the country. We shall therefore only focus on Freetown, with the following characteristics: It is

- ◊ the most densely populated area in the country
- ◊ the sit of government, commercial and economic centre of the country.
- ◊ where the harbour; the entry point of all imported goods is located and the point of attraction of must food stuff produced in the country.

Wastes, as used in this work is defined as "finished products that have been used and disposed of". It is categorized into two groups; **decomposable wastes** and n**on-decomposable wastes**. Non-decomposable wastes comprise sludge and lubricant oils, plastics and galvanized rubber, glass and metals/tins/scrapes, etc. Decomposable wastes comprise garbage from food, vegetables, other garden wastes and water wastes.

Notwithstanding this, majority of the wastes generated in this country are;

1. food and garden wastes in the form of vegetables and fruits.

2. Plastics in the form of carrier bags, bottles and packets are major items in the waste as a result of the number of imported and locally produced items that are packed in plastics.
3. Paper (a combustible waste) is common as a result of the number of imported and locally generated items packed in cartoons, wrapped or parceled in papers.
4. Wood waste in the form of sawdust, woodcuttings and shavings is another type of waste that is generated extensively by carpenters and the timber industry.
5. Sewage in the form of liquid (toxic and non-toxic) and solid wastes (human faeces) are wastes largely generated in Sierra Leone. Again limited data exist on the quantity generated, thus only the Freetown municipality is considered. Flush toilets, Pit latrines and bucket latrines are three forms of human waste collection systems practised. In the rural areas where latrines are rare, bushes and rivers are used as dumping sites.
6. Sludge wastes are generated from power stations in the country. The Kingtom Power Station- KPS generates 10,000 litres per day when in operations. The components of this sludge include; Marine Fuel Oil wastes from the separators and purifiers, lubricating oil from the engine units in operation, used and spilled diesel, spilled and leaking water from the engines and coarse particles.

Table 3.14 shows the type and composition by percentage of generated wastes collected from four locations within the Freetown municipality.

Table3.14: A Typical Type and Composition of Wastes generated in the Freetown Municipality

Container sites	**Sankey Street**	**Taylor Street**	**Cape Sierra Hotel Area**	**Lightfoot Boston Street Area**	**Average**
Type of wastes	Type 1	Type 2	Type 3	Type 4	
Quantity of wastes sorted (Kg)	519	350.4	465	490	**456.1 Kg**
Specific weight of wastes (Kg/l)	0.45	0.3	0.44	0.37	**0.39 Kg/l**
% of biodegradable organic matter	17.4	26.4	48	24.9	**29.175 %**
Percentage of paper	4.9	3.6	14.1	11.5	**8.525 %**
Percentage of tins and scraps	3	1.8	2.8	3.1	**2.675 %**
Percentage of plastics and foils	2.4	1.4	1.6	2.4	**1.95 %**
Percentage of textile	5.6	3.3	1.2	1	**2.775 %**
Stones (>5cm)	1?	0	1	0.8	**0.45 %**
Glass	0.8	0.8	3.2	0.9	**1.425 %**
Wood	0.3	0	0.5	23.3	**6.025 %**
Toxic wastes (batteries)	0.9	0.4	0.3	0.3	**0.475 %**
Miscellaneous	1.4	2.7	3.4	3.7	**2.8 %**
Gravel (<5cm >5mm)	41.7	46.6	22.5	26.6	**34.35 %**
<5mm	20.5	13	1.5	1.4	**9.1 %**

Source: Ministry of Health and Sanitation

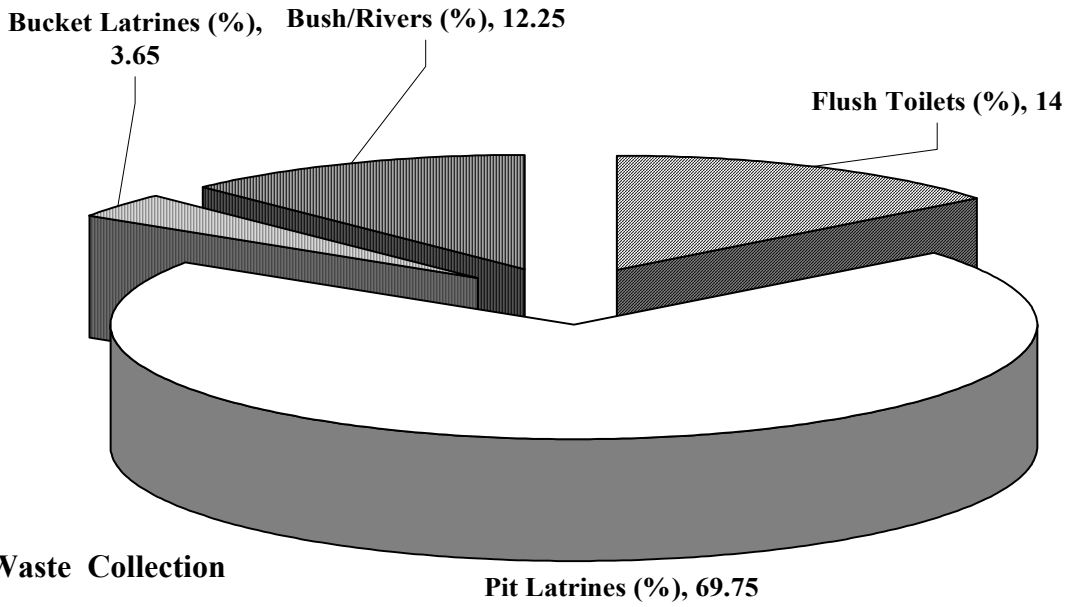


Fig.3.10 Methods used for collecting human excretion in Sierra Leone

3.10 Waste Collection

For markets places, offices and business centres, garbage wastes are collected in 20m^3 containers placed at designated points, whilst for homes and small scale businesses, wastes are collected in smaller containers and deposited at designated points.

For human wastes, septic/septic tanks are constructed in the case of flush toilets. For pit toilets, a hole is dug into which the human wastes are deposited directly. For the bucket toilets, human wastes are deposited directly into buckets and later deposited at designated sites.

For liquid wastes, no collection points exist, gutters are constructed on roads/streets sides for the wastes to empty into streams or rivers or the sea. In places where gutters do not exist, liquid wastes are thrown directly on the ground.

The sludge produced at KPS is collected and stored in a concrete pit with capacity of 130208 litres (32,552 gallons).

Agricultural wastes from harvesting are normally collected in heaps at the location where the activity occurred. For poultry and animal wastes, these are collected and dumped in designated sites within the area where these activities take place.

3.11 Waste Disposal

Disposal of collected wastes in Sierra Leone is done through four methods; **Incineration**, **Landfills and Open-dumps**, **Composting** and **Recycling**.

"Landfill" sites and "Open-dump" sites

Landfills and Open dumps are the most common methods used in the disposal of wastes. In the Freetown municipality, Kingtom (commonly called 'Bomeh') and Granville Brook (Kissy) are the two authorized locations for the disposal of wastes. But as a result of the increase in population of the Freetown municipality and the poor disposal systems that exist in the country, other unauthorized open dump sites have been created at locations where open lands and streams exist. These unauthorized open dump sites are common in areas that are densely populated. The Kingtom landfills site is also used for the disposal of sewage wastes. Transportation of collected garbage wastes to disposal sites is done using carts commonly known as "Omolankays" from where they are collected by sanitary vehicles to designated landfills.

Human wastes that are collected in septic/septic tanks are collected using septic vehicles and disposed off at the Kingtom landfill site. For human wastes that are collected in pits, disposal is done through burying, and those collected in buckets are either buried or emptied into the sea.

Waste Incineration
Incineration of combustible wastes is done mostly during the dry season. The following are the wastes incinerated;
- Burning of garbage wastes; this is done both in homes (leaves shed by deciduous trees) and
  unauthorized Open dump sites.
- Burning of wood-shavings and Sawdust.

Composting
Composting is done mostly on food and garden wastes. This is common in areas where vegetable farming is the main economic activity.

Recycling
Recycling is done mostly on non-decomposable items. The informal sector plays a very important role in this area. Pots, agricultural tools, tin lamps and bushings for cars are some of the items that are produced from recycling.

3.12 GHG Emissions from Wastes
Emissions of GHGs from wastes occur both during incineration and decomposition. In Freetown, were there are both "landfill" and "open dump" sites, decomposition initially occurs followed by case incineration. As a result of these two processes occurring side by side, the amount of GHG emitted into the atmosphere cannot be easily determined.

The emissions of CH_4 and CO_2 from wastes are influenced by the following:

Waste Disposal Practices
Waste disposal practices for CH_4 emissions vary in the degree of control of the placement of wastes and management of the sites. Wastes disposal on land will results in the production of CH_4 if the wastes contain organic matter.

Waste Composition
The composition of waste is one of the main factors influencing both the amount and extent of CH_4 production from "landfill" and "open dump" sites. Municipal solid wastes (MSW) typically contain significant quantities of degradable organic matter.

Physical Factor
Moisture content also influence CH_4 and CO_2 productions. It is essential for bacterial growth and metabolism as well as for transport of nutrients and bacteria within the dump sites. The moisture content of a dump site depends on the initial moisture content of the wastes, the extent of infiltration from surface and groundwater sources, the amount of water produced during the decomposition processes.

Digestion
Digestion is a microbiological process that converts the chemically complex organic wastes to CH_4, CO_2, and an inoffensive humus-like material. This reaction normally occurs in a controlled laboratory conditions in a closed tank or *digester* that is anaerobic— i.e., devoid of O_2. Digestion reduces organic matter by 45% to 60% .

Table 3.15 shows the amount of CH_4 and CO_2 emitted into the atmosphere from anaerobic digestion.

Table 3.15: Transition from solid matter to gases that occur through anaerobic digestion

	Degradable matter	**Water**	**Methane**	**Carbon dioxide**	**Other gases**
Organic compounds	$C_{68}H_{111}O_{50}N$	$16H_20$	35 CH_4	33 CO_2	NH_3
Weight	791 kg	131 kg	255 kg (27.6%)	660 kg (71.6%)	8 kg (0.8%)
*Gas volume**			354 m^3 (52.5%)	333 m^3 (47.8%)	10 m^3 (1.4%)

Source: Kura and Lea (1995).

Table 3.16 shows the length of time during which half of the degradable fraction is transformed into GHGs for varying types of garbage wastes. In all cases, decomposition of the remaining degradable matter extends over long periods of time.

The basic pattern is that GHG emissions from a particular quantity of MSW is highest in the first two years after the waste has been filled. During this time, anaerobic digestion of most of the degradable content of food wastes occurs. GHG emissions continue after this time but at slowly decreasing rates. In most cases, emission of GHGs occur within five years, because food and garden wastes typically comprise a large proportion of all organic materials in Municipal Solid Waste.

Table 3.16: Time taken for decomposition of half of the degradable content of wastes.

Type of waste	Food	Garden	Cardboard

Years	1	5	15
Source: Gendebien et al, 1992.			

Organic matter in Solid wastes disposal sites (SWDSs) is broken down by bacterial actions in a series of stages that result in the formation of CH_4 and CO_2. For these gases to be formed, anaerobic conditions with temperatures between 25 – 40^{O}C have to exist at the disposal site. The Landfilled Gas (LFG) produced consist of approximately 50% of CH_4 and 50% of CO_2 by volume. However, the percentage of CO_2 in LFG may be smaller because of decomposition of substrates with high hydrogen/oxygen ratio (e.g., fats, semi-cellulose) and because some of the CO_2 dissolves in water within the sites).

LFG particularly CH_4, can be of local environmental hazard if precautions are not taken to prevent uncontrolled emissions or migration into surrounding land. LFG is known to be produced both in managed "landfill" and "open dump" sites, and in theory, the life-time yield of a good landfill site is between 150m^3 to 300m^3 of gas per tonne of wastes, with between 50% and 60% by volume of CH_4. This suggest a total energy of about 5 to 6 GJ per tonne of refuse.

3.13 GHG emissions from Garbage wastes

As stated earlier, no accurate data exist on the amount of wastes generated in Sierra Leone, even the data provided by the Ministry of Health is inaccurate as it only considers wastes collected by their vehicles to the designated "landfill" sites. Figures 3.12 and 3.13 show the annual garbage and human waste that the Environmental Health Division of the Ministry of Health and Sanitation disposed of, between 1990 and 1996 within the Freetown Municipality.

From Figure 3.12, there is a gradual increase in the amount of wastes collected and disposed between 1990 and 1994 with a sudden leap in 1995 and 1996, which can be

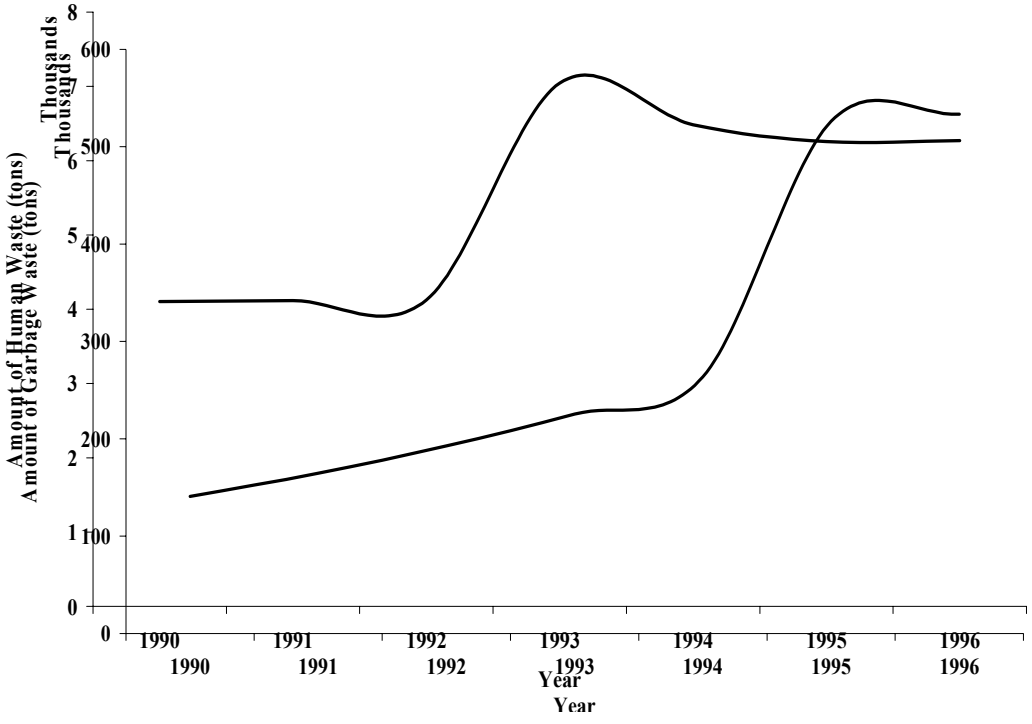


Fig. 3.13: Annual human wastes collected and disposed of within the Freetown Municipality from 1990 to 1996. *[SOURCE: Environmental Health Division of the Ministry of Health and Sanitation]*

attributed to the large influx of internally displaced people from the provinces to the Freetown municipality as a result of the war.

For human wastes, the amount disposed of is determined by the number of septic tanks that are filled an emptied per year, hence the undulation shape of the curve in Figure 3.13. This not withstanding, there is a significant leap in the amount of wastes disposed of in 1993 compared to the period 1990 and 1992. This trend on amount disposed of varies slightly between 1994 and 1996. This trend can be attributed to the increase in number of newly constructed houses with septic tanks and population growth within this period.

As with all activities dealing with emissions, the human factor in terms of the number of households plays a significant role, hence for this analysis, the number of households will be considered for all assumptions that will be made.

Wastes collection and disposal is conducted only within selected areas in the Freetown municipality, hence for this analysis, it is assumed that the information provided by the Environmental Health Division of the Ministry of Health and Sanitation is for about 40% of the households within the municipality. On the average, for the garbage wastes generated by each household, the following assumptions are made:

- that the data provided by the Ministry on garbage wastes is accurate
- that collection is done after every 4 days from government designated dumping sites.

Using these two assumptions, the average wastes generated per household every 4 days can be computed using the formula:

$$\left(\begin{array}{l}\textit{Average garbage generated per}\\ \textit{household in the freetown Municipality in kg}\end{array}\right)=\left(\frac{\textit{Annual Garbage Waste disposed of, at Landfill Site}}{\textit{Number of Households in the Freetown Municipality}*0.4*92\,\textit{days}}\right)$$

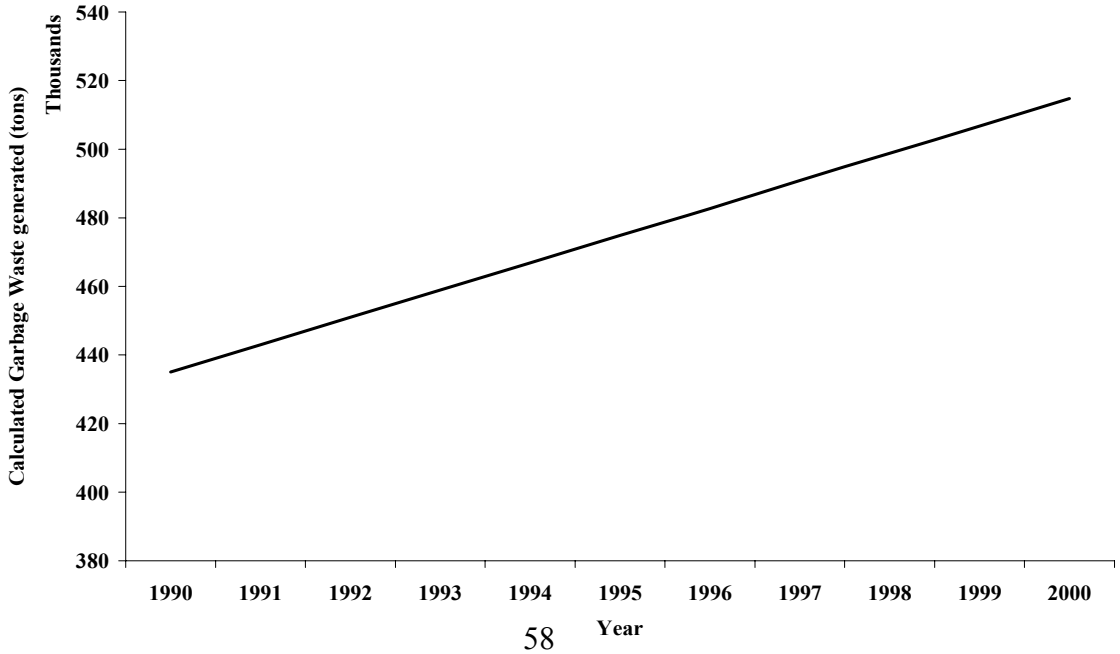


Fig. 3.14: Calculated garbage wastes generated by household in the Western Area Urban from 1990 to 2000.

Taking the mean garbage wastes from 1990-1994, it can be assumed that each household within 40% of the municipality generates about 42.7kg of wastes every 4 days. Base on this average, the annual garbage wastes generated for households in the Western area is shown in Fig 3.15.

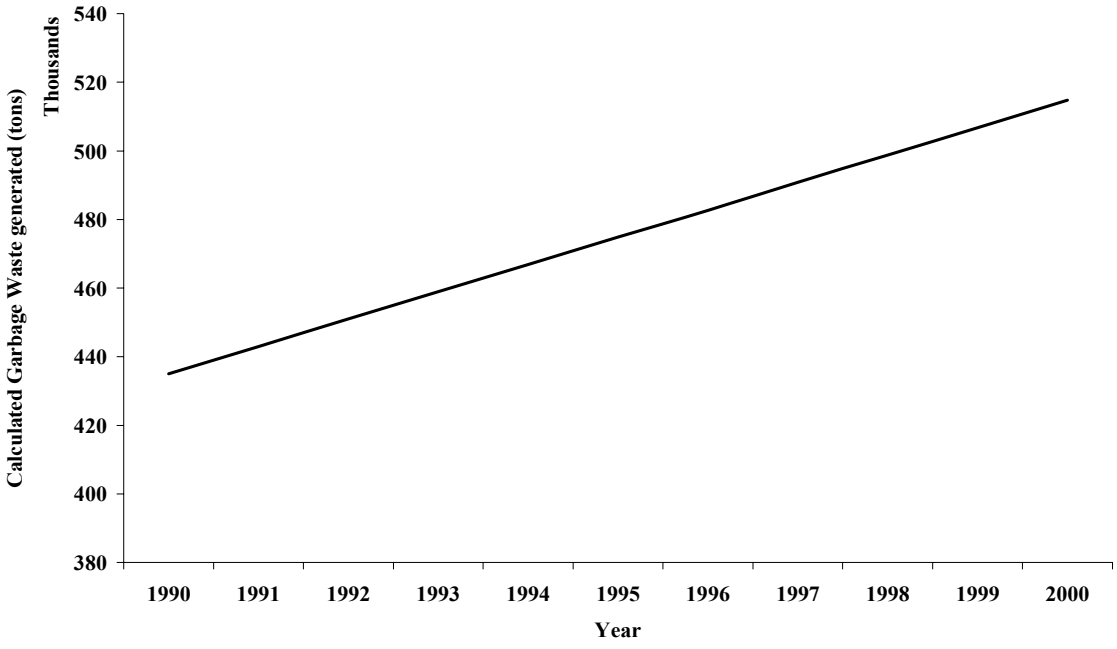
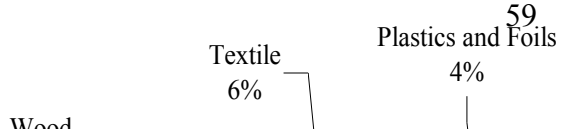


Fig. 3.15: Calculated garbage wastes generated by household in the Western Area Urban from 1990 to 2000



Using the segregated percentages in the composition of the Western area urban wastes of organic matter and combustible wastes (paper, wood, textile and plastics) from Table 3.14, Figure 3.16 was obtained.
Using Table 3.15, the amount of GHGs emitted from the organic component of the data provided by the Environmental Health Division of the Ministry of Health and Sanitation and the calculated garbage wastes can be obtained. For this situation the average quantity of water being considered is 50kg.

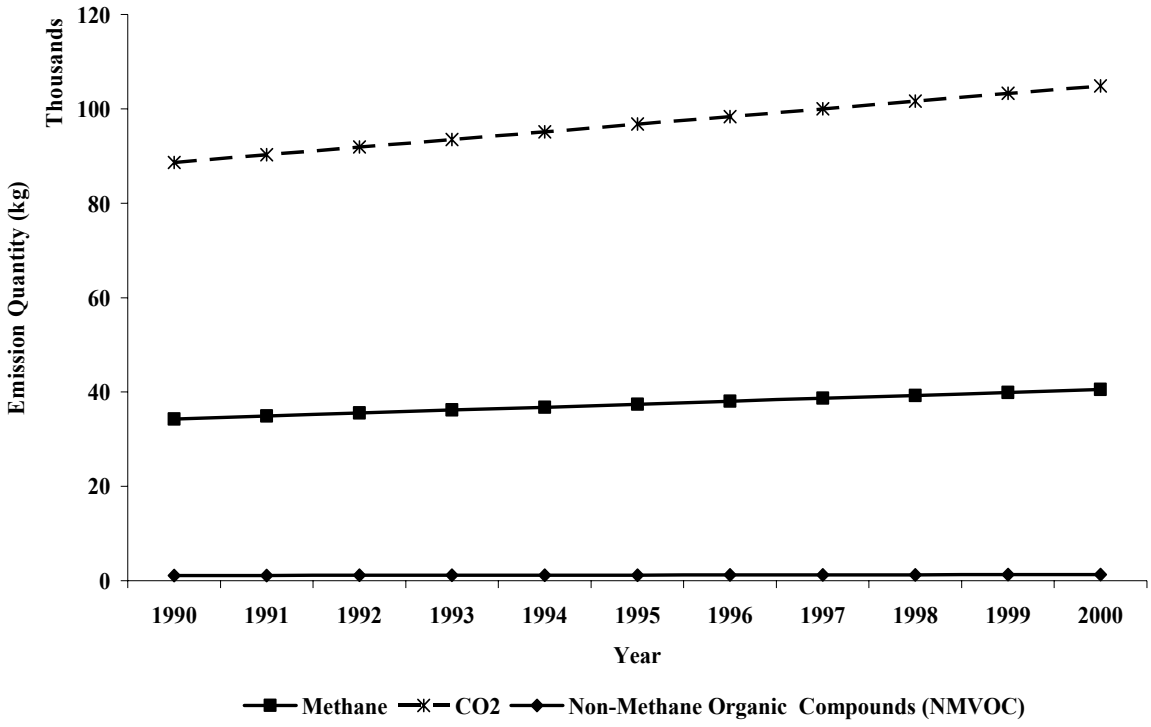


Fig.3.17: Quantity of GHGs emitted by organic component from calculated garbage disposed of in the Western-area-urban (1990 – 2000).

Figures 3.17 and 3.18 show the quantity of GHGs emitted into the atmosphere as a result of anaerobic digestion of the organic components of the wastes information provided by the Ministry and that calculated. Table 3.17 shows the cumulative amount of GHGs emitted into the atmosphere from 1990 to 1996 and the calculated estimated amount emitted from 1990 to 2000.

Most of the combustible materials in the garbage wastes are incinerated. Table 3.18 shows the GHGs emitted into the atmosphere from the incineration of the combustible materials in garbage wastes data provided by the Ministry and that calculated.

Table 3.17: Total GHGs emitted from garbage waste data provided by Ministry and that Calculated (per kg)

GHG	Waste Data provided by the Ministry (kg) (1990 - 1996)	Calculated Waste (kg) (1990 - 2000)
CH_4	11,076	411,212
CO_2	28,669	1,064,312
Non-Methane Organic Compounds	347	12,901

Table 3.18: Quantity of GHGs emitted from incineration of combustible garbage wastes (Ministry data and calculated estimate)

	CO_2	**CH_4**	**N_2O**
Combustible materials (Ministry's data for 1990 - 1996)	821,786	43	17
Calculated estimates for combustible materials (1990 -2000)	2,097,079	110	44

3.14 GHG emissions from human wastes

The method used in the collection of human wastes results in anaerobic digestion. Since collection is done in sceptic tanks, a significant amount of GHGs would have been emitted before emptying commences. This process starts with settling during which large items sink to the bottom. Next, air is bubbled through the sewage. This so-called aerobic phase encourages oxygen-using bacteria to break down organic materials in the sewage, such as human wastes, to acids and CO_2. Most disease-causing organisms are also killed in this phase. The sewage sludge left behind is attacked in a subsequent phase by *anaerobic bacteria* (bacteria that cannot tolerate oxygen). These bacteria break down the sludge to produce methane.

The average size of a typical septic tank is about 36cu.ft and is cleared on the average once every 8 years. As such, calculating the amount of GHGs emitted is difficult and the

assumptions made will be based on the following: emissions take place at the collection points, type of toilet

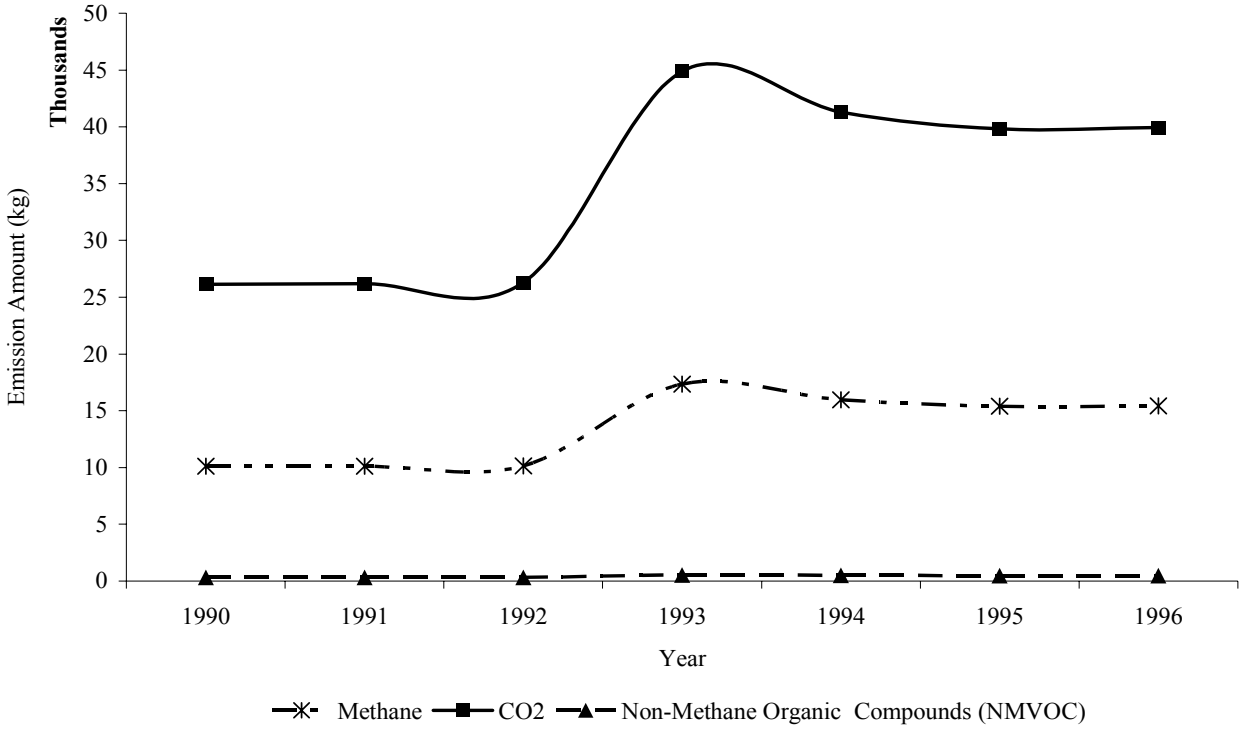


Fig.3.18: Quantity of GHGs from human waste disposed of within the Freetown municipality (1990 – 1996). *[SOURCE: Environmental Health Division of the Ministry of Health and Sanitation]*

is based on data given in Figure 3.11 and, in the case of human wastes collected in septic tanks, relative small percentage of emissions occur during clearing of the tanks and emptying at disposal sites.

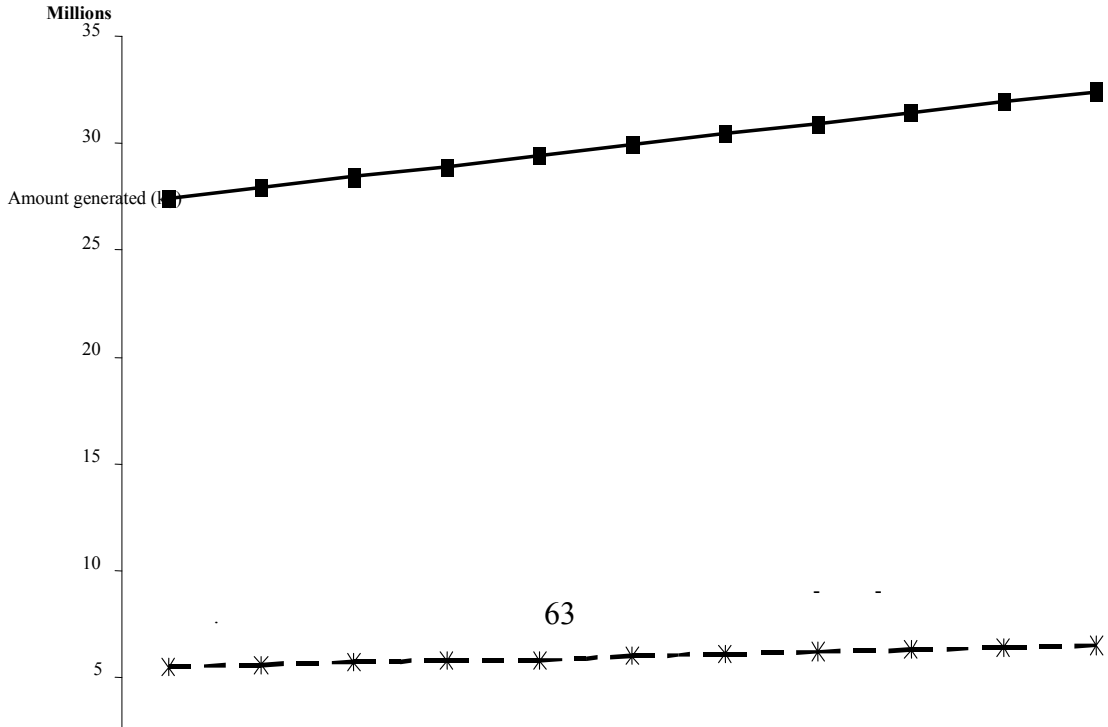


Fig 3.19: Calculated quantity of human wastes generated in the Western-area- urban by type of toilets.

Figure 3.18 shows the quantity of GHGs emitted based on the statistics provided by the Ministry for the Freetown municipality. This data is for users of flush toilets. Figure 3.19 gives the calculated quantity of human wastes generated from the three types of toilets used in the

Western area-Urban and Figure 3.20 gives the amount of GHGs emitted as a result of anaerobic digestion.

Table 3.19 shows the cumulative amounts of GHGs emitted from human wastes into the atmosphere from 1990 to 1996 and the calculated estimated amount emitted from 1990 to 2000.

Table 3.19: Total GHGs emitted from human wastes data provided by the Ministry and that Calculated (per kg)

GHG	**CH_4**	**CO_2**	**NMOC**
Human wastes data provided by the Ministry. **(kg)** (1990-1996)	94,498	244,584	2,965
Calculated Human wastes (1990-2000)**(kg)**	1,018,58	2,636,138	31,953

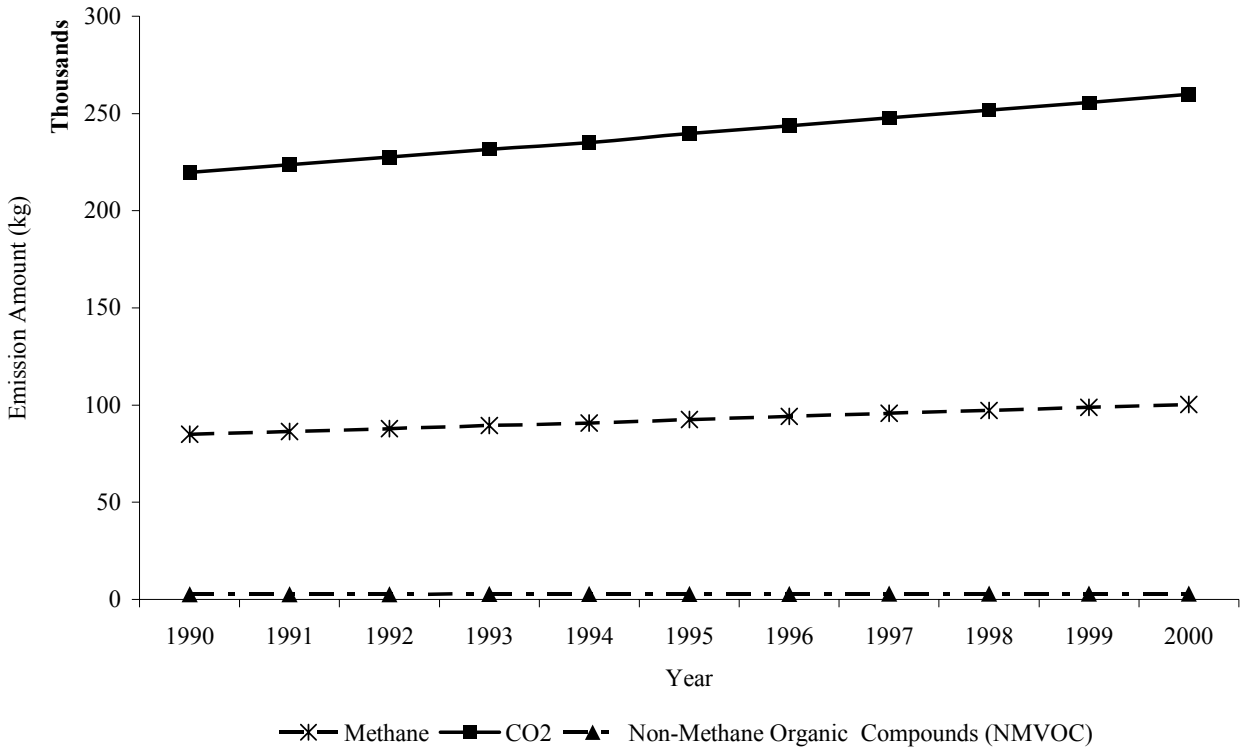


Fig. 3.20: Quantity of GHGs emitted from calculated human waste disposed of in the Western-area-urban (1990 – 2000).

3.15 GHG emissions from Marine Oil Sludge

Incineration is the method used in disposing of the sludge at the Kingtom Power Station. As stated earlier, 10,000 litres (2,642 gallons) of sludge is generated per day from 47,000 litres (12, 417 gallons) of MFO.

Figure 3.21 shows the annual sludge produced during electricity generation at NPA from 1996 to 2002. The shape of the graph in figure 3.21 relates to the quantity of MFO consumed when all or some of the four main generators are in full operation.
Based on the NPA tests, 4% of the sludge produced during generation is water. Table 7 shows the amount of GHGs emitted between 1996 and 2002 from the incineration of the sludge.

Table 3.20: Quantity of GHGs emitted from incineration of NPA Marine and Diesel oil sludge.

(1996 -2002)	CO_2	CH_4	N_2O
Total	93,632,592	3,636	1,939

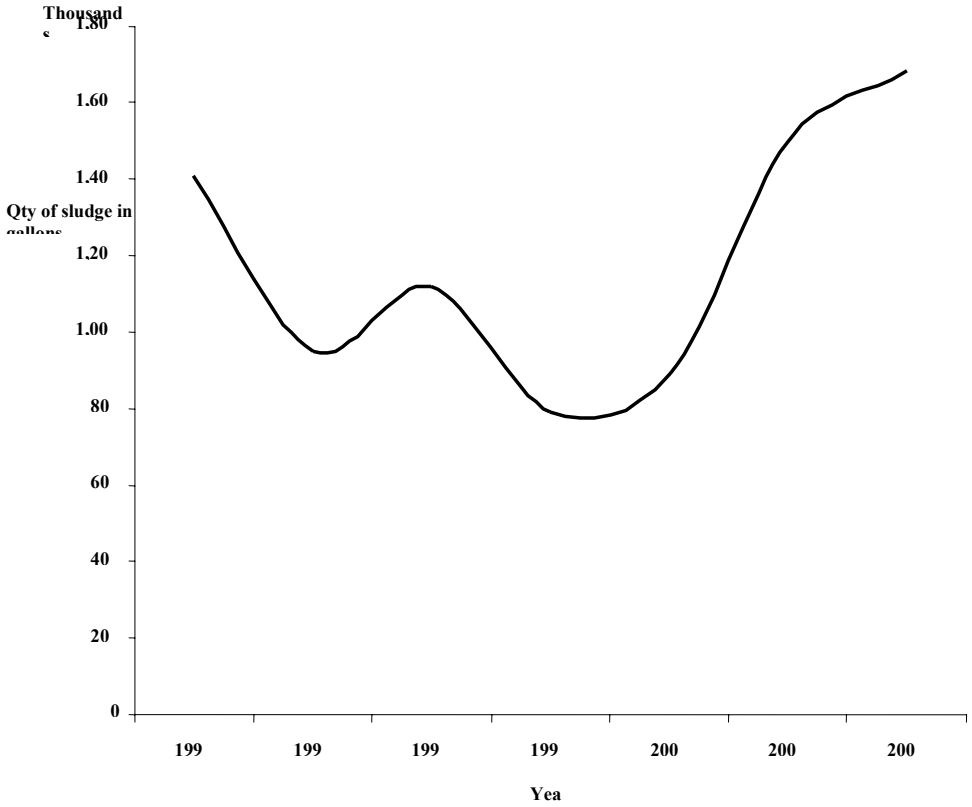


Fig. 3.21: Sludge produced at the Kingtom power station between 1996-2002. Source; NPA data. Conteh 2003

3.16 GHG emissions in the Western- area and Provinces

Garbage wastes

In the rural and interior of the country, a high percentage of the wastes generated is organic wastes because most of the people living in these areas are farmers who get their food stuff from the items they plant. Disposal of domestic wastes is through composting in the rainy season and burning in the dry season. During the harvest season huge amount of garbage waste are generated, which are disposed of in open dump sites located in the bush or forest. In the dry season just before the planting season, burning of farms is done. Each of these activities results in the emission of GHGs. As the areas where farming activities are not monitored for GHG emissions, no data exist on the amount of wastes dumped or incinerated.

3.17 Mitigation options in the waste management sector

Sierra Leone being a signatory to the Kyoto protocol is now embarking on mitigation options that will enable her reduce GHG emissions. To achieve this goal, a consultative workshop was held with stakeholders at which, a consensus was arrived at, on the mitigation options that are to be pursued to reduce GHG emissions, but at the same time

develop and improve the socio-economic status of the people and country. The method used to arrive at the mitigation options proposed by the stakeholders was the "Mitigation Option Weighting" method. The following options Table 8 were identified and weighted:

Table 3.21: Weighted Mitigation Options

Mitigation options	Weighting / 30
Waste incineration	19
Landfills and open-dumps	15
Composting	28
Recycling	25

The weighting method identified transforming organic wastes to manure as the most suitable mitigation option using composting. This method though considered as the best alternative has its constraints with respect to the manner in which garbage waste is collected. As such, for the manure option to be successful, initial separation of garbage wastes must first be done. For separation of garbage wastes to be achieved, the following should be done:

- Effective education of the populace on separation of garbage wastes.
- Separated garbage wastes should be sold.
- Recycling and manure producing (controlled anaerobic digestion) small-scale industry encouraged.

These mitigation options have the following benefits:

Monetary and Employment
Purchased of wastes will bring monetary benefit to garbage collectors as they will be able to sell the different types of garbage wastes to the respective businesses that are engaged in the processing of wastes. Employment will also be provided by these industries.

Methane Production
Controlled anaerobic digestion through the mixing of human wastes and food wastes will lead to high yield of CH_4. This can be sold as LPG for cooking.

Enironmental Benefit
With the reduction of garbage waste through recycling and manure production, the environment will be clean and healthy. This in turn will reduce the amount of money spend on medical bills

In the case of the sludge produced at the Kingtom Power Station, CLOGEN a company in Nigeria has developed a technique for its treating that has no adverse environmental effects. This treatment separates all the components that form the sludge and recovers the oil. This option has a lot of benefits;

- its has no emission since no combustion activity is involved,

- it has a cost recovery component as the oil that would have been lost is recovered
- creates employment

Based on these two scenarios, significant savings can be made from these three categories of wastes.

In the urban areas of Sierra Leone particularly, landfill sites can be designed at strategic places were domestic refuse (MSW) can be safely deposited after sorting to allow anaerobic digestion. The gas, LFG, produced can be collected by an array of interconnected perforated pipes buried at depths of up to 20m in the refuse. In the case of new landfill sites, the pipe system is constructed before the wastes are deposited. The gas collected can be used for electric power generation or heat as required.

3.18 Agricultural residues (both plants and animal wastes)

Crops and animal wastes are known to provide significant amounts of energy. It is estimated, for example, that about 110MT of dung and crop residues can be used as fuel, coming second only to wood as the dominant biomass fuel world-wide.

Wood residues

Operations such as thining of plantations and trimming of felled trees can generate large volumes of forestry residues. At present in Sierra Leone, these are often left to rot on site. They can be collected, dried and used as fuel by nearby rural industries and domestic consumers.

Timber processing is another source of wood residues. Dry sawdust and offcuts produced during the processing of cut timber make very good fuel. The sawdust and offcuts can be collected country wide from furniture industries and processed to produce fuel.

Over 90% of domestic waste in Sierra Leone is currently landfilled, most of the remainder being incinerated. The presence of plastics, metals, bottles and toxins create pollution problems, but landfill and incineration sites can be subjected to operating conditions laid down by appropriate regulatory authorities and designed in such a way to ensure that GHG emissions are reduced to acceptable levels.

However, large scale plans for waste separation, recycling and composting are yet to be effected in Sierra Leone. Energy from wastes is an attractive option but the shortage of suitable landfill sites within the city and the high costs of transporting the wastes to distant sites is a limitation.

3.19 MITIGATION OPTIONS IN THE AGRICULTURAL SECTOR

3.19.1 Sources of GHGs in the Agricultural sector

A recent inventory on GHG emissions from the Agricultural sector in Sierra Leone identified a number of gases such as methane (CH_4), carbon dioxide (CO_2), Carbon monoxide (CO), Nitrous oxide (N_2O) and NOx. (Consultancy Report, 2005. The period of inventory was six years, 1990-1995, with 1990 as the base year.

3.19.2 Estimation of GHGs from the Agricultural sector

Five (5) main sources GHG emissions were considered: *domestic livestock*, *rice cultivation* (deepwater), *prescribed burning of savannas* (bush fires) *field burning of agricultural residues* and *agricultural soils*.

3.19.3 Deepwater and flooded rice cultivation in Sierra Leone

Deepwater rice cultivation is practiced in all the lowland ecologies**:** Inland Valley Swamps, (IVS) bolilands, Mangrove swamped mudflats and the time riverain grasslands.

Flooding in the IVS is caused by direct precipitation, run-off water from the catchments and seepage from underground. Flooding in virgin IVS is permanent. During the growing season, land preparation involves brushing of the previous year's rice straws, clearing or burning the straw on site, and puddling. During puddling, organic matter is incorporated into the soil. The rice is then transplanted or wet seeded, immediately.

In the case of bolilands, flooding occurs once every year. Like the IVS, these saucer shaped lowlands are flooded by direct rainfall, run-off, and under ground seepage. Once flooded, heaps made on the previous year's harvested fields are scattered and the organic matter (rice straw, potato vines, groundunt strubbles), are incorporated into the soil, and the rice seedlings transplanted.

In the riverain grasslands, flooding is mainly from the adjacent rivers and occurs during the rainy season. Before the advent of the floods, the fields are tilled, incorporating the rice straws. Floating rice varieties are then transplanted immediately the flooding begins.

Flooding in the tidal mud flats or mangroves occurs throughout the year twice a day by tides from the ocean. These tides deposit large quantities of organic matter and silt in which seedlings are transplanted.

3.19.4 Mitigation options under deepwater conditions

Deepwater rice cultivation offers very limited management options to reduce CH_4 emissions. A major mitigation option is the prevention of denitrification of the nitrogen in the incorporated plant residues.

In the absence of irrigation where the water regime can be modified (increased or reduced flooding), greater attention should be given to the nature and amount of organic matter in the soil:

- **Low amounts of organic matter**: Should be incorporated at the time of puddling where large amounts of plant residues are incorporated in the flooded soil, toxic gases and elements like CO_2, CH_4, manganese and iron are more likely to be produced.
- **The use of rice-straw compost, and biogas residues:** The use of raw rice straw and other raw organic materials should be avoided. In its raw state, there is room for methanogenesis (production of CH_4). Burning of rice straw or using compost (fermented material) depletes methanogenic substrates. Experiments have shown that the use of compost and biogas residues reduces CH_4 emissions by 58-63% and 10-16% respectively.

- **Mineral fertilizer use:** Lowland rice farmers seem to have more faith in mineral fertilizers than in the use of organic materials because, apparently almost all the soil types are acidic to some extent and low in fertility;

- The problems with fertilizer use are that, majority of farmers have very little or no knowledge about the nature, method of application, time of application and placement of the fertilizer. Their education could be an effective mitigation option for the abatement of GHG emission especially for Nitrogen fertilizers.
- The excessive use of nitrogen, especially urea Nitrogen entails N_2O emission. Since nitrate denitrifies easily in flooded soil, nitrogen fertilizers in nitrate form are not appropriate for deepwater. Ammonium forms of basal nitrogen should be used instead of nitrate forms. Ammonium fertilizers in the reduced zone are not converted into nitrate and nitrogen gas.

- **Fallow incorporation and mulching:** When fallow material and mulch are added to the deep water soils, CH_4 and other GHGs emissions are reduced. Research has shown that in Asian countries, these materials reduced emission levels by 11% each (Wassmam et al, 2000). This reduction effect is explained by the fact that in fallow and mulch materials, the substrates for methanogenesis and the amount of nitrate nitrogen are greatly reduced.

3.20 MITIGATION OPTIONS IN IRRIGATED FIELDS

Irrigated agriculture in flooded rice fields is practiced mainly in the developed IVS scattered over the country. The method of irrigation is flood irrigation where rice plots are flooded with water stored in reservoirs. The irrigation process is mainly supplementary as, the fields are rain-fed during the rainy season. Table 3.22 summarises details of IVS development in selected districts as at 1994. Water levels in the flooded fields can be controlled to ensure that the water requirement of the rice crop is satisfied.

Table 3.22: Status of IVS development as at 1994**.**

District	Area (ha)	Developed (ha)	Perennial (ha)	Seasonal (ha)	Flood 7 + months
Port Loko	62,309	3,240	14,767	44,301	15,062
Koinadugu	116,816	2,430	28,597	85,791	29,169
Moyamba	68,014	2,330	16,421	49,263	16,749
Kenema	64,997	3,208	15,447	46,342	15,756
Total	**312,136**	**11,208**	**75,232**	**225,697**	**76,136**
Source: FAO, 2005 Bankable Projects.					

Under these baseline practices, the following crop management modifications or mitigation options were investigated: Water regime management, organic amendment, mineral amendment, straw management/composting and crop establishment

These mitigation measures can easily be applied in developed IVS in Sierra Leone

1. **WATER REGIME MODIFICATION**

- Flooding of the prepared field: This mitigation option cuts across the three baseline practices outlined above. Thus, a primary mitigation option for the reduction of N_2O emissions is to minimize denitrification by reducing the amount of organic matter in the soil.

- Mid Season drainage: This practice should be adopted in the flooded rice plots when the rice crop is fully established. The draining of the field at this stage, reduces denitrification and methanogenesis. The reduction in emission is even higher when organic matter is introduced. In Asia, it reduced CH_4 emission by 7 - 44%.

- Alternate flooding and drying: This action is aimed at disrupting methanogenesis and denitrification both of which occur only under flooded conditions. It has been found to reduce CH_4 emission by 60% as compared with continuous flooding.

2. **Organic Amendment**

- Application of rice straw compost: Rice straw in the form of compost is an effective mitigation option for reducing CH_4 and N_2O emission in rice fields. The practice of incorporating raw organic matter during puddling should be avoided. The straws or strubbles should be burnt in the field and puddled into the soil. The burning action destroys the substrate for methanogenesis and formation of N_2O.

- Cattle manure and biogas residues: The use of cattle manure and biogas residues (both fermented materials) were found to reduce emission by 77%and 10% respectively under baseline practice (ii) above.

3. **Mineral fertilizer amendments**: For deepwater rice cultivation discussed above, excessive use of Nitrogen fertilizers should be avoided. The use of phosphogypsum, and Ammonium based Nitrogen fertilizers should be encouraged amongst farmers.

4. **Straw Management**

- Fallow incorporation: Fallow material is a poor methonogenic substrate and is also of very little use to denitrifying bacteria. It therefore reduces the emission of CH_4 and N_2O.

- Crop Establishment: Studies in Asian countries (2000), have shown that direct wet seeding (a process also common in Sierra Leone), which reduces CH_4 emission substantially.

3.21 MITIGATION OPTIONS FROM AGRICULTURAL ACTIVITIES

3.21.1 Mitigation Options in Lowland Rice Production

The success of any mitigation option for the abatement of GHG emissions in lowland (flooded) rice fields depends on the thorough elucidation of the prevailing biophysical conditions and how these (biophysical conditions) are manipulated for rice production. It is also essential to understand the chemistry and the pathways of GHG production and emission.

Types and extent of flooded (lowland) areas:

The table 3.23 gives details of the types of lowlands where flooded rice cultivation is practiced.

Table 3.23: Details of the types of lowlands where flooded rice cultivation is practiced

Ecosystem	Extent x 1000
Inland Valley Swamp	630
Boliland	120
Mangrove swamp	200
Riverain Grassland	110
	1070

Flooding Pattern in the Lowlands

- Inland Valley Swamps: These are narrow, flat bothed, seasonally flooded valley occurring throughout the upland areas of Sierra Leone. They vary in size from about 10ha to 200ha, and are more extensively used for flooded rice production than any of the other lowland types.

- Mangrove Swamps: These form part of the coastal ecosystems, where water region is influenced by tidal movements from the ocean. The mangroves or mudflat are flooded twice a day by saline water from the ocean.

- Bolilands: The Bolilands are saucer-shaped to flat grass lands associated with the major rivers of the Rokel series and are mainly in the central plains of the country. They are subject to prolonged inundation in the rainy season partly due to overflow from the scarcies,

- Riverain Grasslands: Riverain grasslands are the extensive alluvial plains along the Sewa, Wanjei and to a lesser extent, little scarcies Rivers. About 70% of the area is seasonally flooded, the depth of flooding being related to variations in topography.

3.21.2 GHG Formations and Emissions in the Flooded Rice Fields

GHG productions and emissions occur both in Irrigated and non-irrigated lowlands. Amongst the categories of lowlands, irrigated rice is grown only in the Inland Valley Swamps. Such irrigation is carried out in the developed swamps and involves mainly water control. During the rainy season, the irrigation gates are closed and the rice fields are rain fed. The dry season crops are irrigated with water stored in the reservoir. A greater proportion of inland valley swamps are still undeveloped while some are still in the virgin state. These are continuously or permanently flooded.

3.21.3 GHG Emission in Flooded Rice Fields: Inland Valley Swamp, Riverain, Grasslands and Bolilands

- Under flooded condition, the nitrogen in the incorporated plant residues is changed to ammonium (NH) form which is stable under flooded conditions and will later be used by the growing rice plant. If the soil is not flooded immediately after polishing, a second microbiological change takes place during which nitrate (NO) nitrogen are formed as in "inland" soils. Then, when the soil is flooded, the nitrate is changed to gaseous form (N and NO). These gases eventually escape into the air as N_2, and N_2O.

The loss of nitrogen into nitrogen gas is called denitrification. Thus the prevention of denitrification is a primary mitigation option for the reduction of N_2O and N.

- Where large amounts of plant residues (organic matter) are incorporated in the flooded soil, toxic gases like CO_2, iron (Fe) and manganese are more likely to research has shown that 2 or 3 weeks should be allowed to pass after the field is flooded before rice seedlings are transplanted to save seedlings from the toxic effects of some of these end products CO_2, CH_4, NO_2, N_2.
- Since nitrate denitrifies easily in flooded soil, nitrogen fertilizers in nitrate forms are not appropriate for lowland rice.

Ammonium forms of Basal Nitrogen Fertilizers

These should be incorporated into the soil to prevent denifrification which could lead to the transformation of nitrogen into nitrogen gas and N_2O into the air. However, denitrification of ammonium fertilizer can be prevented by immediately incorporating basal ammonium nitrogen into the lower zone of the soil. Ammonium fertilizer incorporated into the reduced zone is not converted into nitrate and nitrogen gas. This is why ammonium forming nitrogen fertilizers such as ammonium Sulphate urea and ammonium phosphate should be used for lowland rice.

CH_4 production: CH_4 emission is enhanced by the use of fresh manure. This can be reduced by using terminated material.

3.22 MITIGATION OPTIONS FOR THE REDUCTION OF GHGs FROM LIVESTOCK

The distribution of livestock is not uniform. The Northern province holds nearly 90% of the total cattle population while sheep and goats are more widely distributed. Whereas the cattle are almost exclusively owned or herded by the Foulah pastoralists, the majority of rural households own a few small stock. The relative proportions of sheep and goats vary, with a majority of sheep in the North and goats in the South and East. These animals are reared predominantly on free-range. The lack of security of tenance for the herds men, combined with traditional seminomadism cause the Foulah graziers to move periodically from one chiefdom to another. These circumstances inhibit the introduction of improved management of the animals.

1. **Enteric Fermentation**

Mitigation Options

- Under the present nomadic practice of livestock management, it is quite difficult to implement any mitigation measures to reduce GHGs from the animals. In this regard, the following mitigation options are recommended:

Cattle, sheep and Goats

For these animals, stall feeding should be introduced. This means, Government should create or enforce existing legislations requiring the establishment of cattle ranches in the dominant cattle raring districts, as well as stables for sheep and goats.

Feed and Fodder Modification

The emission level of CH_4 and NO_2 from animals depends on the nutrient content of the feed, and the quantity of the feed consumed. The higher the nitrogen and carbon contents, the higher the amount of NO_2 and CH_4 released.

With regards to the above comments the following mitigation measures are suggested:

- Conduct research on the nutrient content of fodder feed to animals, in order to determine the carbon and Nitrogen contents. Examples of fodder feed are.
    - Grasses - Elephant grass (hasmopodium Spp, Hyparrhenia Spp)
    - Calopo (calopogonium nuiconoides
    - Puero (Pueraria Phaseoloides
    - Fodder legumes: Pegeon Pea (cajanus Cajan) and Leucacna lencocephala
    - Gliricidia (Gliricidia sepium)

- Minimize the use of fodder and feeds with high levels of nitrogen and carbon
- Regulate the timing and amount of feed or fodder.

2 **Manure management**

It is difficult to reduce GHG emissions from animal manure when it is scattered all over the grazing area, as in the case of cattle, sheep and goats. However, manure deposited in ranches, stables, poultry houses and pig pens can easily be collected and used for fertilizing lowland and upland rice fields as well as in vegetable production.

3 **Prescribed Burning of Savannahs**

In the savannah areas, wild bush fires are common during the dry season. Also, the nomadic cattle herder uses burning to regenerate trees and grasses for their cattle. The slash and burn farming practiced in the forest zones of Sierra Leone is also a potential source of GHGs. In fact bush fires produce all types of carbonaceous and nitrogenous GHGs. To reduce the levels of these gases:

- Government should formulate legislations or enforce existing ones to control minimize or even abolish savannah burning.
- Introduce support and promote sedentary farming and cattle raring in the country.
- Encourage and promote irrigated rice cultivation in all the ecologies. This involves very little or no burning

4 **Agricultural Residues**

- Use residues to make compost for use as organic manure in rice fields.
- Burn residues and use ash to fertilize initiated as well as deep water rice fields and rain fed farms. Burning residues reduce CH_4 emission but N_2O increases.

3.23. SUMMARY OF ANALYSIS OF MITIGATION OPTIONS FOR GHG EMISSION IN AGRICULTURE

Table 3.24: Mitigations options for irrigated rain fed and deepwater rice cultivation.		
No.	**Mitigation option**	**Weight /30**
1	Water regime modification	23
2	Organic residue management	23
3	Use of mineral fertilizer	18
4	Straw management	21
5	Crop establishment	24
LIVESTOCK: ENTERIC FERMENTATION AND MANURE MANAGEMENT		
1	Creation of cattle ranches stables pig pens and poultry houses	22
2	Improved intensive/semi-intensive ducks and chicken management	21
3	Animal manure management use of manure in lowland and upland rice fertilization	21

3.23.1 ASSESSMENT OF GREENHOUSE GAS MITIGATION MEASURES AND POLICIES IN THE FORESTRY SECTOR

3.23.2 Forestry and land-use situation:

Sierra Leone is essentially a forestry country, but with the forest types considerably modified by the activities of man. About 95% of the forest production is fuel wood. Most of it is slash-and-burn agricultural system, and does not enter the market economy. Forestry contributes about 2-4% to the GDP of which one-fourth is attributed to the wood processing sub-sector (Artisan).

3.23.3. Vegetation and Land-use of Sierra Leone:

Table 3.25: The relative area of the various vegetation types are as follows:

Vegetation/Land-use type	Area km^2	%	Dominant land-use
Closed high forest	3,652	5	Forest Reserve, Timber
Secondary Forest	2,610	3.6	Timber, firewood, coffee, cocoa
Forest Regrowth	37,744	52.2	Fallow with arable crops in mixed stands, fire wood
Savannah woodland	6,226	8.6	Grazing, Bush fallow with arable crops in mixed stands
Mixed tree savannah	7,320	10.0	-do-

Lophira tree savannah	2,646	3.7	grazing
Coastal woodland	501	0.7	Bush fallow, arable crop in mixed farms
Coastal tree savannah	564	.8	none
Upland grassland	2,552	3.5	Bush fallow with arable crops
Montane grassland	40	0.1	grazing
Rock outcrop	500	0.7	none
Mangrove swamp forests	1,716	2.4	Paddy rice cultivated
Fringing swamp forest	288	0.4	-do-
Raphia swamp forest	355	0.5	-do-
Swamp/riverine grassland	1,819	2.5	Bush fallow, rice some arable crop
Swamp cultivation	2,039	2.8	Paddy rice some water controlled
Upland crops	1,640	-	Arable crops, orchards, scattered crop, plantations
Oil palm plantation	63	0.1	Oil palm
Rubber plantation	21	-	Rubber
Forest Plantation	25	-	Timber/Firewood
Source: FAO/LRS, 1980			

3.23.4 Forest Resources:

Some 6.3million ha have recently been classified as forest lands (UNDP/FAO – LRS 1980) or around 87% of the total area of the country. The forested area, which comprises bush re-growth of the shifting cultivation system (60% of the total), is distributed as follows:

Table 3.26: Forest Resource Areas

Forest type	Area '000ha	%
Closed high forest	365	5.8
Secondary forests	261	4.1
Forest regrowth	3,774	59.9
Savannah woodland	1,619	25.6
Mangrove and Assonated forest	286	4.5
Plantations (Forest Trees)	4.0	0.1
Total	**6,309**	**100**
Source: FAO/TFAP, 1990		

Of this 6.3 million ha, only 5% (365,200ha) are considered as the government Forest Estate which is made up of the following categories:

- Gazetted Forest Reserves, fully under the protection of the Forestry Division of MAFFS
- Proposed Reserves, also under control of the FD but not yet legally gazetted.
- Protected Forests on chiefdom lands, but protected and administered by the FD, and consisting predominantly of strip plantations along roads.
- Game Reserves and National Parks

3.23.5 Major Forest Types:

The major forest types in Sierra Leone are: **Closed high forest** , **Secondary forest**, **Forest re-growth, Savannah woodland** and **Mangrove Swamp forests.**

National and Sector development policies and measures:
A national forest policy was for the first time, explicitly stated in the National Development Plan (1974/95 – 1978/79), which nevertheless was not carried out for a variety of economic and political reasons. The relevant aspects for the Forestry Sector can be summarized as follows:

- Acquisition, management and protection of a forest estate, including the development of plantations, sufficient to ensure the supply of sawn timber poles and fuel-wood and to maintain the quality of the environment.
- Development and expansion of the saw-milling industry in both the Government and private sectors to ensure maximum production from the natural forests and plantations.
- Establishment of wood using industries to ensure maximum utilization of the timber produced by the forests.
- Conduct of forest research and forest training programmes to the extent necessary to sustain the foregoing requirements.
- Preservation and conservation of the country's wildlife resources.

For these purposes, the first National Development Plan stated definite goals to be achieved, such as increasing the area under forest from 4.3% to at least 10% by reservation of an additional 1,600 square miles, to increase the area under plantations by 25,000 acres, to finance and reorganize the Forest Industries Corporation (FIC) to ensure adequate control over timber concessions and to strengthen the Forest Department at all level. Unfortunately, none of the projects were implemented.

3.24 Current status:
For decades forestry has been neglected and its role in land use and economic development has been largely overlooked. The situation has further deteriorated in recent years, and in effect no forest management has been exercised, partly due to the archaic and inadequate forest law but mainly due to inadequate funding.

The need for a broader forest policy related to land use and agriculture was recognised in the 1986 Green Revolution Programme which identified the forestry's roles as:-

- To conserve and develop forest areas so as to protect the soil and water resources and maintain micro-climate stability for a sustainable agricultural production programme.
- To employ forest vegetation to replenish soil fertility on a sustainable basis.
- To increase significantly the production of forest products which contribute directly to food supply and also benefit the rural population in cash terms.

Forest policy, by the nature of the resource involved, is necessarily long term, but to make such policy effective requires the identification and funding of short term priorities associated with long term development benefits. The main short term priorities are:

- Conservation of the forest estate, by instituting sound silvi-cultural management (including control of forestry logging and protection).
- Development of pilot programme in improved agro-forestry cropping systems.
- Development of pilot firewood plantations.
- To manage and sustain a comprehensive research programme to provide sound technical basis for improved agro-forestry systems, to work on fuel-wood species and other species important to the national economy.
- Develop a data base for forest areas to allow the planning of management systems
- Assistance to and coordination of other agencies working in these priority areas.

The longer term approach would continue these priorities, expand successful programme to include increased priorities and programmes for:-

- A fuller conservation programme co-coordinating wildlife and ecology
- Development of mainly forestry watershed management systems in selected catchments
- Development of industrial plantations and investment scale programmes in agro-forestry and fuel-wood.
- Expansion of forest training to match capability to increasing responsibility.

3.25 1mportance of the forestry sector:

The national inventories of GHG emissions were carried out in the Agriculture, Forestry and other sectors. Results obtained indicated that about 85% of total CO_2 emissions from anthropogenic sources originated from changes in forest and woody biomass stocks and from forest and grassland concession. Additionally, of all other sectors, the forestry sector provides a reliable sink for the removal of CO_2 and its sequestration and storage for some reasonable time in woody biomass or in long term durable wood products. in the maintenance of climatic resources, the protection of water catchments areas, the protection of soils and the conservation of biodiversity

- In meeting energy needs
- In the supply of timber and non-timber forest products

3.26 Potential forest Mitigation Options

The following potential mitigation options have been identified:-

i. Reducing the demand for fuelwood (reducing deforestation)
ii. Preserving forested lands as national Parks, Sanctuaries, Aboreta etc
iii. Aforestation /plantation establishment
iv. Community Forestry
v. Forest Conservation
vi. Forest Protection
vii. Agro-forestry cropping System
viii. Reforestation/Rehabilitation of degraded lands
ix. Increasing efficiency of wood recovery/use

x. Substitution of timber for high energy construction material
xi. Substitution of wood and other biofuel for fossil fuels
xii. Integrating trees into existing landuse patterns-shelter belts
xiii. Residential shade trees/roadside vegetation

All these thirteen options have been grouped into

1. Protection options (i.e. maintaining existing sinks)
2. Reforestation/Regeneration options (i.e. expanding sinks)

3.27 Main types of mitigation options in forestry

The main purpose of forestry mitigation options is terrestrial carbon storage, which would reduce atmospheric accumulation and thus delay its impact on global climate. Mitigation options may be classified into three basic types:

- To expand vegetation stocks and the pool of carbon in wood products. This captures carbon from the atmosphere and maintains it on land for several decades
- The existing stands of trees and the proportion of forest products currently in use. Maintenance of existing stands, whether achieved through reduced deforestation, forest protection, prolonged useful lifetime of products or through improved cook stoves, lengthens the duration the carbon stays trapped in terrestrial ecosystems and provides immediate carbon benefits.
- The third avenue is to substitute wood derived from renewable sources e.g. plantations, for more GHG intensive products, particularly fossil fuels. Fossil fuel substitution with biomass derived from sustainable managed renewable sources delays the release of carbon and may increase the standing stock of carbon on land if the biomass is form newly afforested/reforested areas.

3.28 Analysis of mitigation options in forestry

Studies were carried out on measures to mitigate climate change through the forestry and land use sector, using the COMAP (Comprehensive Mitigation Analysis Process) model as an analytical tool. 1980 was chosen as the base year and 2030 as the end of the analytical period of 50years.

3.29 Methodology

The COMAP approach is dependent on finding the least expensive way of providing forest products and services while reducing the amount of carbon emitted from the land use sector.

The mitigation options are then matched with the types of future wood-products that will be demanded and with the type of land that will be available. Based on this information, the potential for carbon sequestration and the cost and benefits per hectare for each mitigation option is determined. The carbon and cost and benefits information is used to establish the cost-effectiveness of each option, which yields its ranking among other options. The information is used to estimate the total and average cost of carbon sequestration or emission reduction.

3.30 Forest Protection as a Mitigation Option

Land area under Baseline Scenario is estimated at 15,000ha and the area to be protected under the Mitigation Scenario is also 15,000ha during the period 1990 to 2030. The biomass density (t/ha) was 200 for Baseline Scenario and Mitigation Scenarios. Also the soil carbon density for both scenario cost of protection was estimated at US$ 2/ha/year.

At the end of the study period (2030) the land area under Baseline Scenario (BSL) and Mitigation Scenario (MTS) were 1,000ha and 12,000ha respectively.

Result of Carbon Pool and Sequestration

	Baseline Scenario	**Mitigation Scenario**
Biomass density (t/ha)	107	238
Biomass Carbon density (tc/ha)	54	119
Soil Carbon density (tc/ha)	100	149
Total Carbon density (tc/ha)	154	268

Result of cost effectiveness of Forest Protection

- Net Present value of benefits is calculated as - US$0.12/tc or US$ 31/ha.
- Benefits of reducing Atmospheric C is US$0.009/tc – year.
- Initial cost of Forest Protection was US$0.020/tc or US$5/ha.
- Present value of costs (Endowment) is US$0.36/tc or US$92/ha.

As a result of these protection measures, an additional 12,000ha of high forest above the Baseline situation would be maintained and managed as productive forest. The rate of deforestation of intact forests would be progressively reduced total carbon density increased from 154 tC/ha to 268tc/ha at the end of the 40 year period.

Among the various activities under the forest protection option, the following are of importance;

- Increased surveillance of the Permanent Forest or Protected Areas.
- Involvement of major stakeholders in the management, conservation and protection of forest.
- Provision of alternate livelihood for local communities as an incentive to prevent deforestation i.e., forest-based eco-tourism, provision of markets for non-timber forest products and Agro-forestry cropping system.
- Creation of National Parks, wildlife sanctuaries arboreta etc.
- Education, sensitization and enforcement of regulations/laws on environmental degradation.

3.31 Reforestation/Regeneration as a mitigation option

Waste land under the BLS was 40,000ha and land to be reforested under the MIT was 1,000ha per annum the period of 40 years. The total carbon density produced was 310tc/ha as compared to 79tc/ha under the Baseline Scenario. The vegetation carbon pool was 180tc/ha over a 40year period. Mean annual increment was 12tB/year/ha.

- Annually created incremental carbon pool in 9,240,000 tC

BLS (waste land)	-	3,160,000	to	3,160,000
Total MIT	-	3,391,000	to	12,400,000
On waste land	-	3,081,000	to	0
On forest land	-	310,000	to	12,400,000

  Cost effectiveness for the 40 years is as follows:
    - Present value of benefits US$.22/tC or US$51//ha
    - Benefit of reducing Atmospheric Carbon is US$0.002/tC-yr
    - Initial cost is US$ 0.1tC or US$27/ha
    - Present value of costs (Endowment) US$0.06tC or US$13/ha

This option will ensure an additional 40,000ha is reforested. In this mitigation, the sequestered carbon is stored in four pools i.e. the growing vegetation, decomposing biomass, the soil and the harvested wood products.

3.32 Mitigation policies in the Forestry Sector

The following Polices may be necessary to implement the mitigation options and can be used to maintain carbon stocks and or expand carbon sinks:

- Polices and local laws protecting cultivation of steep slopes and protecting other vulnerable areas/ecosystems such as PA and Forest Reserve.
- Policies on shared responsibility for managing such PA between local communities and central government.
- Control of logging and harvesting of Forest and non-forest products.
- Planned and aggressive afforestation and reforestation polices by private individuals local communities, FD and Environmental NGOs.
- Land tenure polices that encourage private ownership of some lands with an expressed mandate to sustainable development by planting and retaining trees on their land i.e. parties involving Agro-forestry cropping systems.

Agricultural polices that emphasize more intensive farming and conversion of fewer marginal woodlands.

CHAPTER FOUR

VULNERABILITY AND ADAPTATION OF THE MAJOR ECONOMIC SECTORS AND ECOSYSTEMS OF SIERRA LEONE TO CLIMATE CHANGE

4.1: CO_2 concentration

To attain long term stabilization of atmospheric CO_2 concentrations, there is need to reduce the net anthropogenic CO_2 emissions to the level of persistent natural sinks, which are expected to be less than 0.2 PgC/yr (IPCC WG I TAR, 2001). More research into the climate system is necessary.

4.2: Baseline and Climate change Scenarios

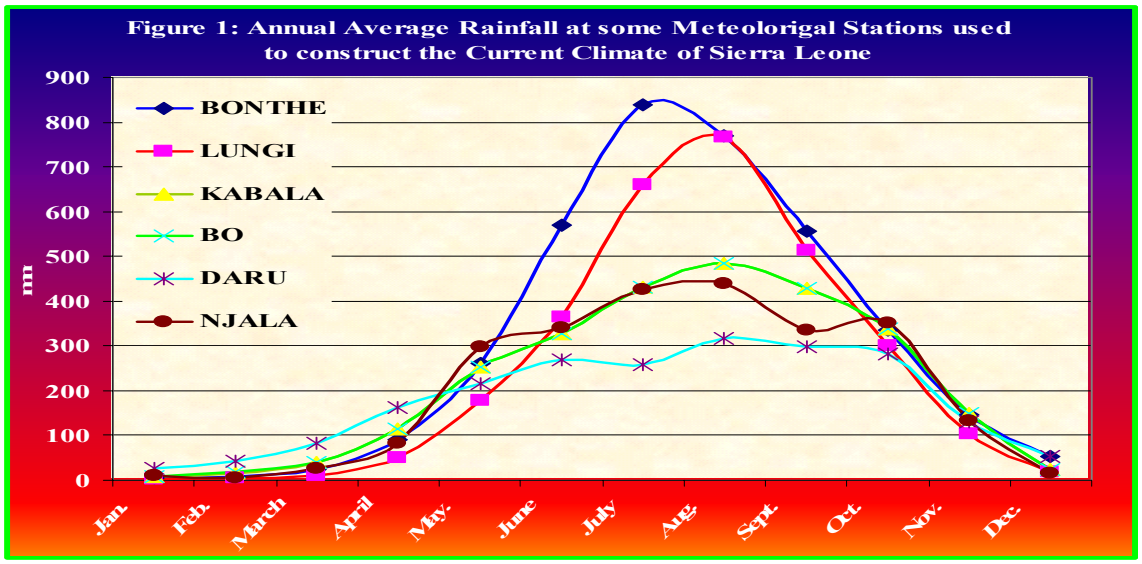
4.2.1: Baseline climate scenarios

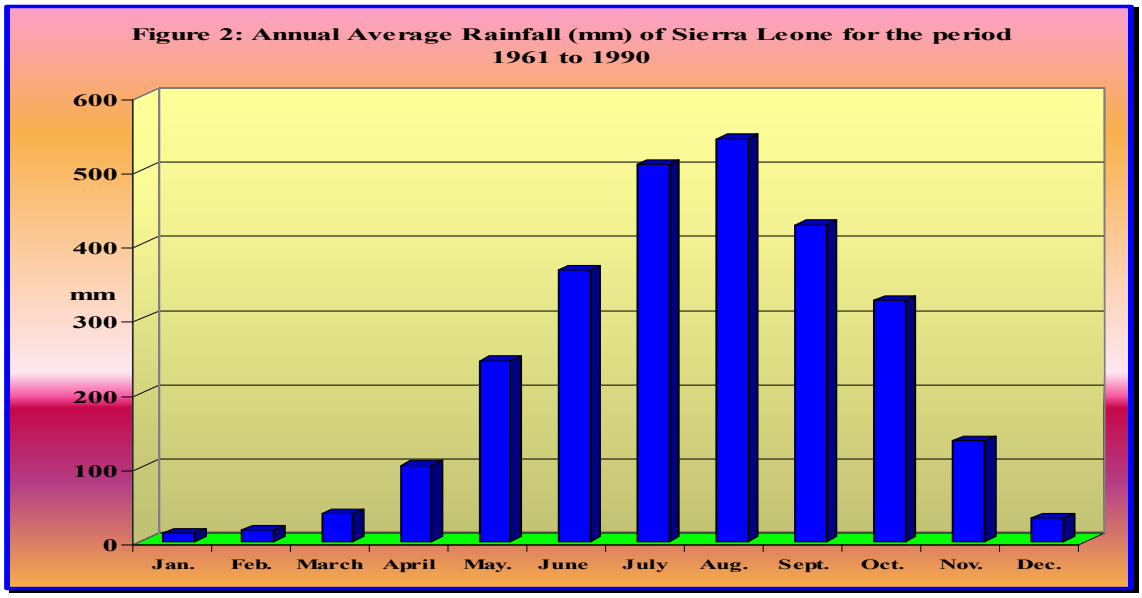
Climate data for the period 1961 to 1990 were used to characterize the current climate and develop the baseline climate scenarios for the country. Data were sourced from the following meteorological stations; Lungi, Bonthe, Kabala, N'jala and Bo. The parameters used for the studies were precipitation, temperature, solar radiation and evaporation etc. The country has two distinct seasons; wet and dry.

Precipitation:

The dry season runs from December to June and is associated with dry and dusty cool Harmattan and the southwesterly pre-monsoon wind of Squall Lines, whilst the wet season runs from June to December and is associated with the southwesterly tropical maritime monsoon with its accompanying thunderstorm especially during the start and withdrawal of the rainy season.

The monsoon period runs from July to September when the direction of the wind continues to be southwesterly and the ITCZ makes its highest northward ascend. The intensification of southwesterly moisture laden wind is at its peak. Thus the coastal areas of the country experiences heavy down pour in the form of torrential rains. These rainfall amounts decrease progressively as one moves eastwards and northwards. For the period 1961 to 1990 the country average rainfall is about 2746 mm and varies from 3659 mm at Bonthe in the south, 2979 mm at Lungi, 2618 mm at Kabala and Bo in the northern and central parts of the country. Figure 4.1shows the monthly variation of rainfall at the major stations whose data have been used to construct the historic climate of Sierra Leone and also the climate change scenarios for the impacts studies.



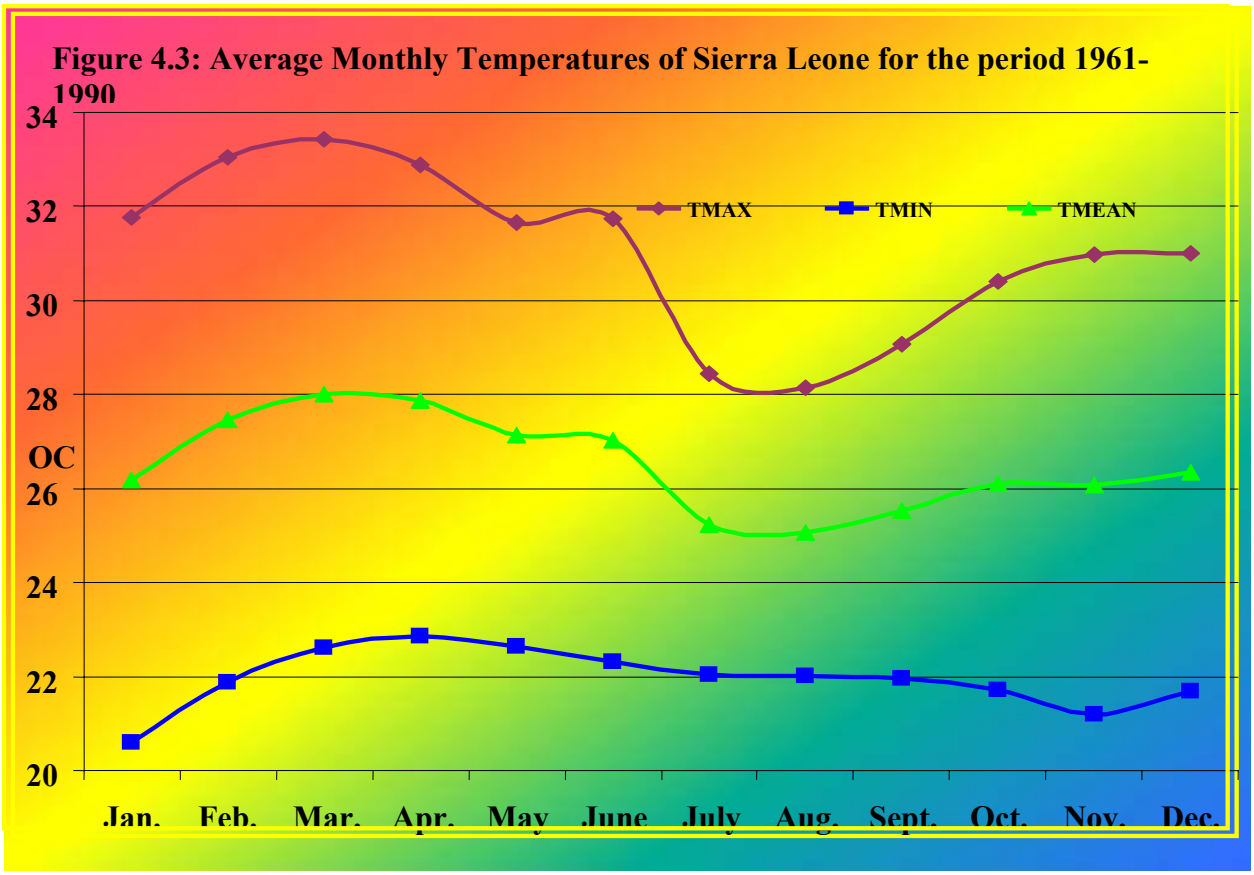


The post monsoon period of October to November is characterized by weak southwesterly winds with less strength to bring rains and it signals the withdrawal phase of the rainy season and also the Southward migration of the ITCZ. During this time, thunderstorms are also very frequent and periodic squall lines result with speed of up to 60kts at least once per season.

Temperatures:

Seasonal temperature variations in Sierra Leone are not large. As shown in Figure 4.3, the amplitude of the average annual mean temperature (middle curve) is about 3ºC. Maximum temperature shows larger amplitude (about 5ºC) whilst minimum temperature has an amplitude of about 2ºC. Highest temperatures are recorded in March and April while lowest temperatures in July and August. The low temperatures in July and August are mainly due to continuous cloudiness and rain during these months of the Monsoon

Season. The average temperature during the dry season is about 32ºC daytime (around 13000Hrs) and 15ºC at night (0600 Hrs). The country is mostly humid. However, humidity is least in the northern part during the hottest period when humidity is recorded at about 40% .



Solar Radiation:

Direct measurement of the solar radiation R_s was not available and hence the relative sunshine duration, n/N and extraterrestrial radiation R_a were used to derive solar radiation R_s based on the Angstrom formula: $R_s = \left(a_s + b_s \frac{n}{N}\right) R_a$

where the parameters have their usual meanings.

Tables 4.1a to 4.1c give monthly values of N and R_a on the 15th day of the month for the latitudes of 8^0 to 10^0 North which covers the area of Sierra Leone and the statistics of R_a, n and N used to estimate R_s. These values provide a good estimate (error <1%) of N and R_a averaged over all days within the month. The values of N and R_a averaged over 6^0 to 10^0 latitude North are used to calculate the solar radiation, R_s.

Table 4.1a: Maximum possible duration of sunshine or daylight hours N (Hrs)

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Lat 10N	11.5	11.7	11.9	12.2	12.5	12.6	12.5	12.3	12.1	11.8	11.5	11.5
Lat 9N	11.5	11.7	11.9	12.2	12.4	12.5	12.4	12.3	12.0	11.8	11.5	11.5

Lat 8N	11.6	11.7	11.9	12.2	12.4	12.5	12.4	12.3	12.0	11.8	11.6	11.5
Lat 7N	11.6	11.7	11.9	12.1	12.3	12.4	12.3	12.2	12.0	11.8	11.6	11.6
Lat 6N	11.7	11.8	12.0	12.1	12.3	12.3	12.3	12.2	12.0	11.9	11.7	11.7
Country Average	**11.6**	**11.7**	**11.9**	**12.2**	**12.4**	**12.5**	**12.4**	**12.3**	**12.0**	**11.8**	**11.6**	**11.6**

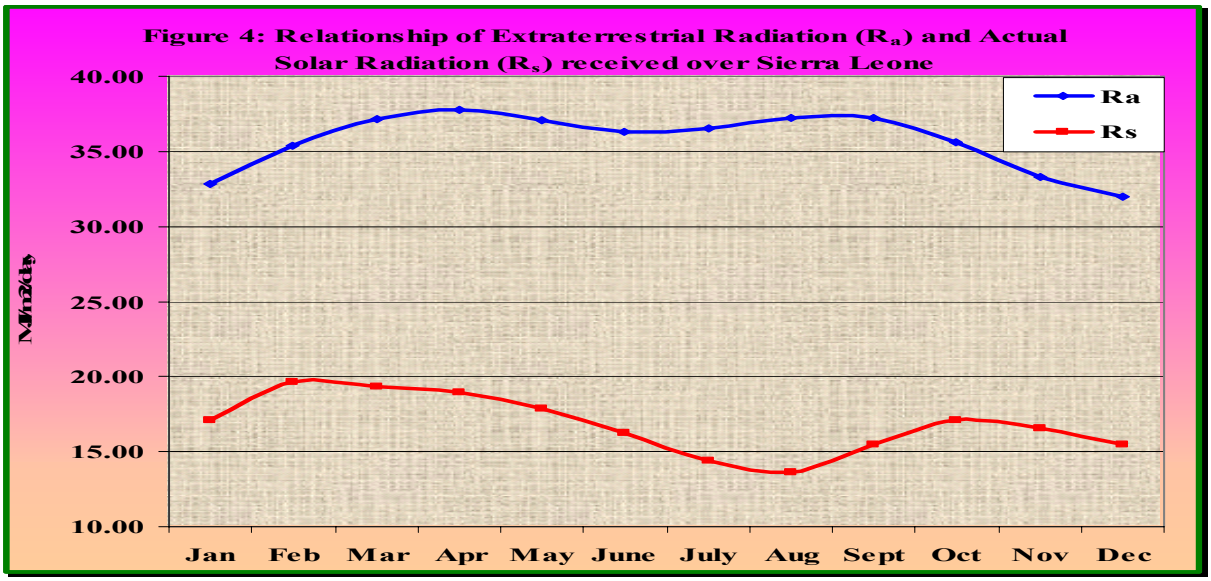
Table 4.1b: Extraterrestrial radiation (Ra) reaching the earth

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Lat 10N	31.9	34.5	36.9	37.9	37.6	37.0	37.1	37.5	37.1	35.1	32.4	31.0
Lat 9N	32.3	35.1	37.0	37.8	37.3	36.6	36.8	37.3	37.1	35.3	32.8	31.5
Lat 8N	32.8	35.8	37.2	37.8	37.1	36.3	36.5	37.2	37.2	35.6	33.3	32.0
Lat 7N	33.2	35.8	37.3	37.7	36.8	36.0	36.2	37.0	37.2	35.8	33.7	32.4
Lat 6N	33.7	35.8	37.4	37.6	36.6	35.7	35.9	36.9	37.3	36.1	34.1	32.9
Country Average	**32.8**	**35.4**	**37.2**	**37.8**	**37.1**	**36.3**	**36.5**	**37.2**	**37.2**	**35.6**	**33.3**	**32.0**

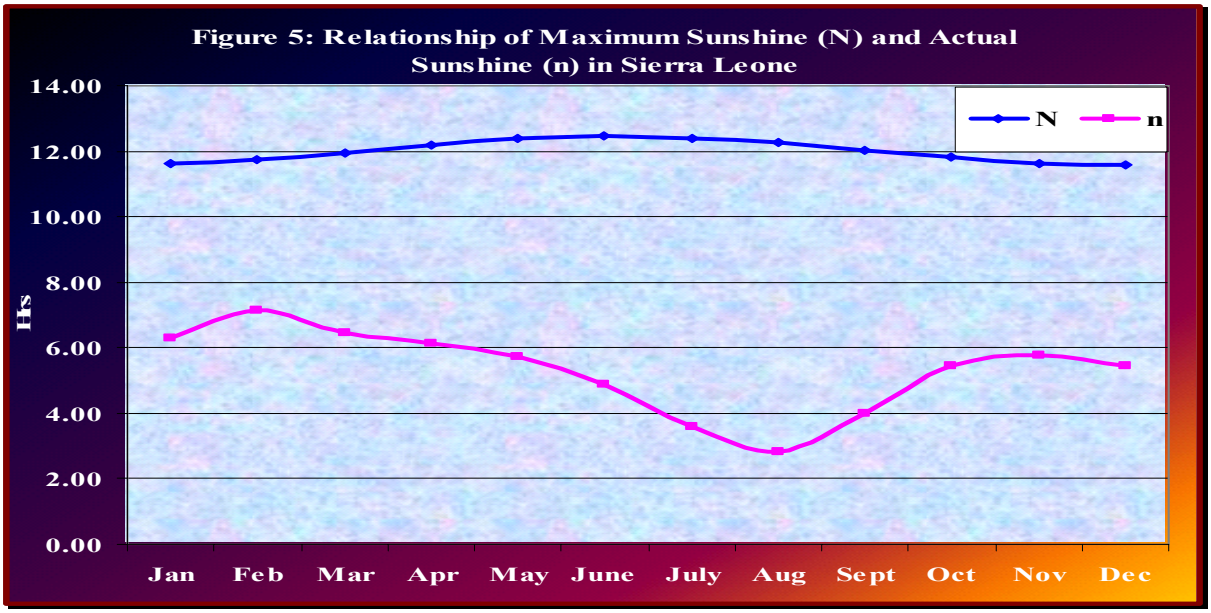
Table 4.1c: Statistics to estimate Solar Radiation from R_a, n, and N

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Country Average n	**6.3**	**7.1**	**6.5**	**6.1**	**5.7**	**4.9**	**3.6**	**2.8**	**4.0**	**5.5**	**5.8**	**5.4**
n/N	0.54	0.61	0.54	0.50	0.46	0.39	0.29	0.23	0.33	0.46	0.50	0.47
b_s	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
b_s*n/N	0.27	0.30	0.27	0.25	0.23	0.20	0.14	0.12	0.17	0.23	0.25	0.23
a_s	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
$a_s+(b_s*n/N)$	0.52	0.55	0.52	0.50	0.48	0.45	0.39	0.37	0.42	0.48	0.50	0.48
$Rs=R_a*(a_s+(b_s*n/N))$	**17.1**	**19.6**	**19.4**	**18.9**	**17.8**	**16.2**	**14.4**	**13.6**	**15.5**	**17.1**	**16.6**	**15.5**
Rs (MJ/m^2/month)	**530**	**412**	**601**	**567**	**552**	**486**	**446**	**422**	**465**	**530**	**498**	**511**

As shown in Figure 4.4 the extraterrestrial radiation (Ra) is about twice the actual radiation (Rs) received at the surface. This is due to the fact that Sierra Leone, being a tropical country close to the equator has a large cloud cover particularly during the monsoon months of June to September.



As shown also in Figure 4.4, actual sunshine duration (n) is about one-third of the maximum possible sunshine duration (N).



Evaporation

As shown in Figure 4.6, evaporation is higher during the months of December to April as the dominant winds are from the north and north east during the Harmattan season. From May, evaporation decreases and is lowest during the months of July and August when the atmosphere is moist as the predominant winds are southwesterly bringing a lot of moisture from the ocean.

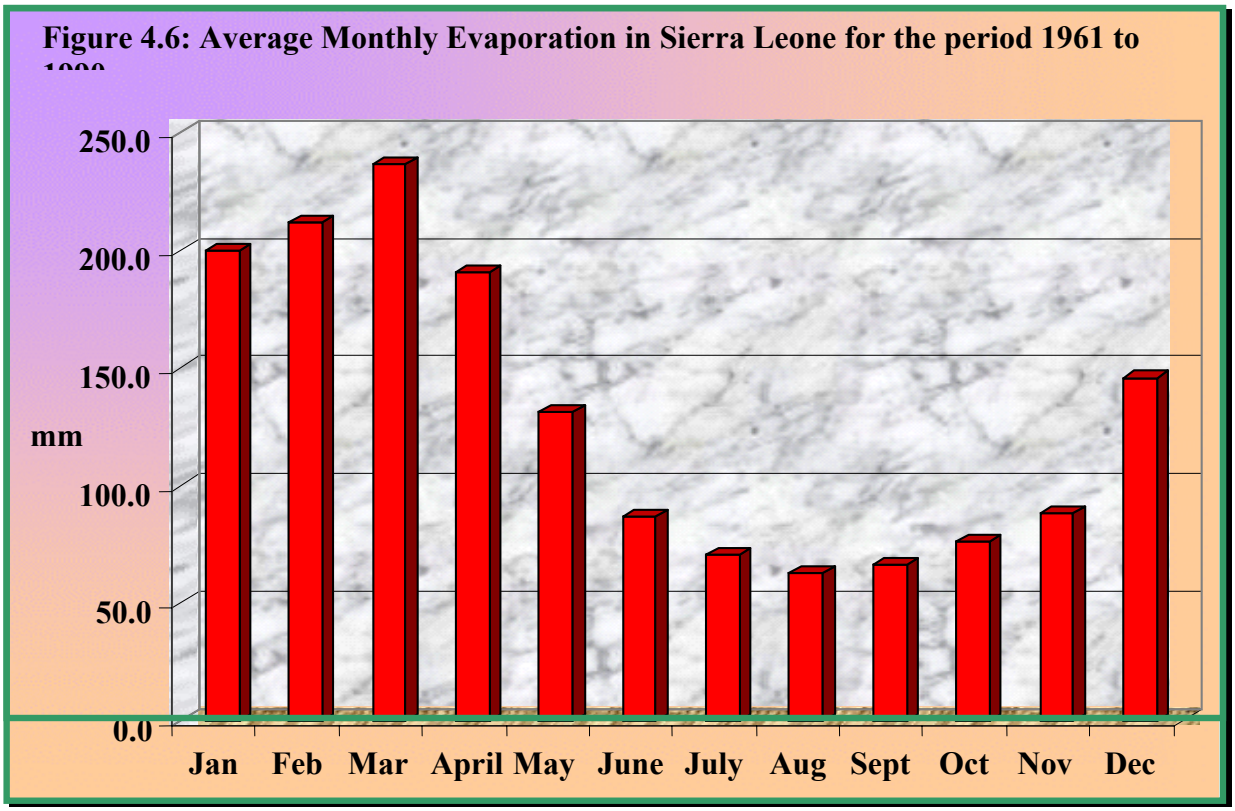
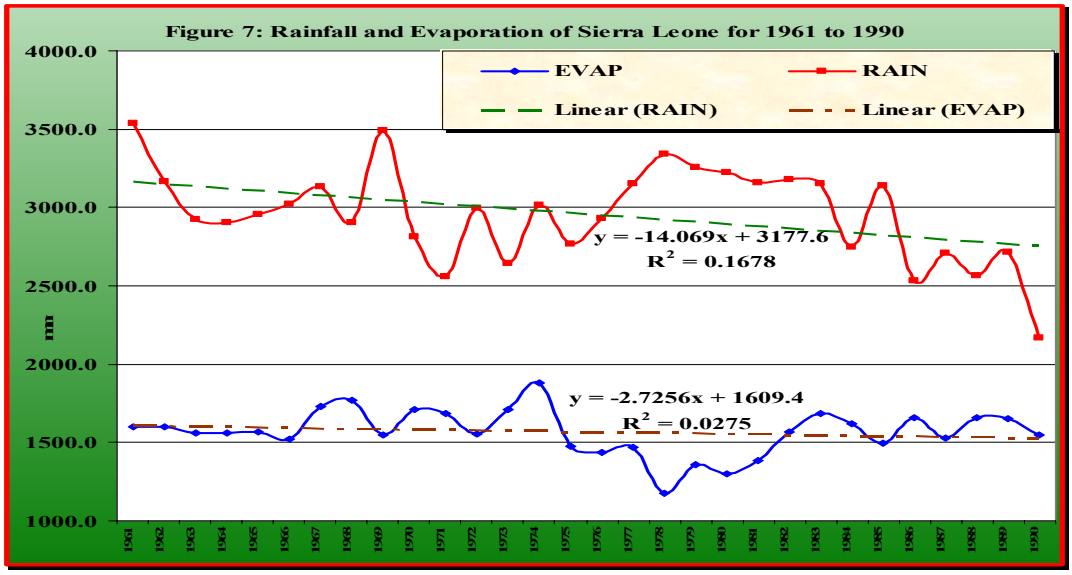


Figure 4.7 shows that since 1961, evaporation has a decreasing trend and was low in the late 1970s. It, however, increases in the early 1980s. The top graph of Figure 4.7 is the plot of rainfall for the same period. The figure illustrates that annual rainfall is about twice the annual evaporations but decrease in rainfall more rapid.



4.2.2: Climate change scenarios

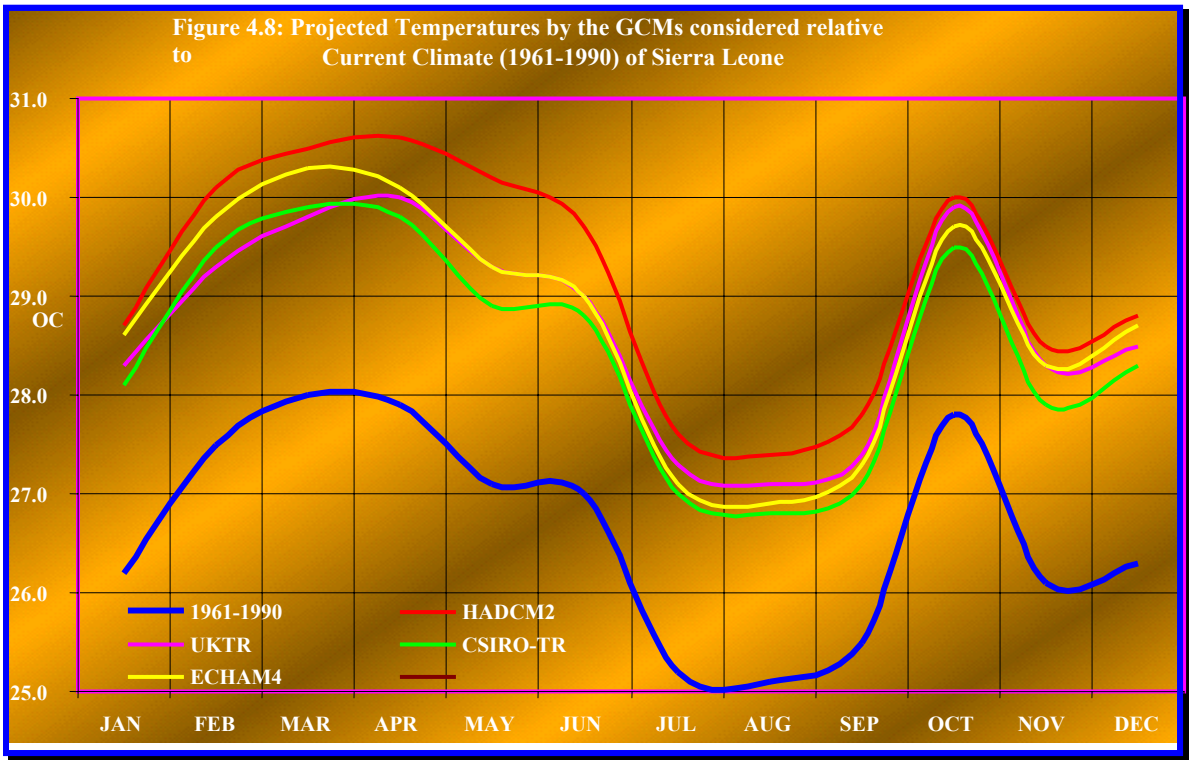
The Model for the Assessment of GHG Induced Climate Change (MAGICC) and the GCM output from the HADCM2, UKTR, CSIRO-TR AND ECHAM4 models were used to develop climate change scenarios for Sierra Leone in this study.

Temperature Scenarios

The average annual temperature for the period 1961 to 1990 and based on observed data from the meteorological stations discussed in preceding sections is about 26.7^{O}C. Combining this average annual temperature with the 2*CO2 output from the GCMs, the average annual temperature for the period 1961-1990 is projected to increase by about 7 to 9 % above this average temperature by 2100. Figure 4.8 and Table 4.2 below show the variation of this projected increase in the monthly average temperatures at 2100.

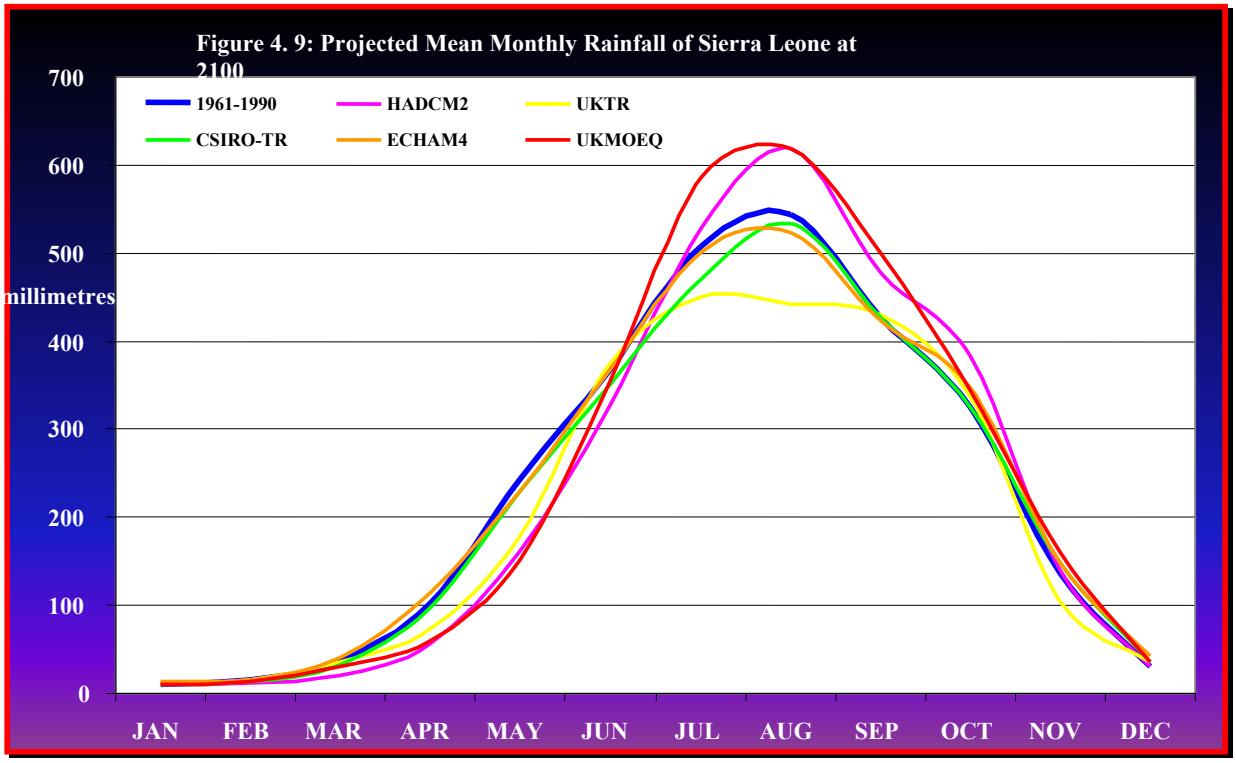
Table 4.2: Current climate (1961-1990) and projected climate change temperature scenarios at 2100

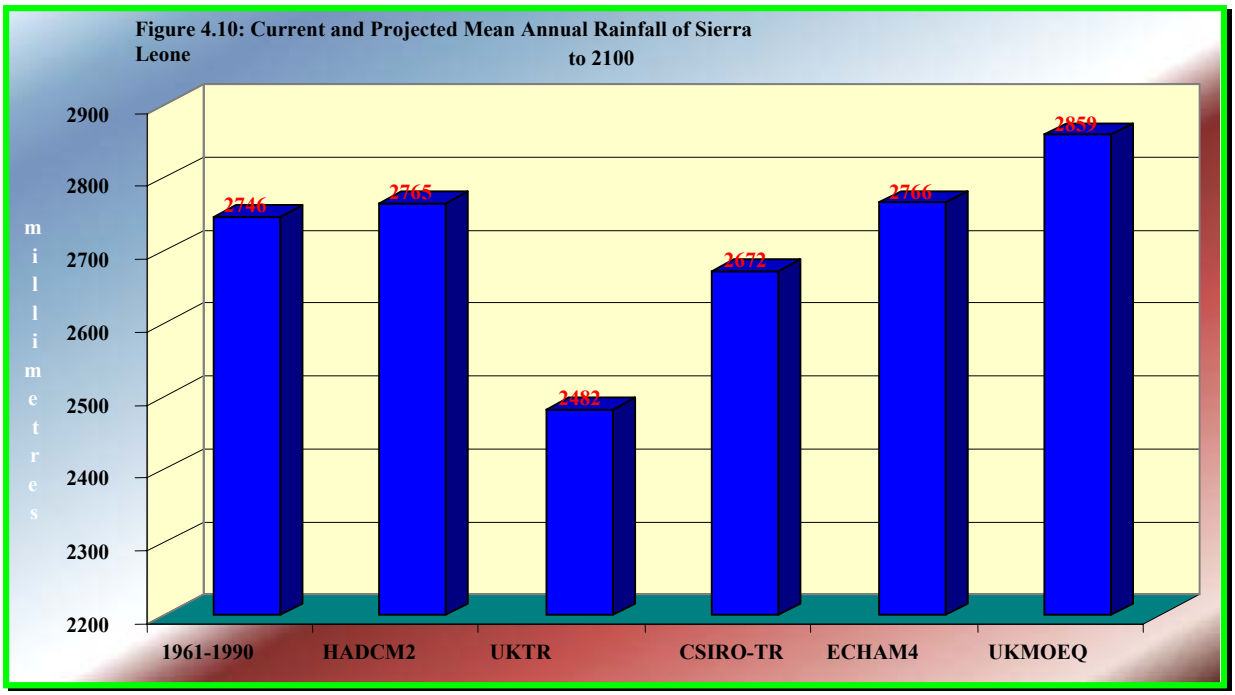
Scenario	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
1961-1990	26.2	27.5	28.0	27.9	27.1	27.0	25.2	25.1	25.5	27.8	26.1	26.3	26.7
HADCM2	28.7	30.1	30.5	30.6	30.2	29.7	27.6	27.4	27.8	30.0	28.5	28.8	29.2
UKTR	28.3	29.3	29.8	30.0	29.3	29.0	27.3	27.1	27.4	29.9	28.3	28.5	28.7
CSIRO-TR	28.1	29.5	29.9	29.8	28.9	28.8	27.0	26.8	27.1	29.5	27.9	28.3	28.5
ECHAM4	28.6	29.8	30.3	30.1	29.3	29.0	27.1	26.9	27.3	29.7	28.3	28.7	28.8



Precipitation Scenarios

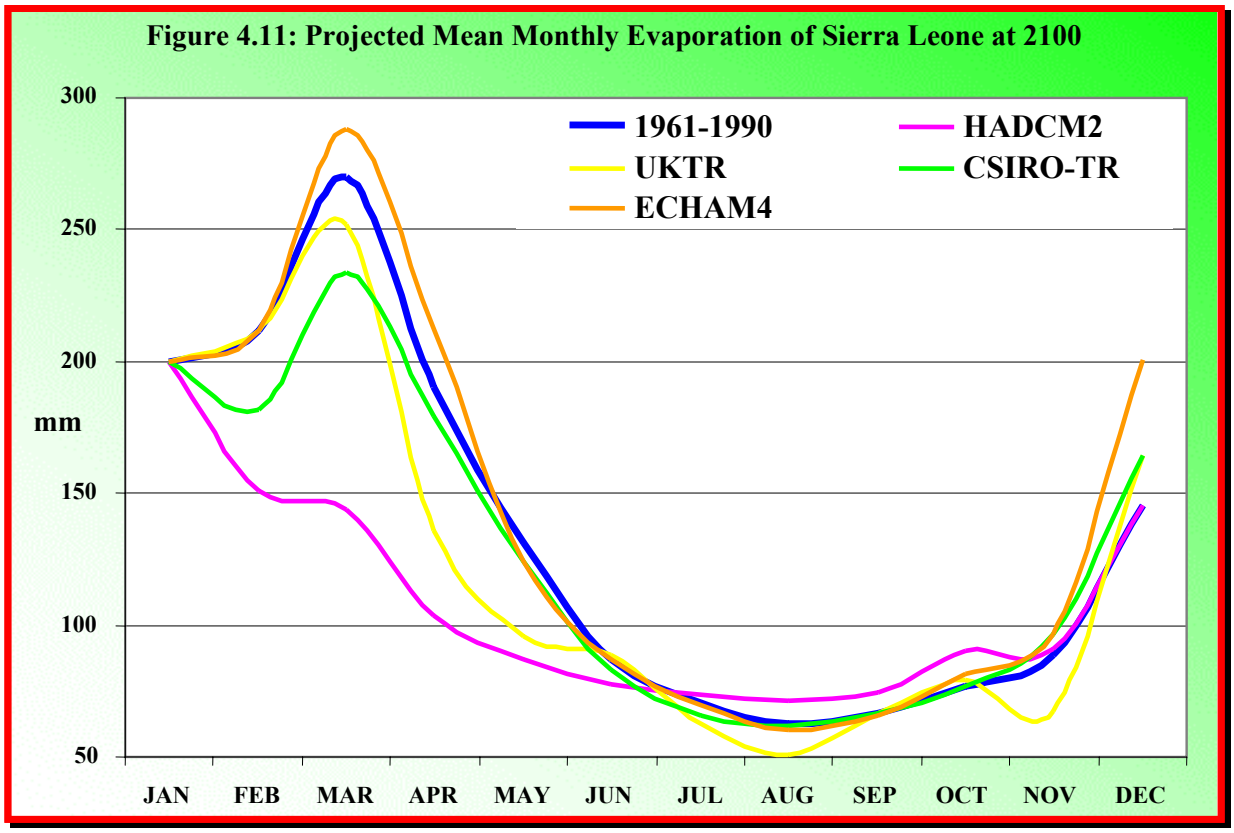
Figures 4.9 and 4.10 show current (1916 -1990) and projected rainfall to 2100. Both figures show that monthly (Figure 4.9) and annual (Figure 4.10) rainfall values by 2100 under the ECHAM4 and HADCM2 models are similar to current climate rainfall values. However, the CSIRO-TR and UKTR models show a decrease in rainfall by about 3% and 10% respectively below current monthly and annual rainfall values.



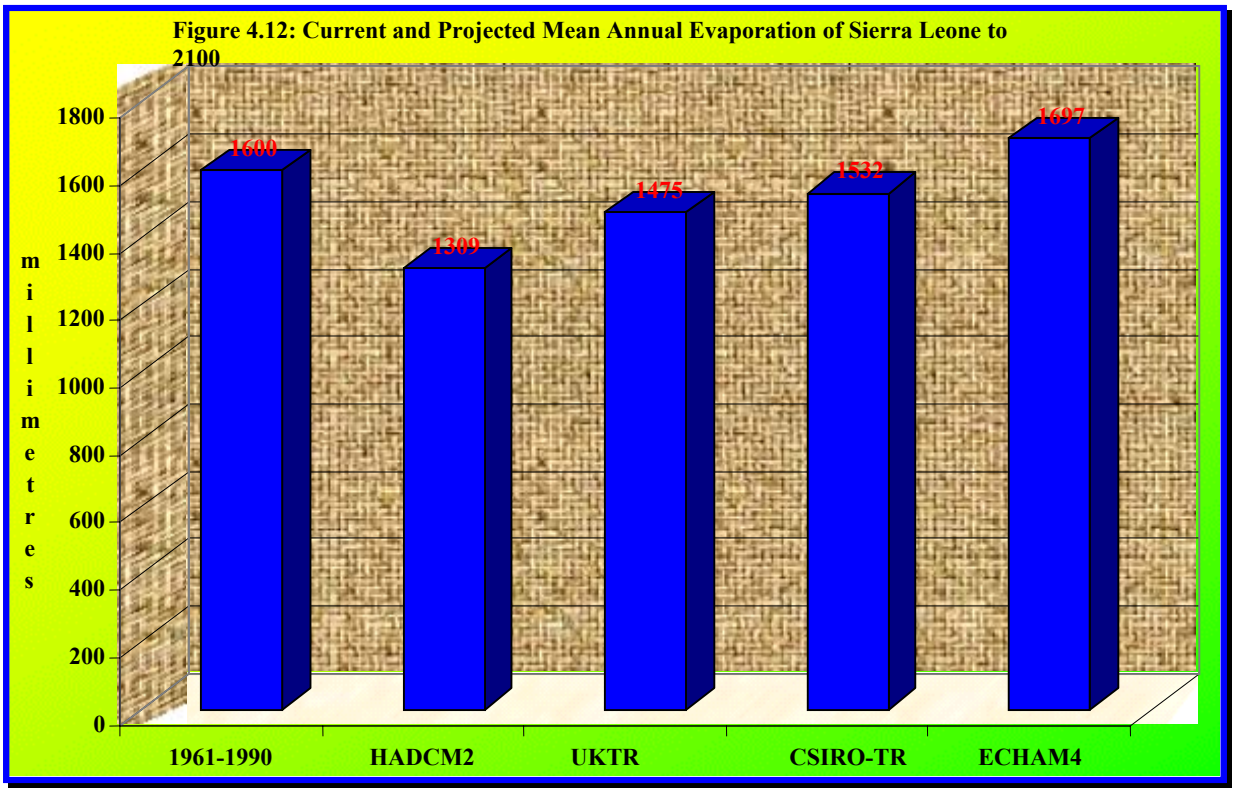


Evaporation

Mean monthly evaporation for current climate (1961-1990) and projected values at 2100 by GCMs are illustrated in Figure 4.11. During the period from January to May monthly evaporation values under current climate are higher than all projects to 2100 by the GCMs except for the ECHAM4 model whose projection is higher than current climate values and projects by all other GCMs used in this study.



The monthly variations in evaporation shown in Figure 4.11 above are markedly reflected in the mean annual evaporation values illustrated in Figure 4.12 below. Variations about the mean annual evaporation of 1600 mm under current climate (1961-1990) show an increase of about 6% under the ECHAM4 model but a decrease of about 22% under the HADCM2, 8% under the UKTR and 4% under the CSIRO-TR models.



Solar Radiation

From Table 4.3, the estimated average annual solar radiation received at the surface is about 6021 MJ/m^2/year for the period 1961 to 1990. Based on projects using GCM outputs this is expected to decrease by 12% under the HADCM2, 9% under the UKTR, and 3% under the CSIRO-TR models but increase by 5% under the ECHAM4 model.

Table 4.3: Current (1961-1990) and Projected (to 2100) Solar Radiation (MJ/m^2/month) for Sierra Leo

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DE
1961-1990	530	412	601	567	552	486	446	422	465	530	498	
HADCM2	530	292	319	306	364	433	464	481	521	626	513	
UKTR	530	412	559	403	403	496	397	341	470	546	378	
CSIRO-TR	530	354	523	533	519	462	415	413	465	530	543	
ECHAM	530	412	641	632	521	486	440	406	462	565	542	

CO_2 levels and Sea Level Rise Scenarios:

Based on the best reference MAGICC/SCENGEN projects CO_2 concentration of about 350 parts per million (ppm) for the 1990s. Double CO_2 concentration levels of about 580 ppm are likely to be achieved by 2075 and about 700 ppm by 2100. Sea level rise (SLR) scenarios adopted in this study are 0.2 m as baseline, and 0.5 m, 1.0 m, and 2.0 m by 2100 (IPCC, 1990).

4.3: Impacts of Climate Change on Economic Sectors and Ecosystems

4.3.1: Agricultural crop production

4.3.1.1: Background to agricultural production

Sierra Leone is an agricultural country. Agriculture is the largest sector in the economy providing employment for over 65% of the labour force, and contributing about 35 to 47 percent of the Gross Domestic Product, (GDP), GOSL, 1994). The area under cultivation is estimated as 409,674 ha. Most of the agriculture is carried out in the uplands largely slash-and-burn, and is on subsistence scale utilizing non-mechanized implements.

Rice, the staple food, is grown by more than 80% of the farmers, particularly in the southern and northern regions. Rice is grown in over 300,000to 400,000ha of land with an annual production of 450,000 to 550,000 mt annually. Rice alone accounts for about 85% of the agriculture sector's contribution to GDP. Apart from the upland rice is produced in four other distinct ecologies – inland valley swamps (IVS), mangrove, revering grassland and bolilands and tuber crops are also grown in upland fields and around the homesteads. These food crops grown are mainly for subsistence purposes.

Perennial tree crops are also cultivated. Cattle and livestock rearing are mainly done in the northern region. In 1984 the estimate of ruminates were 33,220 heads of cattle, 264,000 sheep and 245, 00 goats. There are an unspecified number of pigs and rabbits. The birds (Poultry) include chickens, ducks, guinea fowl and pigeons. The latter are mostly kept as pets.

Clearing of forestland for agriculture through extensive farming and slash-and-burn practices, indiscriminate logging and uncontrolled mining, unregulated grazing and wild bushfires, increase in demand for forest products, unauthorized development on hilltops and valleys, increased sediment flow in the lowlands and erosion in the upland fields that bare furrowed down the slope and along the coastline, all of which are intrinsically linked with high population density, and lack of adequate policies and legislation and enforcement are among the primary causes of environmental/land degradation in Sierra Leone. The soils are generally infertile and there is a lack of proper management practices. The estimated soil loss due to erosion varies from 14.0 to 109 tons/ha/year depending on the soil type, slope, vegetation and landuse (1999).

Deforestation as a major environmental problem in the country has many adverse effects on crop production. This is especially so, as in most cases it involves burning and removal of the cleared vegetation, followed by intensive cultivation or urbanization or utter neglect. The predominance of the agriculture sector in the country's GDP makes matter worse.

Continued reliance on subsistence farming for food production through shifting cultivation will accelerate the process of land degradation. This vulnerability is already evident in the northern region where precipitation patterns are beginning to fluctuate. The potential impacts of land degradation, if left unchecked could be more serious for Sierra Leone than countries that have resources to cope with these effects.

4.3.1.2: Study Methodology

The vulnerability assessment of the agricultural sector to climate change and adaptative measures started with a training workshop. Data and information on soils, temperature, rainfall, solar radiation, sunshine hours, crops and crop management practices were use for the study.

The stations Kabala, Lungi and Bo representing the North, North-west and Southern regions respectively. Rice, cassava and potatoes are predominantly grown in these sites. The GCM scenarios from the HADCM2, UKTR, CSIRO-TR and ECHAM4 models were used to analysis the climate change impact on the crop production as sub-sector of agriculture. These scenarios, crop production and socio-economic data were input into the DSSAT3 biophysical model for the simulation of impacts of climate change on crop production. For this study only the harvest/crop yield as an output of the mode was considered. For maize, the simulations were done to determine sensitivity of yield to changes in planting dates and changes in atmospheric carbon dioxide.

4.3.1.3: Potential impacts of climate change on crop production

The unavailability of the DSSAT3 biophysical model made it difficult to input the GCM scenarios, crop production and socio-economic data to run the simulation of impacts to climate change on crop production in the country. The simulations for rice, cassava and potatoes could therefore not be run for the three sites. Nonetheless, expert judgment from consultations with in-country agricultural specialists was used to suggest likely effects of climatic changes to major crops grown in the country as indicated in table 4.4 below.

4.3.1.4: Sensitivity of crop production to climate

Crop production in the country is very sensitive to climate variation. The fluctuation in yearly crop yields is mostly due to weather effects and climate variability (See Table 4.4). The different crops grown are sensitive to climatic – related elements. The country is now experiencing prolong period of dry days even in the months of July/August and September which are supposed to receive the highest precipitation. The heavy rains now falling in March have prevented farmers from properly burning their farms which leads to early emergence of weeds resulting in poor yields of crops.

Table 4.4: climate threshold of some crops in Sierra Leone

Crop type	Temperature Limits	Moisture Limits	Growing Season
Cereal			
Rice	25^0C retards growth and reduces yields 35^0C spikelets fertility drops off noticeably	Not less than 700mm	May-December
Maize	21-30^0C at tasselling 18-21^0C for germination	450-800mm	Two growing seasons May-June (Long duration) and October-November

			(Short duration)
Millet	25^0C-35^0C	350mm – 700mm	May-June and harvested in September (short duration) November (Long duration)
Root Crops			
Cassava	Confined between Lat 15^0N and 15^0S and grows best in warm humid climate	40 in -80 in (100 – 200cm)	Plant in May and harvest from mid June the following year
Sweet Potato			
Tree Crop			
Cocoa	18^0C – 21^0C minimum average daytime temperature should not exceed 15^0C and absolute minimum is 10^oC below this temperature, trees are likely to suffer severe damage	1500 – 200 mm; should precipitation fall below 100mm irrigation is recommended	Perennial crop
Oil Palm	25^0C to 28^0C with an average minimum of 18^0C	1500 – 2000mm	Perennial crop
Citrus	Will withstand light frost for short periods only. Growth activity is reduced below 13^0C. Can withstand temperature of over 36^0C	Average annual rainfall of 875mm required. High atmospheric humidity increases the incidence of pest and diseases	Perennial crop

4.3.1.5: Potential adaptation measures

- **Promotion of multi-cropping and crop diversification**

A reduction of reliance in mono-cropping and diversification of crops grown will reduce vulnerability and promote food security in the country. The use of better heat and drought resistant crops would also help to counteract the effects of climate change and fulfill current and future food demand by improving crop yields.

- **Development of seed banks**

Development and maintenance of seed banks will provide a variety of seed types that preserve biological diversity and will enable farmers to make informed choices to counteract climate change impacts and maintain food security.

- **Promotion of sustainable agricultural management practices**

Agricultural management practices such as terracing, contouring, conservation tilling, agro-forestry and planting vegetation cover as windbreaks, protect crop fields from water and wind erosion and assist in retaining moisture by increasing water infiltration and reducing evaporation.
Management practices such as irrigation farming, water harvesting and a change in planting dates, row spacing, planting density and cultivar choice will assist to counteract the effects of limited moisture due to low levels of precipitation in the northern province and would allow for greater resiliency in adapting to future climate changes without reducing crop yields.

- **Reducing the use of some pesticides**

The reduced use of some pesticides could directly reduce GHG emissions and also reduce water pollution thereby contributing to both adaptation and mitigation.

4.3.2: Forestry and forest resources

4.3.2.1: Background on the forestry sector

Sierra Leone lies in the eastern-most extent of the Upper Guinea lowland forest block renowned for its abundant biodiversity. It is essentially a tropical rain forest country as the climatic conditions can support closed high forests in about 80% of the country. Information available and relic stands of high forest indicate that about 70-80% of the country was at one time covered with tropical closed forests, but only few patches remain protected in isolated forest reserves on hillsides. Remaining closed high forests cover only 5 to 6% of the country land area (about 185,000ha) located largely in the eastern part of the country. Slash-and-burn agriculture, rapid increase in population, demand for forest products (timber, fuelwood and building poles), mining of minerals, recurrent bushfires and urbanization are the primary causes for the clearance and drastic reduction of the original forest cover.

Today, most of the country is a mosaic of forest regrowth and agricultural lands in the center, woodland savanna in the north, swamps and mangroves along the coastline and in the estuaries of Scarcies, Sierra Leone, Sherbro and Malan Rivers. The extent of Sierra Leone's Forest is limited to 87% of the land area or 6,305,500 ha (See table 4.7). Timber resources occupy an even smaller area restricted to closed forest formation of about 365,000 ha.

The forest sector accounts for 6-7% of the Gross Domestic Product (GDP).Forests still remain the basic provider of domestic energy supply (95%) in the form of fuelwood and charcoal and also provide 20% of the domestic sawn timber needs and 4% of construction poles (Kamau 1988). Most dwelling houses in villages utilize bush poles, canes, etc. in the construction of mud and wattle buildings.

Apart from providing fuelwood and saw timber to majority of the population, forests also provide food, medicine, job opportunities and income. The coastal mangrove forests in addition protect the coastal and river banks against erosion and are important natural habitat and breeding grounds for various aquatic life and sanctuary for migratory birds. Forests are therefore critical for biological diversity conservation and sustainability.

Table 4.5: FOREST RESOURCES OF SIERRA LEONE

Major Vegetation Types	1950		1996	
	000 ha	%	000 ha	%
Closed high Forests	3,300	50		
Secondary Forests	655	10	626	10
Forest Regrowth (Farm Bush /BushFallow)	1,158	18	3,774	60
Savanna(Woodland/Lophira)	790	12	1,619	25
Wetlands (Mangrove/Coastal grass)	707	10	286	4.92
Plantations	450	0.006	5	0.08
Total	**6,610,450**	**100**	**6,310,000**	**100**

Forestland lost to infrastructural development, encroachment etc amounts to 300,450 ha
Source; Forestry Division 2000

4.3.2.2: Methodology used for Vulnerability and Adaptation Assessment:

Preliminary screening and Simulation techniques were the two techniques used to assess the Vulnerability and Adaptation of Forests to Climate Change in Sierra Leone.
Preliminary Screening Technique was used to identify the following as Areas Critical to forest conservation in Sierra Leone:

- Western Area Peninsular Forests
- Loma Mountains and Kangari Hills
- Bush Fallow Forest Regrowth
- Mining Areas of Kono and Moyamba districts
- Mangrove/Wetland ecologies
- Outamba/Kilimi National Park and
- Gola Forest Complex/Tiwai Island

The Technique was also used to identify the following as Critical to Forest Production in the country:

- Gola Forest Complex
- Tama Forest Reserve
- Tonkoli Forest Reserve
- Bush Fallow constituting 60% of the land surface area of Sierra Leone and
- The Mangrove ecologies.

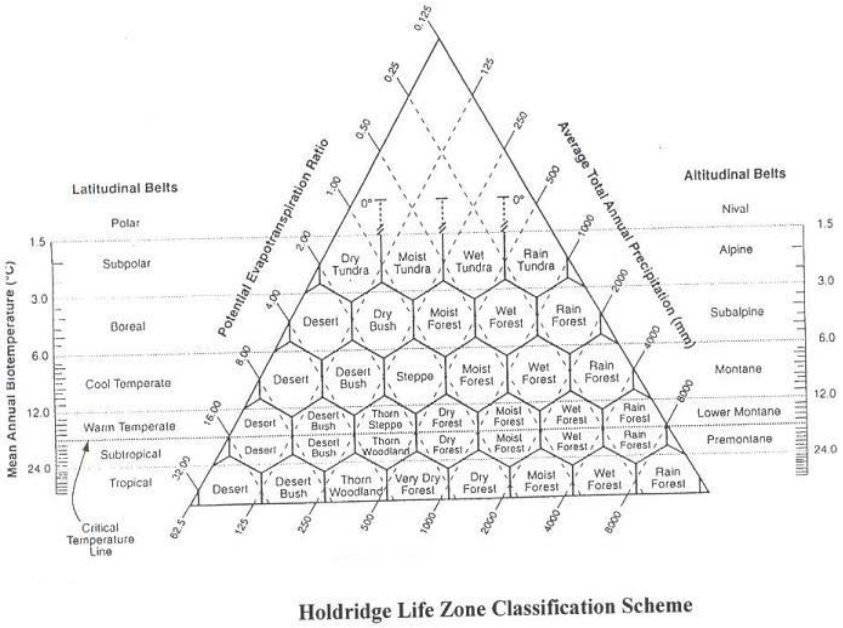
Thirty species within these identified critical areas were also compiled using the screening technique.

4.3.2.3: Impacts of climate change on the forest resources

The Holdridge Life Zone Classification Model and the Forest Gap Model are the two biophysical models used in evaluating the potential impacts of climate change on the forest ecosystems of Sierra Leone.

The Holdridge Life Zone Classification Model:

This is a climate classification model that relates the distribution of major ecosystem complexes to the climate variables of bio-temperature, mean annual precipitation and the ratio of potential evapotranspriation to precipitation (PET ratio). The PET ratio is the quotient of PET and average annual rainfall. It is suitable for examining the broad-scale pattern of vegetation as they relate to climate and the influence of climate changes on the suitability of a region to support different vegetation/forest types. Figure 4.3.2.1 illustrates the Holdridge Life Zone classification scheme:
The life zones are depicted by a series of hexagons in a triangular coordinate systems. Identical logarithmic axes for average annual precipitation form two sides of an equilateral triangle. The PET ratio forms the third side, and an axis for mean annual bio-temperature is oriented perpendicular to its base. The two variables bio-temperature and annual precipitation, determine classification. By striking equal intervals on these logarithmic axes, hexagons are formed that designate the Holdridge Life Zone (Smith 1994).



Holdridge Life Zone Classification Scheme

Figure 4.3.2.1 Holdridge Life Zone Classification Scheme

Implementation of the Holdridge model for a region requires only data on annual rainfall and bio-temperature for a grid network based on latitude and longitude. Bio-temperature is calculated from mean temperature values at monthly resolution. The values of mean annual precipitation and bio-temperature are then used to classify each grid cell to determine the potential land cover based solely on climate. The resulting database of potential land cover (Life zones) can be mapped, providing a base map of the country.

The Forest Gap Model:

This model evaluates changes in the species composition and productivity of specific forested sites. It simulates the establishment, growth and mortally of individual trees on a forest stand on an annual time step. Because the model simulates the response of individual trees on a forest plot, it can predict changes in species composition, forest structure (i.e. size class distribution) and productivity. It also incorporates forest management practices, which allows for evaluation of adaptive strategies.

The potential growth of each tree is estimated from species-specific optimal growth curves. This growth curves are derived from simple silvicultural data on maximum tree size and longevity.

The Gap model can simulate species composition and structure on an annual basis. It also simulates the temporal dynamics of forests in response of vegetation to changing environment conditions. The model is limited due to the fact that information (species composition and productivity) required to parameterize the model relate to site specific features such as topographic position, soil characteristics, land use and present vegetation structure, all of which may vary over short distances. The present climate and climate change scenarios have been applied to the forest gap model as a step function i.e. changes in weather elements such as temperature and rainfall are assumed to occur within a single year.

Only six (6) of the twelve (12) species used in the simulations are discussed in greater detail:
Chloraphora Regia , Chloraphora, Cordia platythyrsa, Cordia, Hannoa Klaineana, Nauclea didderrichii, Naculea,Terminalia ivorensis, Terminalia, Terminalia ivorensis, Terminalia, Tieghemelia heckelii –

4.3.2.3 Simulation Results from the Holdridge Model
The indications from the analysis are that under an equilibrium climate, the potential land cover of Sierra Leone will tend to the tropical dry forest category as a result of the projected decrease in precipitation (Figure 4.12) , increases in temperature, (Figure 4.12) and the increase in potential evapo-transpiration (PET) values (Figure 4.13) indicated by the year 2070.
It is further more illustrated from the analysis of the total precipitation and bio-temperature that by the year 2070:

60% of the country will be under tropical dry forest
24% tropical very dry forest and
16% will be sub-tropical moist forest in the South-East of the country.

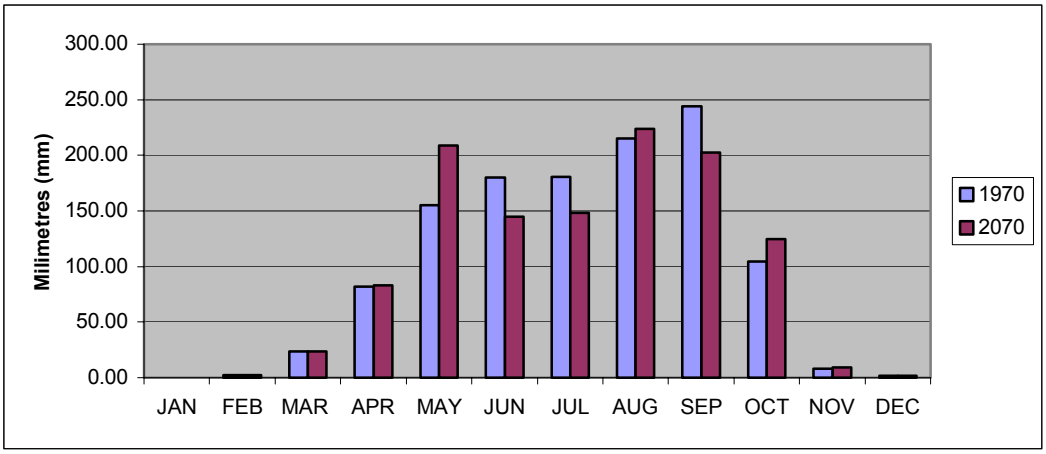


Figure: 4.12: Projected Decrease in Precipitation

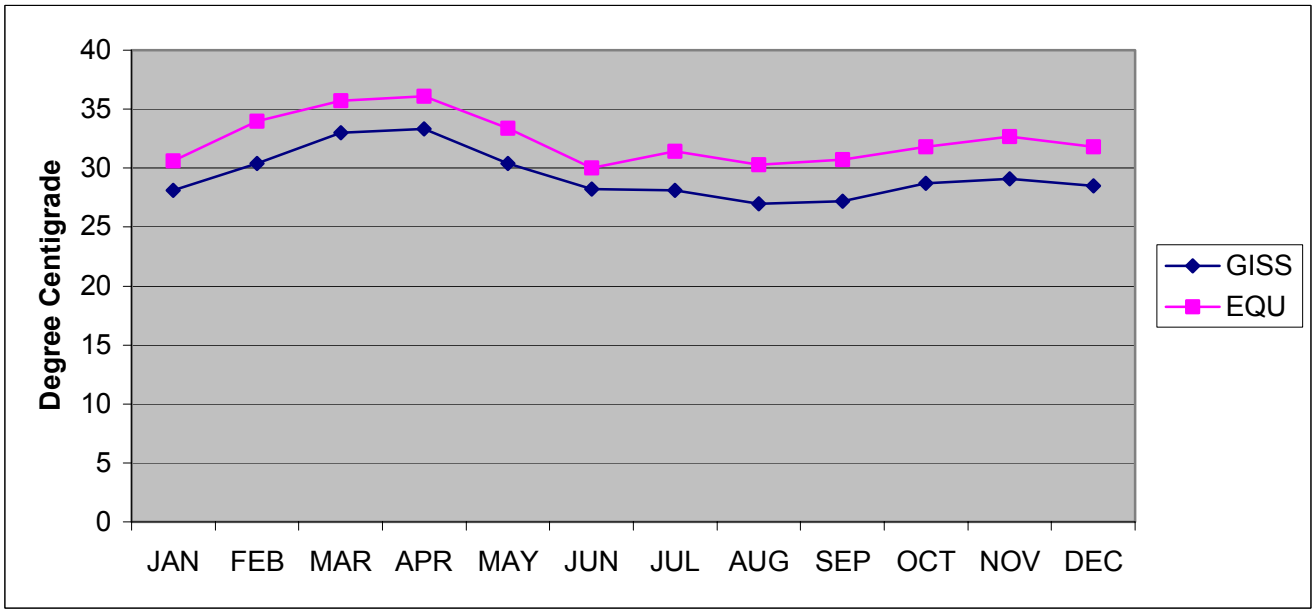


Fig. 4.13: Projected Increase in Temperature

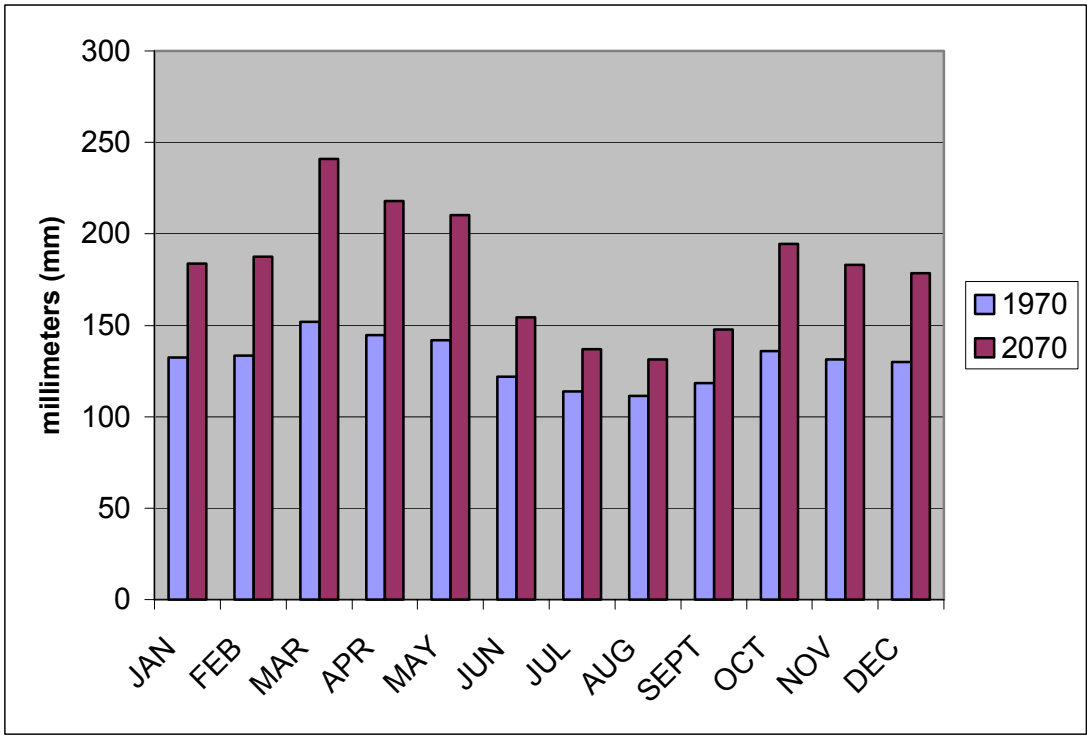


Figure: 4.14 Increase in Potential Evapo-transpiration rate

4.3.2.4 Simulation Results from the Forest Gap Model

Species specific growth in diameter

Data on diameter size and diameter increment were inputted into D-CURVE component of the GAP Model to determine the growth characteristics of the twelve individual tree species. Figures 4.15 and 4.16 show the species-specific optimal growth curve for Chlorophora regia, one of the most valuable, wide-spread and multipurpose species simulated.

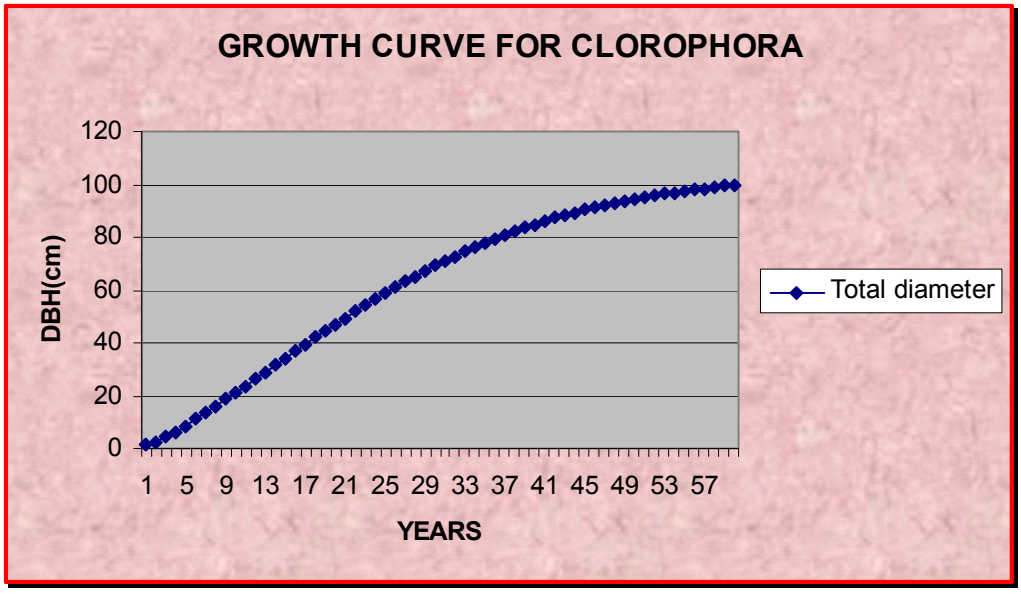


Fig. 4.15 Growth Curve for Chlorophora regia

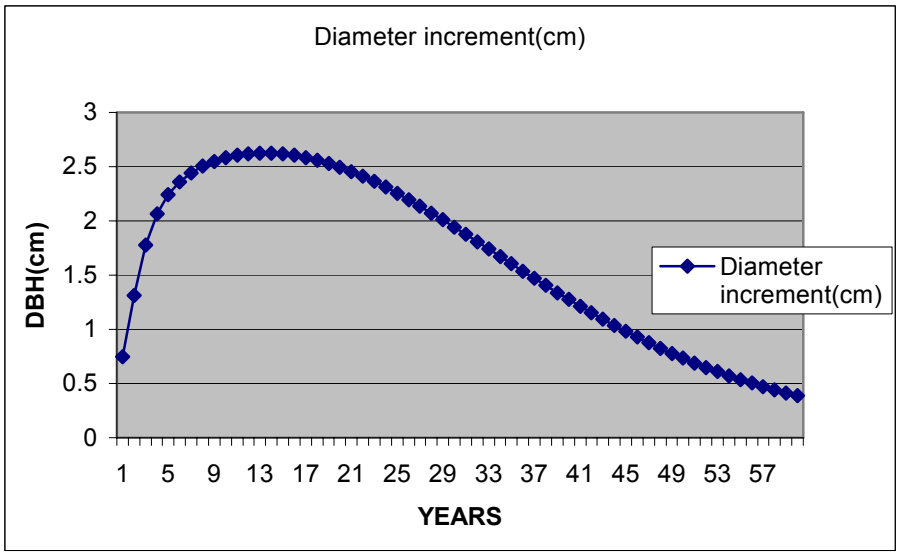


Fig. 4.16 Diameter Increment for Chlorophora regia

Growth is defined as a function of time, and diameter increment as a function of current diameter. These optimal curves serve as input into the Gap Model in which this potential optimal growth is modified by the environmental conditions on the plot.

Diameter size class distribution

Simulation results suggest that all species do not attain their current maximum diameter for all climate change scenarios. However, diameter increment for each of the simulated species varied widely as shown in the table 4.6:

Species	Maximum diameter increment (Cm)	Year of maximum diameter
Ceiba pentenda	2.5	32
Chlorophora	2.6	13
Cordia	1.76	12
Daniella	1.47	11
Gmelina	1.85	10
Hannoa	3.01	10
Khaya	2.22	13
Nauclea	2.49	8
Pakia	1.65	9
Tectona	1,86	14
Terminalia	2.32	11
Tieghemalia	1.80	20

Table 4.6: Maximum diameter increment for twelve species

4.3.2.5 Potential adaptation options and measures/responses

As stated in this report, about 95% of the energy supply for domestic use in Sierra Leone comes from forests in the form of fuelwood and charcoal. Forests also provide 20% of the domestic saw timber needs of the country (Kamau 1988). Results of the vulnerability assessment of the selected species indicate that, under an equilibrium climate the potential land forest cover of Sierra Leone will tend to the tropical dry forest category as a result of the projected decrease in precipitation and increases in temperature and potential evapo-transpiration values indicated by the year 2070. Result of the vulnerability analysis of the total precipitation and bio-temperature further indicated that 60% of the country will be under tropical dry forest, 24% tropical very dry forest and 16 percent will be sub-tropical moist forest in the south-east of the country.

From the vulnerability analysis, Sierra Leone needs to develop potential adaptation options and measures to enable its people have continuous access to the benefits obtained from the forest products. The following adaptation options and measures may be adopted to minimize the negative impacts of climate change on forest resources:

- **Promotion of effective silvicultural and forestry management practices**

Tropical trees and other woody plants in Sierra Leone have remarkable recuperative capacities and rapidly reoccupy disturbed forests and open spaces. However, regenerating and economically and socially desirable species that are used locally and/or have a marketable value require additional silvicultural interventions. Prominent among these are stimulating natural regeneration from seed trees; afforestation; reforestation; enrichment planting and introduction of new species/provenances. Adjusting planting and harvesting dates and switching to more drought-resistant species are also important sivilcultural and appropriate management practices that can be applied in the adaptation of forests.

Refining and liberation thinning are equally important silvicultural interventions that can be applied as management and adaptation measures in the country. Refining is the elimination of silviculturally undesirable trees, shrubs and other plants that will inhibit site occupation by desirable tree species. It allocates growing space to one group of species, the so-called potential final-crop trees, at the expense of others. Liberation thinning is a cutting that relieves young seedlings, saplings and trees in the middle layer from over-head competition. It stimulates growth since tree growth is directly related to the formation of a healthy and dense crown.

Refining and liberation are important, in the initial stages, to demonstrate measurable effects from management and adaptation efforts. They also reduce the time in which a merchantable crop of wood and non-wood forest resources will become available. Therefore silvicultural interventions need also to be considered as an important policy tool in the management and adaptation of forests to climate change.

Policies for Adaptation responses

Currently the National Forestry Policy formulated by government and strategies to achieve policy objectives are those outlined in paragraphs 2.3.1.4 and 2.3.1.5 above.

With most of our primary forests in Sierra Leone disappearing, adaptation to changing environmental conditions are becoming a major part of many rural landscape and their importance in the supply of goods and services is growing rapidly.

4.3.3 Water Resources

4.3.3.1 Background on the country's surface and groundwater systems

The survival of post conflict Sierra Leone is hinged partly on the availability of water resources for sustainable development. Consequently, any impacts on this vital resource emanating from climate change, which is the direct result of an increase in greenhouse forcing, can have serious socio-economic implications.

Sierra Leone is drained by 12 major river basins (see table 4.7), with 9 of these having their sources within the country. The Great Scarcies, the Moa, and the Mano, however, have their sources in Guinea and Liberia. (See Fig 4.3.3.1). The Dodo stream located in the east of the country near Kenema currently supports a hydroelectric scheme, which provides 4 MW of electricity to the district headquarter town of Kenema in the east and to the city of Bo in the south.

The Rokel watershed which is the third largest in the country supports the biggest hydroelectric scheme (Bumbuna Falls Hydroelectric Project) and is expected to provide 50 MW of electricity to major towns in the Northern Province as well as the capital, Freetown. It is also the source of irrigation water for the sugar cane plantation located at Magbas near the town of Magburaka in the Northern Province. The River has a total length of 380 km and drains an area of 10620 km^2. It rises in the Sankorama Hills in the North –north east of the Interior Plateau. It flows westwards within the plateau area and deflects southwards in the Interior Plains. From the interior plains, it flows in a southwest direction into the Atlantic Ocean.

Elsewhere in the western area, the Guma Dam, located on the Guma River, currently provides 96 million litres of water daily, which is grossly inadequate to meet the domestic and industrial needs of the capital, Freetown and its environs. The Guma Scheme also operates a 1 MW turbine that provides power for the water processing plant. A mini hydroelectric scheme for the eastern province is currently in the planning stage.

Table 4.7. The location, length, and catchment area of the major river basins.

River Basin	Total Length (km)	Catchment Area (Km^2)	% Area
Great Scarcies	**160**	**3115**	**4.3**
Little Scarcies	**280**	**13 000**	**17.9**
Rokel/Seli	**380**	**10 620**	**14.8**
Sewa	**430**	**14 140**	**19.7**
Pampana/Jong	**300**	**7 511**	**10.4**
Moa	**320**	**9 220**	**12.7**

Mano	**180**	**2530**	**3.4**
Waanji	**200**	**4 510**	**6.2**
Coastal Streams/Creeks	**120**	**6969**	**9.6**

Source: ESCG (1988)

Groundwater resources represent the biggest source of fresh water in the country, used mainly for domestic purposes such as drinking, washing and laundry. In the eastern and southern parts of the country, groundwater occurs within the Crystalline Basement Aquifer, comprising fractured bedrock and the weathered mantle. Groundwater abstraction is possible through shallow hand dug wells, which are widely distributed in the provincial towns and villages. Boreholes are much more productive but are relatively few due to high drilling costs. About 60 % of the population uses groundwater for drinking.

The natural quality of groundwater within the Crystalline Basement Aquifer is excellent in for the fact that dissolved solids content is relatively low. However, water obtained from open, unprotected, shallow wells may be subjected to contamination.

4.3.3.2: Assessment Methodology

The Rokel Basin was selected for the assessment of the potential impacts of climate change on water resources in the country. Training workshop on vulnerability and adaptation assessment was conducted which was followed by data and information collection on stream discharge for a period of about thirty years and stream flow for a period of fifty-nine years. Data on air temperature and precipitation covering the same period for the Bumbuna, which is a representative station of the Rokel Basin, were collected from the Ministry of Energy and Power and the Environment Department. Data on potential evapo-transpiration records for the same period was not available to undertake the vulnerability assessment.

Water supply and demand data was also collected to assess the potential impacts of climate change on water resources supply and demand using a water supply scheme that had operated over the past 35 years. Population estimates were also used to assess future changes in supply and demand due to rural-urban migration.

The vulnerability assessment of groundwater to climate change was not possible due to dearth of hydro-geological data and information on recharge rates and time series data such as fluctuations in the water table. However, a brief analysis of the role groundwater plays in providing drinking water for the mainly rural population is made.

4.3.3.3: IMPACTS ON WATER USE / DEMAND

For the analysis of demand and supply, the Guma Valley Water Supply Scheme was chosen as it provides water for the domestic and industrial needs of the capital, Freetown, where 20 % of the country's population are residing. Table 8 shows the major uses of water by the various sub-sectors in Sierra Leone.

Table 4.8. Water use by sector

SUB-SECTOR	MAJOR WATER USE
AGRICULTURE	Irrigation
DOMESTIC	Drinking
	Cooking
	Personal and domestic hygiene
INDUSTRIAL	Beer, spirits, and soft drink manufacture
	Cooling and waste disposal
ENERGY PRODUCTION	Hydroelectric power production

Domestic Demand

Migration of the rural population to the capital, Freetown, during the civil conflict (1991 – 2001) has put considerable pressure on the water demand. Domestic demand is assessed on the basis of the available water as against the population served. It is estimated that for all purposes the current average per capita demand for residents in Greater Freetown is 53.4 litres/person/day, which is projected to increase to 56.7 litres/person/day by 2016 (See table 4.9). The graph in Fig. 4.16 shows a steep rise in domestic demand from 2006 to 2016. Current domestic demand is estimated to be 59 % of the total, and is expected to decrease to 58 % by 2016. Consequently, a change in the hydrological regime following climate change may have little or no effect on domestic demand, as the latter is influenced by population changes and tariffs rather than increases in the available water.

Table 4.9. Projected Domestic Consumer Water Demand for Greater Freetown (2004 – 2016)

Year	Population	Water demand Projection				
		m^3/day	Million gals/day	Million litres/day	Per capita demand	
					Gals/person/day	Liters/person/day
2004	1 191 485	63 644	14.0	63.65	11.8	53.4

2006	1 276 648	68 190	15.0	68.19	11.8	53.4
2011	1 559 202	85 919	18.9	85.92	12.1	55.1
2016	2 021 968	114 559	25.2	114.56	12.5	56.7

Fig 4.17: Projected Per Capita Water Demand

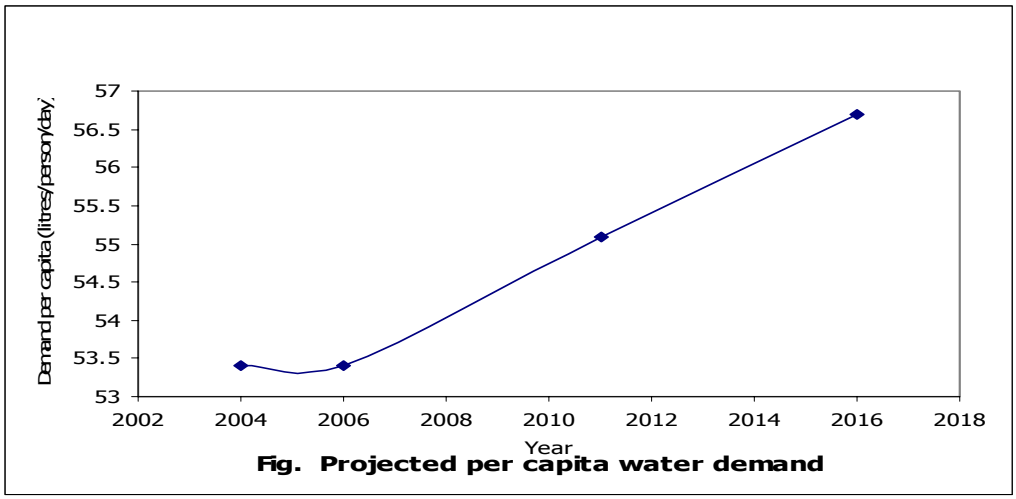


Fig. Projected per capita water demand

Industrial Demand

The major industries that utilize water directly in their manufacturing process are concentrated in the capital. The major users of water include the Brewery, the Soft drink factory, and the spirit manufacturers. To a lesser extent water is used by industries for cooling purposes. Table 4.8 suggests that current industrial demand is 34. 61million litres/day. This is projected to increase to 60.63million litres/day in 2016. Thus within the next 10 years industrial water demand would increase by 63.7 %. Since industrial demand is also associated with socio-economic considerations there may be no significant impact as a result of climate change.

Agricultural Demand

Agricultural demand is restricted to irrigation, which practice is still in its infancy in Sierra Leone. The sugar cane plantation supported by the Rokel River at Magbas, in the northern province, is the biggest irrigation scheme in the country. No figures are yet available for irrigation water demand. Most of the crops grown in Sierra Leone are rain-

fed, therefore, it is difficult to assess the demand for agriculture and hence the impacts from climate change.

Table 4.8: Projected Total Water Demand for Greater Freetown (2004 – 2016)

Year	*Population*	Water demand Projection			
		m^3/day	Mgal/day	Per capita demand	
				Gals/person/day	Litres/person/day
2004	1 191 485	98 250	21.6	18.1	82.3
2006	1 276 648	105 115	23.1	18.1	82.3
2011	1 559 202	131 950	29.0	18.6	84.6
2016	2 021 968	175 185	38.5	19.0	86.4

Table 4.9. Population projections and water demand projections for greater Freetown (1994-2016)

Year	Population Growth Scenario			Water Demand	
	Low (3 %)	Medium (4.5 %)	High (5.5 %)	Mg/day	m^3/day
1994	-	-	-	14.0	64,764

1996	950,000	950,000	950,000	17.7	81,880
2001	1,101,301`	1,083,208	1,241,612	23.1	106,861
2006	1,276,721	1,276,648	1,622,737	30.2	139,705
2011	1,480,069	1,559,201	2,120,853	39.4	182,264
2016	1,715,806	2,021,964	2,771,870	51.6	238,702

Table 4.10. Water Demand Projections (2004-2016)

Year	Water Demand Projections					
	Communities and Institutions		Industrial		Total (m^3/day)	Total (mg/day)
	(m^3/day)	%	(m^3/day)	%		
2004	2994	59	2095	41	5089	1.1
2006	3170	59	2200	41	5370	1.2
2011	3780	58	2750	42	6530	1.4
2016	4732	58	3352	42	8084	1.8

Energy

The hydropower potential of Sierra Leone is estimated at 1513 MW distributed in 27 sites across the country. Hydroelectric power production is currently restricted to the Dodo Scheme, with a maximum power output of 4 MW and the Guma Water Supply Scheme, which supports a 1 MW turbine used for processing drinking water. Water used for hydroelectric power production is considered as non-consumptive. It is expected that by 2008 the Bumbuna Hydroelectric Scheme located on the Rokel River, would have been completed and it will provide 50 MW of electricity to several towns in the northern region and to the capital Freetown. Hydropower production is limited by variation in river discharge between seasons. Thus, the turbines are switched off in the thick of the dry season in March, when river discharge is at its lowest. The demand for energy is difficult to ascertain, however, it is highest when river flows are lowest.

4.3.3.4: Impacts on Water Supply Public Water Supply

The Guma Valley Water Company has the corporate responsibility of supplying water to domestic and industrial consumers in Freetown and its immediate environs. The results of a 10-year assessment study of water supply in Freetown is presented in Table 10 below.

The total quantity of water supplied between 1992 and 1999 was constant at 27 822 million litres annually. This was increased to 33640 million litres in 2001 following increases in demand due to expansion of the city as population increased. The average daily supply remained unchanged at 77 million litres from 1991 to 1999, but increased to 96 million litres in 2000 and 2001. The authority currently supplies a daily average of 105 million litres of water.

From 1991 to 2001 the estimated population of the coverage area increased 2.7 folds from 610 000 to 1 650 000. The total number of properties (private and public) within the area increased 1.5 folds from 32 900 in 1991 to 48 500 in 2001, while the number of properties supplied increased from 9 831 in 1991 to 12 480 in 2001.

The average daily supply as against the population of the authorized area indicates that 127 litres of water was available per person in 1991, while in 2001 only 59 litres were available. This shows a 50 % decrease in per capita supply within a ten – year period. If 30 % of the water supplied were used by the industrial sector, then these figures would be drastically reduced.

A change in the hydrological regime following increases in precipitation will have an impact on available water resources. Consequently more water will be available for allocation to the various sub-sectors. However, the per capita supply may continue to decrease unless steps are taken to increase the storage facilities/reservoirs.

Table 4.11. Water supply to Freetown and environs (1991 – 2001)

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Total quantity of water supplied	6,100	6,120	6,120	6,120	6,120	6,120	6,120	6,120	6,120	7,250	7,400
	27,731	27,822	27,822	27,822	27,822	27,822	27,822	27,822	27,822	32,959	33,640
(Million gallons)											
(Million litres)											
Average Daily Supply											
	17	17	17	17	17	17	17	17	17	21	21
(Million gallons)	77	77	77	77	77	77	77	77	77	96	96
(Million litres)											
Estimated Population	610 000	620 000	630 000	800 000	820 000	1 000 000	1 200 000	1 300 000	1 500 000	1 600 000	1 650 000

Total properties within area	32 900	35 088	35 200	36 000	37 050	37 200	37 400	37 100	39 250	42 273	48 500
Number of properties supplied	9 831	10 162	10 300	10 500	11 000	12 000	12 000	12 000	12 589	12 273	12 480
Number of properties not supplied	23 069	24 926	24 900	25 500	26 050	25 200	25 400	25 100	26 661	30 000	36 020
Supply per capita (Gals/person/day)	28	27	27	21	21	17	15	13	11	13	13
(Litres/person/day)	126	124	122	96	94	77	64	59	51	60	58

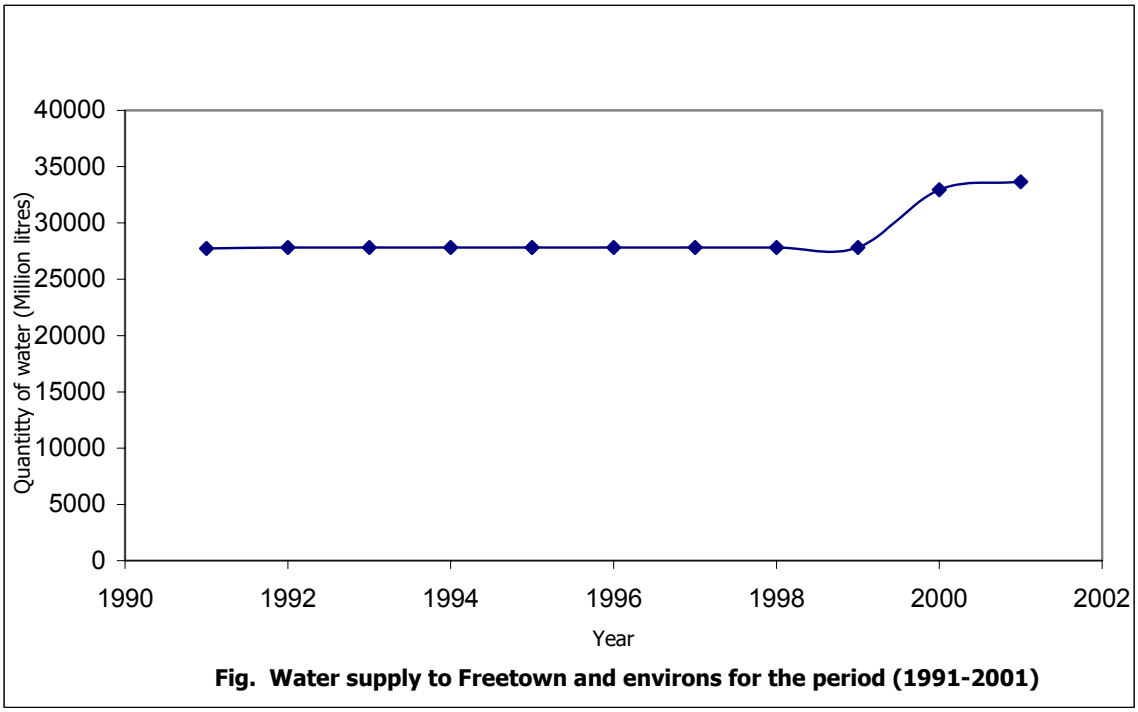


Fig. 4.17: Water supply to Freetown and its environs for the period (1991-2001)

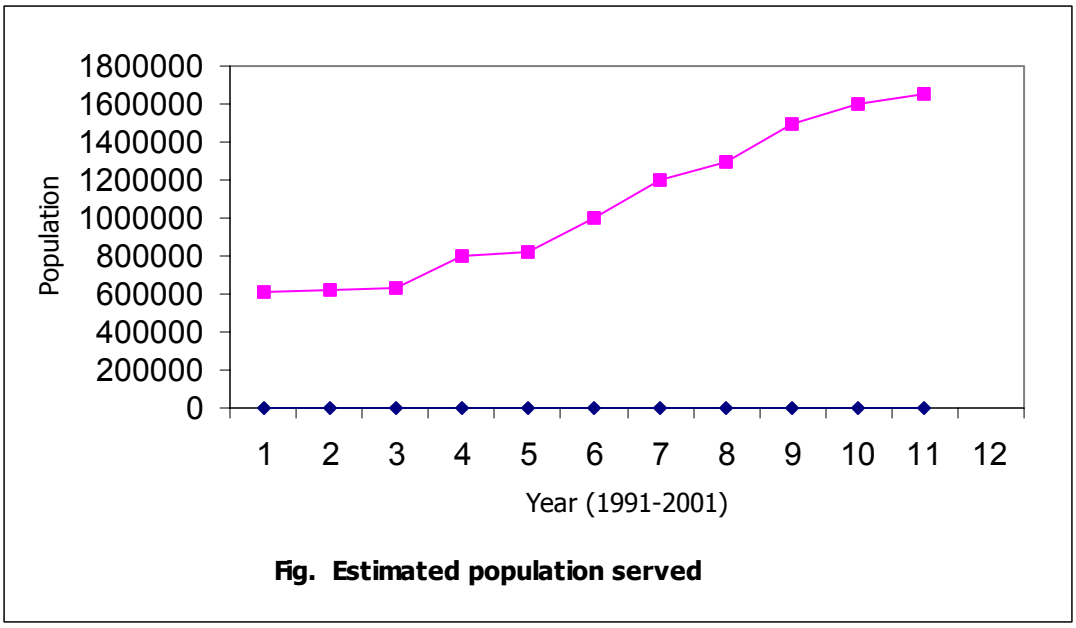


Fig. 4.18: Estimated population served

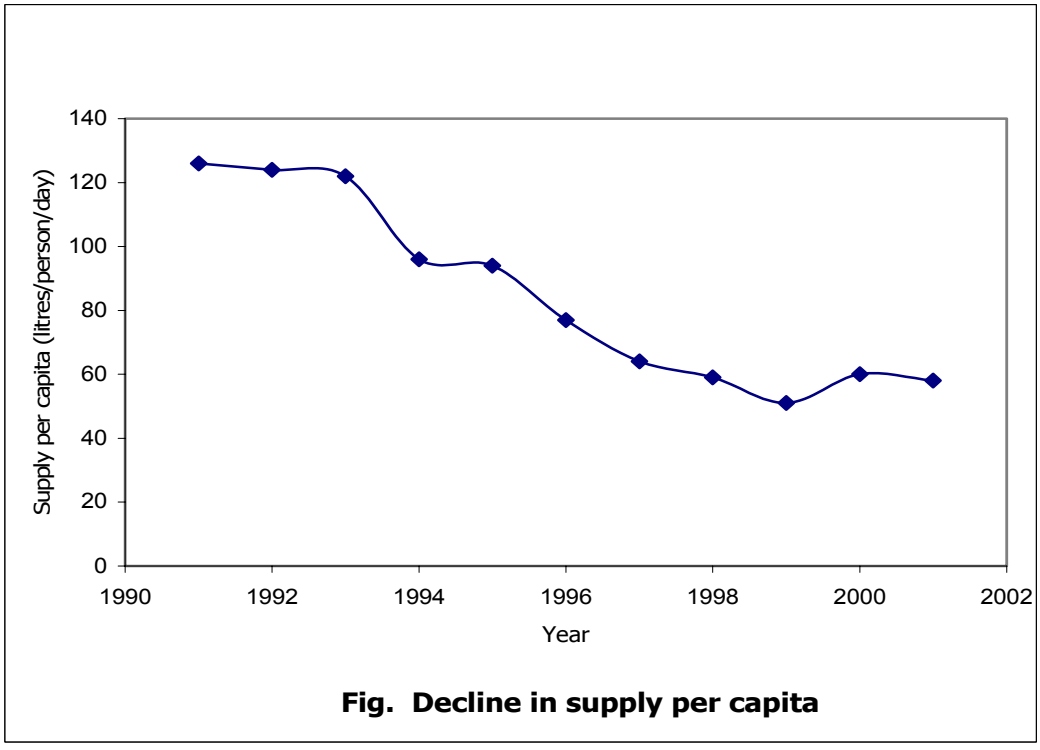


Fig. 4.19: Decline in supply per capita

Private Sector Water Supply

Private sector participation in the provision of water is relatively small. However, there is a growing market for drinking water supplied in bottles or sachets by vendors operating small water processing plants. It must be recognized though, that most of these so called 'pure/mineral/spring water' are undoubtedly water initially supplied by the public water authority. They are subjected to further treatment, usually by filtration with the filtered water undergoing further screening through ultra violet light, which apparently destroys most of the microorganisms.

The quantity of water supplied by the private sector, mainly for drinking, is almost impossible to quantify. Perhaps the key reason lies in the failure of vendors to disclose their primary sources. In the capital, Freetown, it is estimated that about 10 % of all drinking water (both in bottles and in sachets) is supplied by the private sector.

4.3.3.5: ADAPTATION MEASURES

Institutional support for the water resources sector

The management of water resources for sustainable development requires an integrated approach. The Water Resources Sector as already mentioned comes under the direct supervision of the Ministry of Energy and Power. With support from the World Bank and the Economic Commission for Africa, the Ministry is in the process of formulating a National Policy Guidelines and Action Plan for Water and Sanitation in Sierra Leone. The establishment of a Water Resources Council has been proposed for inclusion in the National Policy Guidelines and Action Plan. The Council will have the overall responsibility of ensuring that the Water and Sanitation Sector functions according to the mandate spelt out in the Policy Guidelines, which includes among others National Capacity Building.

The objective of the effort is to reduce poverty and embark on sustainable development through increasing access to water supply and sanitation. This is in keeping with the provisions set out in the United Nations Millennium Declaration of 2000. One of the key provisions of the Millennium Development Goals is the responsibility of all nations to have their population access to safe drinking water by 2015. A similar commitment is contained in the Sierra Leone's Vision 2025 (Government of the Republic of Sierra Leone, 2005).

Meeting the target contained in the Millennium Development Goals is not synonymous with the provision of adequate infrastructure to cope with the impacts expected from changes in the hydrological regime following climate change. Thus, any strategy for increasing access to water should incorporate the effects of climate change.

Relocation of populations from areas vulnerable to flooding

An increase in river discharge resulting from increases in the intensity of precipitation, in addition to bad land use practices, could cause widespread flooding in low-lying areas. The effects will be more severe in the flood plains where poor water control is already creating salinity and iron toxicity problems.

The adaptation options will include the establishment of a no farming exclusion zone defined on the basis of the maximum probable flood level. They include the relocation of

farming communities located on the flood plains of major rivers and the change in land use pattern.

Reviewing and enactment of legal instruments on water resources management
In the Climate Change domain the relevant existing legislations are the Water Supply and Control Act (1963), the Forestry Regulations (1990), and the Environmental Protection Act (2000). These legislations contain sections on catchment management and pollution control that need review and updating. As a follow up to the recommendations contained in this report other legislations aimed at mitigating or minimizing the effects of climate change on the water resources sector need to be enacted.

Results of the Study

The results of the study include:

1. There will be little or no effect of climate change on the domestic demand for water.
2. Industrial demand may not be affected by climate change.
3. The demand for agriculture cannot be assessed due to lack of data.
4. The demand for energy is difficult to ascertain due to insufficient data.
5. Per capita water supply to the various sub-sectors by the public water authority may decrease as a result of climate change.
6. Flooding is a likely impact as there will be an increase in surface runoff.
7. Since flooding cannot be prevented the adaptation options include relocation of populations and change in land use practices.
8. There are legal and institutional arrangements at the national level for addressing the impacts of climate change.

Recommendations for future assessments
The study was hampered by the paucity of specific hydrological and meteorological data. Some of the data required to run the water balance model are unavailable, therefore, the simulation cannot be done at this stage. As a matter of urgency gauges should be installed in all major rivers in the country. This would facilitate the measurement of stream flow data, which is one of the input parameters required for the simulation.

4.3.4: Coastal Zone and Resources

4.3.4.1 Background on the Coastal Zone

The coastal zone of Sierra Leone extends for a distance of about 456km. It has 155km square of open ocean coast and about 70 miles (190km) e.g. sheltered coast along the Sierra Leone coastline. The sheltered coast is dominated by extensive mangrove systems (230 km) and mud flats. Only about 150 km of the coastline is significantly developed and this includes Freetown (the capital).

The coastal resources of Sierra Leone comprise mangrove swamp forest which cover an area of about 0.2 million hectares. These forests form a protective barrier to waves by reducing coastal erosion and stabilizing estuarine flood plains, provide detritus and nutrients which form the food base of many marine and fresh water organisms.

Sandy beaches are also important coastal resources of Sierra Leone. They are found along the coastline south of the River estuary. They are interrupted in some areas by rocky headlands, bays, estuaries and creeks. Like the mangroves, these beaches play significant role in shorelines stabilizing by serving as barriers for coastal erosion. They also serve the tourist industry as recreational sites and the fishing communities as landing sites. Other resources include hard rock, gravel in sea beds, clay materials, salt etc.

4.3.4.2 Potential Impacts of Climate Change on Coastal Zone

The main limiting factor for making accurate assessment of the vulnerability of the coastal zone to sea level rise has been the lack of data on the topography of the coastal area to the desired accuracy (i.e. to allow the delineation of the appreciation contour line). Some sections of the coast particularly the urban centres of the Capital, Freetown and coastal towns of Kambia, Bonthe Sherbro Island do not have these data. As much as possible data was derived from limited information on survey bench marks and surveys of roads within the coastal areas. The elimination of areas outside the Risk Zone was assisted by the availability of maps showing the 30m contour.

Shoreline Recession

Climate change impacts Sierra Leone's sandy beaches in two ways:

1) Accelerates the rate of recession on sandy shores
2) Increase in littoral transport capacity arising from increases in the intensity and duration of storms.

Coastal Structures

The coastal structure that could be affected by rise in sea levels are jetties along the coastline, gabion groynes protecting some stretch of the Lumley beach, and piers at government wharf. The maintenance of these structures would require the re-assessment of their structure integrity in the light of new evidence of water level increases.

Flooding and Inundation.

Flooding and inundation can be expected for some coastal segments of the Freetown peninsular (bays, estuaries and beaches).

Saltwater Intrusion

In addition to sea-water intrusion, salinization and contamination of coastal aquifers may result from various sources.

The notable factors among these (according to FAO , 1997) are evapo-transpiration concentration of rain water and aerosol salts in surficial water bodies, ground water flow disturbance engendered by ground water exploitation: anthropogenic contamination and return flows of waters used for irrigation of saline soils.

Sea level rise augments a decrease in the quality and quantity of ground water resources otherwise caused by man's activities.

Population at Risk
The estimated number of people at risk shows a total of 2,315,860. This population represents all that will be impacted both by inundation and shoreline recession.

Land at risk

A total of 26 km^2 of land estimated to be lost if nothing is done. The land at risk includes significant areas that are currently wetland and substantial amounts of mangroves.

Coastal Habitats and Biodiversity

The collateral impacts of rising sea levels on the coastal zone will include, shoreline recession, increased flood frequency probabilities, inundation of coastal lands and wetlands, and the salinization of surface waters and ground-waters. These impacts will in turn affect coastal habitats and biodiversity. In Sierra Leone, the retreat of the shoreline will result in significant loss of the mangroves of the Kambia district and elsewhere, strand vegetation, coastal swamps and the habitat of marine biodiversity (turtles, snails etc).

The most vulnerable wetlands are those of the Kambia district and areas of the Western area (Freetown) i.e. Aberdeen creek which is one of the Ramsar sites in Sierra Leone.

The loss of beach will adversely affect the survival of intertidal organisms and those that make use of the sandy beaches at some stage of their life cycle.

Rising sea levels will also alter water depth and salinity which are the factors critical to the feeding of migratory birds. These include the fishing terms, stalking herons/egrets, herbivorous tree ducks and fishing pelicans. Others include the foraging waters. Increases in salinity of both surface and ground water within the coastal zone will impact aqua culture which in a significant industry within Sierra Leone's coastal area.

Sea-level rise on the coastal zone are largely concentrated on Freetown peninsular where about 70% of the vulnerable areas are located. The beaches here are mainly medium to coarse sand and most of the Risk Zone is sandy. The population density within this segment of coast averaging about 120 persons per square kilometre is high compared with the national average of 67 persons per square kilometre. The impacts of sea level rise can be expected from the effects of erosion, flooding and inundation, which are already occurring and devastating communities.

Incomes within the coastal zone are generally low except for the urban centre such as Freetown. For the large proportion of the districts within the coastal zone, incomes are below US$150 per person. The low incomes further exacerbate the capacity of the communities within the coastal zone to adapt to sea-level rise. The population along the shoreline is also increasing putting further pressures on the resources of the coastal zone.

Mangroves are primarily found within the north central and south coasts. Those located within the estuaries have been utilised by local communities for fuel wood on account of the limited choices available for the local communities for energy. Mangroves also have various important functions within the wetlands that their management is now a necessity. Sea-level rise is expected to inundate many of the areas covered by mangroves along the Sierra Leone coast.

The full protection of all the vulnerable shores will demand an estimated amount of US$1,144 million, which is about 17% of GDP (1994). The protection of important areas only will cost US$600. In the absence of any protection, the land at risk is estimated at 1,220 km^2 most of which lies within the north and south coast.

4.3.4.3: Autonomous adaptation strategies/Options

The following are adaptation strategies recommended to combat coastal erosion:

Set Back, which means allowing space between the shoreline and associated coastal hazard and property to act as buffer.

Controlled abandonment, which requires abandoning existing line of defence and allowing nature to redefine the shoreline position. Monitoring would be required regularly and possible intervention in the form of protection applied when necessary to achieve objectives in respect of environment enhancement.

Coastal protection, deliberate actions to maintain the shoreline at a particular location often through the design and construction of artificial structures. The structures include revetments, sea walls, groynes, artificial headlands and beach nourished.

Do nothing, refers to the option that involves abandoning, the existing line of defence without any future monitoring or intervention of any kind.

The various option of managed retreat will be considered for each of the shoreline segments North coast, central coast and south coast. For shores that have been undeveloped, (North and South Shores) more detailed assessments of the situation is possible to come up with a rational response.

4.3.4.4 BARRIERS AND APPROPRIATE POLICIES

Legal Framework

In Sierra Leone, a legislative framework for coastal zone management is absent. However, there are a large number of scattered legislations and regulations, which are designed to directly or indirectly protect the coastal zone. Again the implementation of

these sectoral legislations that border on the coastal zone has generally being very poor resulting in a large number of illegal activities, which have been allowed to perpetuate, mainly as a result of overlapping mandates.

The National Environment Action Plan (NEAP) raised the profile of the management and conservation status of the coastal zone. However, it is necessary to draft a law to leverage legislative support for the management of the coastal zone. This law should provide for the following:

- The power to designate any area within the coastal zone as protected coastal area for the purpose of preserving and developing the physical, biological and human resources of the coastal zone.
- The declaration of some areas as protected coastal areas. The removal or carrying away of any rock, stones, shingles, gravel, sand, soil or any part of the coastal zones should be prohibited.
- The power to reserve and portion off the foreshore or uncultivated land or an open space, of the beach of protected coastal area, for landing or for other purposes.
- The power to reserve any suitable coastal areas of the coastal zone for agricultural use.
- The power to make regulations to control the use of chemicals in agriculture and agricultural development and practices within the coastal zone.
- The power to monitor and assess the impact of irrigation projects and agricultural development within the coastal zone.
- The definition and extent of the coastal zone to comprise the land including lagoons, lagoon depressions, marshes and estuaries swamps together with the intervening interfluves areas within 30 metre contour adjacent to the ocean space; and continental shelf of Sierra Leone as defined by statute for the time being in force.

Institutional Framework

It is proposed that a National Coastal Management Board (CMB) be created to harmonize all the activities of the coastal districts. The relevance of this Board is that no coastal segment can be treated in isolation. An activity within one segment of the shoreline is bound to impact on adjoining shores.

4.3.4.5 Vulnerability and adaptation projects

The most important issues to be addressed in the management of the coastal zone in Sierra Leone are: - Establishment of CMB/Studies on coastal erosion in Sierra Leone, Delineation of flood and erosion hazard area, Further work to improve on the quality of topographic data for the coastal zone, Monitoring of the Coast, Sand and Gravel Mining, Education and Research

The various conflicts arising from the uses of the coastal zones for different objectives could be resolved through the management authority (CMB).

The impact of sea level rise would take decades. However, the gathering of the information required and the work of the institution to manage the coastal area would be a slow process. It is therefore necessary that the establishment of the institution be initiated now.

Delineation of Flood and Erosion Hazard Areas

Efficient management of coastal erosion can be achieved only through the collection of data to enable the delineation of potential areas that are prone to erosion. Areas that could be affected by sea-level rise and those that would be affected by flooding from the sea would also be included.

The extent of land area affected by the hazards and probabilities of the hazards occurring need to be determined accurately to assist the management process. There is the need to produce accurate information on areas that could be affected by sea level rise and shoreline recession. Broad mention is made of areas perceived to be vulnerable to shoreline recession. This has to be delineated based on scenarios on sea level rise and historical shoreline data to determine future shoreline positions.

Monitoring of the Coast

The most vulnerable coast areas in Sierra Leone fall under the Central Coast comprising about 147km of shorelines that are sandy. This area is expected to be affected by all the various descriptions of impacts of sea-level rise including flooding and inundation, shoreline recession, increasing salinity of estuaries and aquifers and rising water tables and its adverse consequences on earthquake hazards and building foundations. Already, the population living within this segment is being displaced by flooding and shoreline recession. Various attempts are being made to protect these areas.

The monitoring of beach profiles should be carried out monthly for the first year to establish trends of erosion within all sandy shores and thence monitoring should be carried out at intervals of the three months. It will be necessary to link the monitoring of offshore profiles with those of the beaches. On account of the expensive nature of determining offshore topography it is proposed that the offshore profiles be determined at intervals of 6 months and focused on the North and South Coasts.

Sand and Gravel Mining

The removal of sand and gravel from the beaches for construction purposes could result in the erosion of shores. Examples of these abound in the Central Coast. Although this has been prohibited, enforcing this law has been a problem.

The cost associated with sand and gravel removals from the beaches and the potential to cause erosion should be evaluated as part of the procedures for the Environmental Impact Statement for all developments in the coastal protection zones. A study could be undertaken to determine alternative sources of sand other than the beach for communities within the coastal zone. Where the alternatives are not promising, detailed investigations could be conducted to determine the impact of sand removal from selected beaches.

Education

The current understanding of the public on coastal erosion processes is inadequate. For instance, the removal of a few million Leones worth of sand from a beach and then having to protect that beach with expensive rock worth billions of Leones has to be understood by all stakeholders in the coast. An educated public would be able to make informed choices in purchasing and developing coastal lands.

The cost of eliminating the vulnerability of land is quite expensive. Without understanding of the issues involved in sea-level rise, it is unlikely to get the cooperation of the local people who will be impacted most by sea-level rise.

The public must be educated through the media about hazards associated with the Risk Zones. The consequences of the removal of sand and gravel from the beach must be well understood by the public to ensure a better management of the shorelines by the relevant authorities. More education on the consequences of sea level rise has to be carried out prior to and after the establishment of proposed Coastal Management Board.

Research

Current understanding of coastal processes is still poor. In particular, the causes of erosion, the ability to predict erosion both in the short and long term, and the prediction of shoreline dynamics or morphology with time have a profound influence on shoreline management. Tidal gauges along the coast are necessary to provide information on sea level changes.

It is necessary to improve the understanding of coastal processes in Sierra Leone. This could be done through the CMB. More accurate determination of sediment input into the littoral zone is necessary. The seasonal dynamics of tidal inlets i.e. lagoons and estuaries need better understanding through research to enable a more rational management strategy for the coastal zone.

CLIMATE CHANGE AND HUMAN HEALTH

4.3.5.: Human Health

The health sector of Sierra Leone is a government institution set up by an Act of Parliament to deliver health services to all citizens. The conduct of vulnerability studies for climate change is a policy of the I P CC within its framework.

Health is a focus that will reflect the combined impacts of climate change on the physical environment, ecosystems, the economic environment and society. Long-term changes in world climate may affect many of the requisites of good health, food sufficiency, safe and adequate drinking water and secure dwellings. Hence the collateral effects of climate change will eventually be felt in the health sector.

Nationally, infectious disease remains a major cause of human morbidity and is responsible for about two-thirds of all deaths. The control reduction and elimination of these diseases are at the centre of the country's public health programmes.

- **Climate change is expected to have wide-ranging consequences on human health.** Public health depends on sufficient food, safe drinking water, secure shelter, good social conditions, and a suitable environmental and social settings.
- **Heat waves are linked to cardiovascular, respiratory, and other diseases.** Illness and deaths from these causes could be expected to increase, especially for the elderly and the urban poor.
- **By reducing fresh water supplies, climate change may affect water resources and sanitation.** This In turn could reduce the water available for drinking and washing. n increased incidence of diarrhea diseases.
- **Any increase in the frequency or intensity of extreme weather events would pose a threat.** Heat waves, flooding, storms, and drought can cause deaths and injuries, famine, the displacement of populations, disease outbreak, and psychological disorders.
- **Higher temperatures may alter the geographical distribution of species that transmit disease**. In a warmer world, mosquitoes, ticks, and rodents could expand their range to higher latitudes and altitudes. Climate change impacts models suggest that the largest changes in the potential for malaria transmission will occur at the fringes-in terms of both latitude and altitude-of the current malaria risk areas; generally, people in these border areas will not have developed immunity to the disease.
- **People will have to adapt or intervene to minimize these enhanced health risks**. The most important, urgent, and cost-effective is to rebuild the public health infrastructure in countries where it has deteriorated in recent years.
- **Assessing the potential health effects of climate change involves many uncertainties**. Researchers must consider not only future scenarios of climate change but many non-climate factors as well.

4.3.5.2: ADAPTATIONS

4.3.5.3: THE HEALTH POLICIES IN SIERRA LEONE

The focus on health policies has been placed by government on the development of promotive and preventive services and the expansion and gradual extension of Primary Health Care (PHC) to cover all the districts. This development is expected to continue and to intensify with the setting up of medical manpower training institution so as to provide a constant supply of all categories of manpower needed in PHC and other health care programmes country wide.

The policy goals of the most recent National Health Policy.

- To decentralize the administrative structure of the health care delivery system culminating in the creation of district, provincial and Area Health Board which will function within the frame work of less stringent central control.
- To identify areas of possible mobilization of resources to ensure sustainability.
- To provide adequate manpower both in numbers and quality of effective health care delivery.
- To provide reliable transport and communication system to facilitate effective health care delivery.
- To establish the Directorate of Primary Health Care
- To reduce the high mortality and morbidity among mothers and children thereby improving their quality of life.
- To establish a Directorate of Hospital and Clinical Services to provide support for PHC activities.
- To provide alternate sources of health care by encouraging private practice;
- To develop and make optimum use of the potential that drugs have in controlling common diseases in Sierra Leone.
- To reduce the incidence and prevalence of communicable diseases.
- To improve the nutritional status of the population, especially children and mothers and other vulnerable groups.
- To provide relevant information for planning and management of the health services.
- To educate the general population on health matters and to bring about the necessary changes in behaviour that will lead to the attainment of better health.
- To train appropriate cadre of health personnel to meet the health needs of the country.
- To ensure the highest standards of ethical behaviour in Medical and Allied Professional practice.
- To determine research needs and ensure ethical acceptability in research and
- To ensure that medical practice conforms to the laws of Sierra Leone.

To realize these Aims or Goals:

- The manpower of the Ministry has been restructured to create the Director Generals of Management and Medical Services respectively and nine Directorates including a Directorate of PHC.

- A National Health Action Plan has been put in place spelling out 8 technical and 5 supporting programmes.
- Each district has a District Medical Officer (DMO) who heads a District Health Team to ensure effective health care delivery and service development.
- Various Programme Managers have been appointed who with the DMOs will focus on particular aspects of health promotion, disease prevention and control.
- New training schools have been established and the existing ones have been strengthened.
- In-service training programmes are used to continue to update the skills of serving personnel in all areas of the medical service,

4.3.5.4 ADAPTATION OPTIONS

Adaptation measures can be used effectively to greatly reduce many of the potential health impacts of climate change (Gubler, 1998d: McMichael and Kovats, 2000; WHO, 2000). The most important, cost-effective, and urgently needed measure is to rebuild public health infrastructures. In Sierra Leone, these infrastructures have declined in recent years. Many diseases and public health problems that otherwise may be exacerbated by climate change could be prevented substantially or completely with adequate financial and public health resources. These resources would encompass public health training programs, research to develop and implement more effective surveillance and emergency response systems, and sustainable prevention and control programs.

Understanding vulnerability to changes in ranges or rates of disease is the first step in addressing adaptive capacity. Adaptation involves the ability to change behaviour or health infrastructure to reduce these potential negative impacts or increase potential positive impacts of climate change. Interventions early in the causal chain of disease are preferred (e.g. “primary” prevention to remove or reduce risks before any human cases occur). To the extent that this is not always feasible (or the risk factors unknown), “secondary prevention” or surveillance for early warning to prevent any further cases also is important.

Adaptation is a function of several societal systems, including access to financial resources (for individuals and populations), technical knowledge, public health infrastructure, and the capacity of the health care system. Adaptation can occur via two routes: autonomous adaptation, which is the natural or spontaneous response to climate change by affected individuals, and purposeful adaptation, which is composed of planned to projected climate change-typically by governmental or other institutional organizations (Maciver and Klein, 1999).

Purposeful adaptation also can occur via deliberate modification of personal, family, and community lifestyles, particularly in response to public education programme. Anticipatory adaptations are planned responses that take place in advance of climate change.

Adaptation to the impacts of climate change may occur at the population, community, or personal level. The capacity to adapt to potential changes in the climate will depend on many factors, including improving the current level of public health infrastructure; ensuring active surveillance for important disease; and continuing research to further our understanding of associations between weather, extreme events, and vector-borne disease. In addition, continuing research into medical advances required for disease prevention, control, and treatment-such as vaccines, methods to deal with drug-resistant strains of infectious agent, and mosquito control-is needed.

RESEARCH

More generally, research is needed to identify adaptation needs, evaluate adaptation measures, assess their environmental and health implications, and set priorities for adaptation strategies. The following subsections outline adaptive measures that have been developed for two areas of climate change impacts on health.

Major impacts on human health may occur via changes in the magnitude and frequency of extreme events. Mitch, a range of policies to reduce the impacts of such extreme events has been identified (PAHO, 1999). These include:

- Undertaking vulnerability studies of existing water supply and sanitation systems and ensuring that new systems are built to reduce vulnerability.

- Developing improved training programs and information systems for national programs and international cooperation on emergency management.

- Developing and testing early warning systems that should be coordinated by a single national agency and involve vulnerable communities providing and evaluation mental health care, particularly for those who may be particularly vulnerable to the adverse psychosocial effects of disaster (e.g. children, the elderly, and the bereaved).

In Sierra Leone, institutional and cultural barriers to the use of seasonal forecast information remain. Decision makers should be educated or encouraged to use scientific information that may lead to reductions in losses from natural disasters (Ptaff et al., 1999).

4.3.5.5 ADAPTATION TECHNIQUES

Ongoing monitoring, both of human diseases and critical ecosystem indicators, will be essential to the timely institution of interventions as disease systems change.
Because of the inertia of large ecosystems, and the fact that changes in human diseases due to climate factors generally represent the end result of ecosystem changes, substantial ecosystem changes will have occurred by the time an increase in disease incidence is detected, and intervention will be far more difficult.

Therefore, surveillance should include intermediate indicators the need may be greatest in the critical areas where experience with disease is limited but the risk of the spread of disease is high. Educating diverse groups of people in a way that does not conflict or negate present belief systems can be quite difficult.
Educational methods need to be adapted to the local ethnic belief systems. Without the education and involvement of local communities, regional and national adaptation efforts will not succeed. Water treatment facilities and shelter may be further threatened by severe storms and sea level rise.

Investment in safe relocation and expansion of these facilities may have substantial current benefit and will be of use in adapting to future conditions. Consideration should also be given to improving efficiency of existing water systems. This is another area in which present day investment will have public benefits with or without human behaviour has a considerable influence on disease incidence storage of open water containers or the improper disposals of human wastes are examples of behaviours that create favourable environmental conditions for disease-causing agents to reproduce. Also the types of clothing worn and the filtering of drinking water, affect exposure to disease agents.

Adaptation measures including public education efforts will be needed, both to inform about the causes of disease and human impacts on disease, as well as to instruct on ways to. For vector-borne disease: Installing window screens in areas endemic to insect-borne diseases. Expanding coverage of vaccination programs in critical areas aimed at infectious diseases that are likely to increase with climate change, e.g. yellow fever; public education to encourage elimination of manmade breeding sites (i.e. small water containers).

EDUCATION

Education campaigns to sensitize health care givers in geographically vulnerable regions. Release of sterilized male insects to reduce reproductive capacity of vector populations. Promoting the use of pyrethroid impregnated mosquito bed-nets. For water-born diseases: possibly creating early warning systems based on algal blooms to predict cholera.

Public education on sources of infection. Distribution of low-technology water filtration systems (i.e. nylon mesh, cloths).
For heat-related illness: Designing building to be more heat resistant (insulation, air flow). Planting trees within cities to reduce the urban heat-island effect.

Adopting land use planning to minimize erosion, flash, precarious residential placements. Sitting intakes for water facilities for enough upstream to tolerate saline a strategy for global monitoring of health effects of climate change has been proposed involving remote sensing and extensive telecommunications networks of environmental and health professionals.

Similar but smaller effort is strongly needed on a regional and/or national scale, targeted at the critical geographic areas identified in the sensitivity analysis; this will be important for national and/or regional adaptation strategies. For agricultural stresses: producing

climate-resistant transgenic plants (genetically engineered). Rducing the proportion of monocultural for better crop resistance to pest promoting land reforms that would favour environmentally sound land usage. When considered in total, these adaptive measures will offer varying amounts of protection to human health. Many diseases may not be amenable to preventive actions. Problems may occur tat many stages: inability to provide sufficient resources for engineering options, development of pesticide and/or drug resistance in disease agents and vectors, and lack of local public support critical evaluation of implemented strategies will be needed to inform a dynamic process of adaptation. Furthermore, it should be emphasized that this list should not be viewed as an alternative to addressing the root causes of global warming through policy initiatives.

HEALTH STATUS

For adaptation techniques in climate change, improving the health status must be taken into consideration as they are generally poor and vulnerable to any adverse conditions.

The recently concluded conflict was accompanied by a deterioration of the health status of the majority of Sierra Leoneans as evidenced by the indicators from various studies. Concurrently, the resources needed to resuscitate the devastated health care delivery system are extremely limited, facilities country-wide not functioning fully due to a variety of reasons that include damaged infrastructure, inadequate staffing, and insufficient drugs and medical supplies.

The Directorate of Planning and Information is at the forefront of efforts to rehabilitate the devastated health care delivery system, and is in constant consultation with the major stakeholders in the sector to identify and prioritize the numerous problems, and appropriately allocate the limited resources to address them through the following main strategies:

- Development of Health policies and improvement of the administration of the health services, including decentralization.

- Rehabilitation of the network of health facilities at primary, secondary and tertiary levels. Development of Human Resources for Health; promotion of food safety and the provision of nutritional services; control of communicable disease with improvement of Maternal and Child Health and Immunizations.

- Strengthening of Mental Health, Counseling Services, as well as support to the physically and physically and psychologically challenged; promotion of community participation and involvement and also inter0sectioral cooperation in health care delivery; strengthening cooperation with international agencies and NGOs; and Intensification of resource mobilization.

The socio-economic burden of disease is very high in Sierra Leone, particularly for the common communicable and epidemic-prone disease. It plays an important role in the poverty cycle because it slows economic growth and human development by depleting the workforce and productivity country-wide.

To increase access to Safe water and reduce the incidence of water-borne diseases through. Widespread construction of low cost wells, water supply systems And

Ventilated Improved Pit (VIP) latrines, and promotion of education on hygiene and water quality. Although the Ministry of energy and Power is directly responsible for supply and management water, the Ministry of Health and Sanitation and its partners have a crucial role to play in ensuring water safety. The link between unsafe water and many of the common communicable disease is well known, and the Ministry of Health and Sanitation is working closely with the MEP and other stakeholders to increase access to safe, potable water.

- To improve environmental sanitation through:
- Intensification of sanitary inspections; and
- Intensification of vector control measures.

This is important because most of the common communicable diseases in Sierra Leone are directly linked to poor environmental sanitation.

To control the spread of HIV/AIDS through. Intensification of voluntary confidential counseling and testing and improvement of care for people living with AIDS (PLWA).

Although the constraints and challenges are numerous, the Ministry of Health and Sanitation is committed to improving the health status of Sierra Leoneans by strengthening the health care delivery system. This should definitely contribute significantly towards economic recovery that will lead to the achievement of our developmental goals.

4.3.5.6 WHAT NEEDS TO BE DONE TO REDUCE VULNERABILITY TO CLIMATE CHANGE

The process of decentralisation and sustainability constitute the fundamental platform for the comprehensive implementation of all components of PHC service. The first need is to decentralize and INCREASE COVERAGE: that is, to make accessible and acceptable to many more people, especially those in remote rural areas and urban slums. To achieve this we need to:-

- Decentralise proper Health Care Delivery System
- Provide logistics for supportive supervision
- Construct and improve the Peripheral Health Units (PHUs) and their facilities (clinic, toilet, well, staff quarters and incinerator)
- Recruit, train and retrain appropriate and adequate staff
- Deploy well-trained health staff to man the PHUs appropriately (that is, Community Health Officers, retrained Nurse Dispensers and EDCU Assistants, MCH Aides and Stat Enrolled Community Health Nurses, Community Health Assistants (CHAs) and Midwives Environmental Health Officers).
- Distribute the PHUs within the District equitably, whilst maintaining 3-5 miles radius using the planning scheme
- Ensure regular supportive supervision of PHUs from the District level

- Strengthen District Health Programmes
- Improve feedback mechanism at all levels
- Strengthen integrated disease surveillance and response on communicable diseases
- Organize and improve the referral system between PHUs and District Hospitals
- Assist the PUH staff to work with TBAs and with the community
- Strengthen intersectoral co-operation, collaboration and co-ordination

Secondly there is need to improve the **PREVENTIVE/PROMOTIVE SERVICES.** Some of the preventive actions needed are to:-

- Increase the number of children who are immunized;
- Increase the number of women who have safe deliveries supervised by either MCH Aides or trained TBAs in the rural areas
- Increase the number of women of child bearing age who have anti-tetanus immunization
- Increase the number of women attending ante-natal clinics;
- Improve health education service
- Increase local food production;
- Improve nutrition education and growth monitoring;
- Develop district programmes for the control of priority diseases (e.g. tuberculosis, diarrhoeal diseases etc.
- Involve the community at all levels of Planning Management and Implementation
- Promote community Based Health Programmes
- Improve data collection and use of health information
- Improve road network and conditions to facilitate referral
- Improve communication between PHU and District hospitals

Thirdly improvement on the **CURATIVE SERVICES**
This would involve:-

- Improvement in the diagnostic skills of PHU staff
- An improved system of referral from PHU to the District and regional hospitals
- The provision of essential equipment.
- The supply of basic essential drugs at affordable cost

Of the above mentioned requirements, two are related to curative care, viz:-
- treatment of common diseases" and the provision of essential drugs".

Adaptations to the health hazard posed by global climate change can be both proactive and reactive, and can occur at the macro, and micro-scales; that is, at the population, community and individual levels. Climate change represents a one-off global experiment

to carry out preliminary evaluation of adaptation options. Therefore a strong case for mitigating and adaptation to its impacts of climate change.

CHAPTER FIVE

RESEARCH AND SYSTEMATIC OBERVATIONS

5.1 INTRODUCTION

Sierra Leone being a signatory to the United Nations Convention on Climate Change (UNFCCC). Under Article 4, paragraph 1 (g) of this convention, Sierra Leone like other parties of the convention is committed to cooperate, support research, to implement the protocols of the Convention systematic observations and development of data achieves related to the climate change system and also the achievements of the goals and targets of international efforts as agenda 21.

5.2 RESEARCH

Most Institutions in Sierra Leone have technical arms which are responsible for collection of data and materials in their relevant fields. For example the Meteorological Department of the Ministry of Transport and Communications is responsible for collection and collation of data on weather and climate and has a few scientific research papers to its credit. Other institutions such as the division of the Environment, Ministry of the Lands Country Planning and the Environment, the Ministry of Agriculture and Food Security, Ministry of Health through the epidemic disease control research institute (Bo Paramedic) and the Universities of Sierra Leone and Njala are also involved in research activities. The recently established climate Change Project Secretariat is conducting a series of research studies relevant to climate change in collaboration with the universities and government institutions and the findings will soon be made public.

As part of the climate change project studies of Sierra Leone, climate change scenarios for climate variables have been constructed for the years 1990,2000, 2025, 2075 and 2100, for the whole country using the baseline 1961 - 1990.country data. This was done in accordance with the sector assessment teams, agriculture forestry, water resources, fisheries and coastal zone etc.

The variables used for the study are rainfall, temperature (maximum, minimum daily) and other meteorological elements for specific meteorological stations (Bonthe, Lungi, Kabala, Bo Daru and Njala) for which data were readily available.

5.3 SYSTEMATIC OBSERVATIONS:

The following were observed from the constructed Scenarios:

5.3.1 PRECIPITATION: -

generally the coastal areas of the country experienced the heaviest rainfall.

Rainfall amounts decreased progressively as one moves eastwards and northwards. For the period 1961 to 1990 the average rainfall was about 2746

millimeters (mm) and varies from 3659 mm at Bonthe in the South, 2979mm at Lungi in West (Freetown), 2618mm at Kabala in the Northern part of the country.

During the post monsoon period, October to November the prevailing wind direction is South Westerly but with lesser strength and it signals the withdrawal phase of the rainy season and the southward migration of the Inter tropical Convergence Zone (ITCZ).

Thunderstorms are also very frequent and periodic squalls result with wind speed of up to 60kts at least once per season.

5:4 TEMPERATURES:

Seasonal temperature variations in Sierra Leone are not very large.

Maximum temperatures show large amplitude about $5^{o}C$ while the minimum temperature has amplitude of about $2^{o}C$.

Highest temperatures are recorded during the months of March and April whilst the lowest temperatures are recorded in July and August. Low temperatures in July and August are mainly due to continuous cloudiness and rain as these months fall within the Monsoon Season.

The average temperature during the dry season is about $32^{o}C$ daytime (around 1300Hrs) and $15^{o}C$ at night (0600Hrs).

5.5 ***Other Meteorological Elements***

Humidity: The country can be characterized as mostly humid. However, the humidity is least in the northern sector during the hottest period when humidity is recorded at about 40% while it is mostly above 60% throughout the year.

5.5.2 EVAPORATION

Evaporation is observed to be higher during the months of December through April as dominant winds are from north and northeast in the harmattan season whiles evaporation is lowest during the months of July and August when the atmosphere is moist as the prevailing Southwesterly (SW) Wind bring in a lot of moisture from the Atlantic Ocean.

5.5.3 SOLAR RADIATION

The extraterrestrial radiation (Ra) is about twice the actual Radiation (s) received at the surface. This is due to the fact that Sierra Leone being a tropical country close to the equator has a large cloud cover particularly during the monsoon months of June to September. With radiation also, similar variations are observed with sunshine duration.

5.6 CLIMATE CHANGE SCENARIOS

The climate change scenarios reported for Sierra Leone in our study was accomplished through the use of MAGICC (Model for the assessment of the Greenhouse Gas Induced climate change) and references were made to other models such as the UKTR, HADCM2, ECHAM4, CISRO-TR.

The Model MAGICC/SCENGEM)

Global climate dataset was used to examine climate variability over the twentieth century to evaluate the simulations of the various GCMs over the period 1961 – 1990 and combined observation of 1961-1990 Global land field with the users – defined GCM change field generated a future climate field for any time slice and variable.

The reference year 1990 has been used for climate model output as it is assumed to be the baseline year against which future changes in the various climate and socio-economic variable are calculated. This year is assumed to represent the period 1961-90, the thirty year period used to define the baseline climatology's use in SCENGEN. The year 2100 is the assumed end-year of simulations.

5.6.1 TEMPERATURE SCENARIOS

The average annual temperature of Sierra Leone for the period 1961 through 1990 and based on observed data from the Meteorological stations is about 26.7^{o}C. Combining this average annual temperature with 2* Co_2 output from the GCMs, the average annual temperature for Sierra Leone for the period 1961 – 1990 is projected to increase by 7 to 9 percent above the average temperature in 2100. The study also shows a projected increase in the monthly average in 2100.

5.6.2 PRECEPITATION SCENARIOS

From current 1961 – 1990 and projected rainfall to 2100 points that monthly and annual rainfall under the ECHAM4 and HADCM2 models show similarity to the current rainfall pattern. However the CSIRO – TR and UKTR models show decease in rainfall of about 3 – 10% below the current monthly and annual rainfall.

5.6.3 SEA LEVEL RISE

For sea level rise it is observed that a rise of 0.2m – 0.5m is expected by the year 2100 and could change to 1– 2m under the same emission scenario.

5.7 CONSTRAINTS IMPEDING SYSTEMATIC OBSERVATIONS

The 10 years rebel war has greatly affected the proper and efficient running of meteorological services as most of its instruments and equipment were destroyed during the war and this has left the service in a deplorable state.

The service cannot be restructured nor instruments and equipment replaced because of inadequate funding by the government and donor partners and this is responsible for poor service delivery by the department.

The MENSSIR vision computer Satellite System was recently installed at the Forecasting Centre, Lungi International Airport. This forecasting tool which was provided through donor funding of the PUMA Project is greatly assisting the Meteorological Services to render efficient and timely forecast. The personnel attached to this section need to be properly trained to interpret the output of the satellite.

In human resources the service has lost most of its trained staff due to poor working conditions of service. At the moment the department can only boast of a few graduate meteorologists who are mainly engaged with administrative work. As a result of the inability of the government to meet its contribution to the world meteorological organization (WMO) the service cannot benefit from the training programmes of this organization. It is in government's interest to make early settlement of its outstanding contributions to WMO.

To improve on the output of the meteorological department, Government as of priority should improve on the current conditions of Service of workers in a bid to attract qualified people and at the same time retain the few trained personnel already in the service.

5.8 PRIORITY ACTIVITIES RELATED TO SYSTEMATIC OBSERVATIONS

For Sierra Leone to meet its international obligations some important priority activities need to be undertaken at both the national and Regional levels. This will enhance effective recording and monitoring of climate data and phenomena leading to improvement of studies and climate change information.

The following priority activities need urgent consideration:-

5.8.1 Strengthening of the climate data base of the national meteorological services and other relevant sister institutions of the country. This can be done by providing up to date computer facilities and train experts in the input and storage of climate related data.

5.8.2 Provide automatic recording equipment and instruments for continuous recording of meteorological, hydrological and climatological elements and phenomena.

5.8.3 Rehabilitation and expansion of meteorological stations for the collection and monitoring of all categories of data.

5.8.4 Capacity building in Human Resource in the Meteorological department should be urgently embarked upon to meet the present and future challenges.

5.8.5 Education and sensitization of the public on climate change issues should be intensified and given high priority.

5.8.6 Create a National Climate Change Committee which should meet frequently to advice the Government and stakeholders on Climate Change issues

5.8.7 The need to intensify Research on Climate Change issues in collaboration with the universities and other institutions in the country and also with Regional and Global organization/Institutions in the field of climate change.

CHAPTER SIX

EDUCATION, TRAINING AND PUBLIC AWARENESS

6.1 Introduction

The UNFCCC defines Climate Change as "*a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere in addition to natural climate variability observed over comparable time period"*. This implies that climate change is not a stand-alone problem. It will both affect and be affected by socio-economic policies and by choices involving development and sustainability. There is therefore a growing need for action to be taken to help communities and ecosystems to either cope with, through adaptation, or mitigate against changing climate conditions. This can be effectively achieved through education, training and mass public awareness programs. The dissemination and assimilation of development information, including information on climate change can be achieved through education. The general public needs to be adequately informed about issues relating to climate change and the consequences of climate change. This will help them play their different roles in influencing policy and decision making processes in implementing the UNFCCC.

6.2: Education

Education is the backbone of socio-economic development of any nation. The content of the curricula at all levels of the educational strata in Sierra Leone should be such that it is relevant and meets the contemporary needs of the society. Weather, climate change and all other related environmental elements should be deeply incorporated into the university curricula and treated to such a depth to reveal the consequences of anthropogenic activities on climate change. The necessary adaptation and mitigation measures should also be incorporated in national curricula.

6.2.1 Formal Education

At present, climate change is not addressed as an isolated component in our educational system, but rather treated as subsections in subjects like Geography, Environmental, Physics and some aspects under Energy studies. The Ministry of education, in collaboration with the climate change and environment offices and all other sectors in the national economy should design curricula to reflect issues relating to climate change in order to help implementation of the UNFCCC in Sierra Leone. The mitigation and adaptation measures identified in all sectors considered in the National communication should be incorporated in the school curricula at both lower and basic levels. At lower school levels, they can be incorporated in subjects like Integrated Science; whilst at higher school levels in Geography and Environmental sciences. At tertiary levels, both government and private educational institutions should be mandated to develop and incorporate relevant curricula on climate change as core modules or specialist areas. Human capacities should be built to enable the collaborating educational institutions to effectively implement curricula on climate change.

6.2.2: Informal Education

The issue of climate change should be treated as a universal problem and therefore be incorporated in the curricula of all sectors of the educational system including the informal sector. Special awards can be awarded to communities and recognized bodies for their respective roles in climate change activities. Important figures and opinion leaders should be encouraged to act as propaganda machines for issues on climate change. Youths and women who are key figures on the ground should be particular focus and encouraged to participate in climate change activities. Mass media techniques such as video/television, radio, print media, traditional communicators and extension agents can be used in well designed campaigns aimed at achieving favourable results in climate change, by changing attitudes and ushering in the right behaviour with regards to issues relating to climate change.

6.3 Training

A series of workshops, seminars were held in the Climate Change Secretariat, Tower hill, Freetown to train the members of the different technical teams (GHG Inventory, Vulnerability and Adaptation and Mitigation) in the implementation of the project.

6.3.1 Training of the Greenhouse Gas Inventory team.

An International Consultant and trainer was recruited from the sub-region to provide services to GOSL/GEF/UNDP project on the development of the Initial National Communications for Sierra Leone with particular reference to the National Inventory of Greenhouse Gas Emissions. This training was done with the help of the National Consultant and it lasted for about nine (9) days. It consisted of lectures and discussions on the 1996 revised IPCC Guidelines estimation using the Reference Approach and other tiers, and data requirements for each tier were treated in great detail.

A lot of the training time was devoted to hands-on-exercises on all the modules (Energy, Industrial Processes, solvent, agriculture, Land use change and Forestry and Waste management) and guidelines using our country data. The experts were able to easily identify data gaps during the development of the sectoral inventories reported in Chapter 2 of the National Initial Communications report

6.3.2 Training on Assessment of Greenhouse Gas Mitigation Options.

The training was done by the same Consultant a few months after that of the Vulnerability and Adaptation Assessment training. The results from the Vulnerability and Adaptation Training were found very useful in the Mitigation training. The Consultant/Trainer in conducting the training explained the Basic Methods and concepts of Mitigation assessment for the Energy Industrial, residential, commercial transport and transport, agriculture, rangelands and grasslands, land use and forestry and waste management sectors. The national Experts were also introduced to the basic steps in the analysis of Mitigation options. These steps include:

- Determination and collection of the data and information needed for the assessment;
- Screening to identity mitigation options significant to the country.
- Development of baseline and climate change scenarios of the options.

- Development and projection of future GHG net emissions and cost scenarios;
- Evaluation of the cost-effectiveness of mitigation option;
- Development and evaluation of policies, institutional arrangements and incentives necessary for the implementation of the cost-effective mitigation options;

The training was followed up with a two day scoping workshop in which the national experts and other stakeholders participated and made meaningful contributions. These inputs are reported in Chapter 3 of this report

The Consultant advised that the models for now should not be included in the report due to time constraints but hopefully will be included in the 2nd communication report.

6.3.3 Training on Vulnerability and Adaptation assessment.

This training took place in the Secretariat mainly for the Vulnerability and Adaptation technical team although members of the two other groups (Mitigation and GHG Inventory) were also invited to participate. The Vulnerability and Adaptation Assessment is very important for developing countries especially Least Developed Countries (LDC's). As a result a member of the Vulnerability and Adaptation team has recently been appointed Coordinator of NAPA project because his experience gained in the training exercise.

The Consultant/Trainer explained the various steps involved in conducting the assessment which varies from defining the scope of the problem and assessment process, defining and describing the scenarios underlying the assessment, determine the biophysical impacts, evaluating the adaptation measures, practice and technologies, integration of the sectoral results. The scope of the assessment includes:

(a) Identification of data and information required for the training and development of the Vulnerability (Impacts and Adaptation) report as a component of the Initial National Communication of Sierra Leone.
(b) Definition of the sectors to be studied.
(c) Selection of the study region (e.g. administration units, geographic or physiographic unit, ecological zone, climatic zone and sensitive regions:
(d) Selection of time frame (usually 20-100 years).
(e) Determination of data needs of the study.
(f) Development of the context and schedule for the assessment.

The experts were introduced to the preliminary screening technique and simulation. During the training on the simulation techniques, experts discussed and carried out exercises on hands-on-exercises on the execution of the various biophysical models (DSSAT, WATBAL, Holdrige life classification and Forest Gap Model) that have been used to assess impacts of climate change on the economic sectors of Sierra Leone. As a follow-up to the above mentioned training the National Expert on Forestry of the Vulnerability and Adaptation group on the request of the International

Consultant was sent on a few days attachment to further work on the holidrige life classification model and finalise his sectorial report for inclusion in the National Initial Communications report. This mission proved successful.

6.4 Public Awareness

1) During the implementation of the various studies incorporated in the Initial National Communications, sensitization and public awareness campaigns were carried out by the project throughout the length and breath of the country. These campaigns took the form of workshops, seminars panel discussions and question and answer sessions. These deliberations were mostly conducted in the krio language with relevant translations depending on the type of audience. This encouraged the grassroots people to participate actively in a bid to enhance public awareness on climate change. It is interesting to note that the workshops and seminars organized were attended by Government Ministers, high level Government officials, representatives of NGOs, CBOs, Farmers, Teachers, Students, Heads of Parastatals, Cultural and Drama groups etc.

2) As a sign of Government continued commitment and support to the climate change process, his Excellency the Vice President of the Republic of Sierra Leone launched the project early 2003. The Resident Representative of the United Nations Development Programme, Government Ministers and very important dignitaries graced the occasion.

3) The following activities are planned to enhance Public awareness:

1) Development of sensitization materials to enhance public awareness of climate change.
2) Visits to secondary schools in the capital to give talks on climate change.
3) Presentation of a paper on the climate change process to the NCCC (SL)

CHAPTER SEVEN

CAPACITY BUILDING AND TECHNOLOGY TRANSFER

7.1 Background

Article 4.5 of the UNFCCC implores developed country Parties to support the development and enhancement of endogenous capacities and technologies of developing country Parties. It is also stated in Article 5 that Parties should take into account the particular concerns and needs of developing countries and cooperate in improving their endogenous capacities and capabilities to participate in the efforts to implement commitments under that Article.

7.1.1 Capacity Development

At various sessions of the Conference of parties (COP) and its subsidiary bodies, the issue of capacity building has been extensively discussed and decisions taken. By its Decision 2/CP.7, the COP adopted the framework for capacity building in developing countries. The framework sets out the scope of, and provides the basis for action on capacity building related to the implementation of the Convention and preparation for the effective participation of developing countries in the Kyoto Protocol process.

7.1.2 Activities Undertaken

During the past years, the capacity of the NCCU has been built through training workshops (see Chapter 6). Thee workshops covered the development of National Inventories of Greenhouse Gas emissions, assessment of greenhouse gas mitigation measures, assessment of vulnerability of the national economy and ecosystems to projected climate change, and development and evaluation of CDM projects. These were executed and funded by the GEF through UNEP and UNDP. Sierra Leone benefited in limited training in negotiation skills through side events organized at SB and SABSTA. The NCCU is, however, constrained in the capacity to execute methodological concepts of cost assessment of mitigation and adaptation measures and to develop full projects in these areas.

Institutional capacity development is limited to procurement of computer hardware and software through projects funded by GEF Projects implemented by GEF/UNDP/UNFCCC. The project provided training for the local experts and stakeholders.

The GEF has provided financial and technical resources to Sierra Leone to enable the Task Forces of Biodiversity, Desertification and Climate Change to undertake country-level capacity needs assessments and to develop specific capacity-building activities consistent with the Conventions. The Environmental Division of the Ministry of Lands, Country Planning and the Environment is coordinating these activities. The NCC will

pay particular attention to the capacity development framework annexed to Decision 2/CP-7 of the UNFCCC. The NCCU would identify the specific needs, options and priorities for capacity building for Sierra Leone and this will be achieved through the participation of a wide range of stakeholders, including government, national and international organizations, civil society and the private sector. Where possible and more effective, the services of regional Centers of Excellence will be utilized to develop and support capacity-building activities in Sierra Leone.

7.1.3 Activities to be undertaken

Adequate human and institutional capacity is a necessary condition for the implementation of the UNFCCC. To build on the limited national capacity developed over the years the following will be required.

1. The current capacity of the National Climate Secretariat of Sierra Leone is limited to coordination and development of national GHG inventories and evaluating sectoral impacts of climate change. There is limited expertise in the assessment of mitigation and adaptation options, participation in the Kyoto Protocol process and development of appropriate implementation strategies. Thus, it is a high priority to strengthening the capacity of the national climate change secretariat to enable the effective participation in the implementation of the Convention and its Kyoto Protocol process. This will involve:
   (a) The development of a comprehensive climate change action plan and integrated implementation strategy that takes into account the capacity building needs of the various institutions participating in climate change activities particularly in research and training;

   (b) Development of education and training programmes, and specialized skills or expertise and scientific institutions with the necessary equipment and scientific information; and

   (c) Enhancement of public awareness on climate change at all levels with the ultimate objective of improving decision – and policy-making through re-orientation and development of appropriate policies.

2. In the area of development of inventory of national GHG emissions the members of the National Task Force assigned the study will need capacity to move beyond the mechanical use of the 1996 Revised IPCC Guidelines and the emission factors contained in those guidelines. The Task Force should be capacitated and involved in the development of national and/or regional specific emission factors with the ultimate objective of reducing uncertainties in the national inventory statistics. This is likely to be achieved through the involvement of Sierra Leone in the UNDP/GEF emissions factor project in West Africa.

3. Technical expertise of some members of the NCCU has been developed to execute climate change scenario development tools (GRADs, SENGEN, IMAGE, etc.) and biophysical models (DSSAT, WATBAL, SPUR2, etc.) in the assessment of vulnerability (impacts and adaptation) of the economy to climate change.

However, these members of the Committee have very limited expertise in influencing the source codes of these models so as to "*fine tune*" them to Sierra Leone environment. For a comprehensive vulnerability assessment the technical capacities and skills of experts need to be developed and enhanced beyond those acquired workshops. The experts need to be trained on modeling at institutions of higher learning through fellowships and/or internships. There is a need for the leading global climate modeling groups to collaborate with Sierra Leone in building the capacity of members of the NCCU in the development and execution of climate change and biophysical models. The collaborative efforts should include the transfer of the model technology to Sierra Leonean experts.

4. Understanding and participating in the climate change debate and development and implementation of climate change programmes is a process that depends on access to a reliable body of scientific information. The information is developed from raw data acquired from national, regional and global system of observation networks. Sierra Leone has limited historical climate data and the meteorological and hydrological networks established in the late 1930s have deteriorated and gaps in data have been realized from the mid-1990s. Inadequate or non-availability of equipment for systematic collection of long-term instrumental observation of climate system variables has the consequence of limiting vital data required in the development of adequate and accurate input variable model and simulate climate and climate change. The present status of the network stations of Sierra Leone will not contribute meaningfully to the future of data for national regional and global climate change initiative. It is thus a priority in Sierra Leone to reverse this deterioration of the observation networks and improve the data and information Improvement will entail acquisition of automatic recording equipment and expansion of networks to get more representative coverage of the country.

7.2 Technology Transfer

By its Decision 4/CP.7 the COP adopted the framework for meaningful and effective actions to enhance the implementation of Article 4, paragraph 5, of the Convention by increasing and improving the transfer of and access to environmentally sound technologies and know-how. The successful development and transfer will require a country-driven, integrated approach, at national and sectoral levels and this should involve cooperation among various stakeholders. Activities include technology needs assessments, technology information, enabling environments, capacity building and mechanisms for technology transfer.

7.2.1 Activities Undertaken

In recent past, Sierra Leone has promoted and encouraged the shift to more environmentally friendly technologies based on the awareness of the consequences of desertification and environmental degradation. The shift has been from fossil fuel to

renewable (solar and wind) energy. Penetration of solar energy technology is high in the government, Commercial and Residential sectors of the economy.

Sierra Leone is therefore aware and receptive of clean technologies. There are a lot of opportunities and avenues in Sierra Leone for collaboration in the transfer and diffusion of climate friendly technology.

7.2.2 Activities to be undertaken

Activities that need to be undertaken include, among others:

- Technology needs assessment;
- Establishment of an efficient information system in support of technology transfer; and
- Capacity building in the promotion of the widespread dissemination, application and development environmentally sound technologies and know-how.

CHAPTER EIGHT

Implementation Strategy of the UNFCCC

8.1 Sectoral Activities and their Implementation

8.1.2 Forest and Wetland Ecosystems

Priority actions for Forestry and Wetland Ecosystems.

Short-term Priorities

- Conservation of the forest estate, by instituting sound silvicultural management (including control of forestry logging and protection)
- Development of pilot programme in improved agroforestry cropping systems.
- Development and pilot firewood plantations
- Manage and sustain a comprehensive research programme to provide sound technical basis for improved agroforestry systems to work on fuelwood species and other species important to the national economy.
- Develop a data base for forest areas to allow the planning of management systems.
- Assistance to and coordination of other agencies working in the priority areas.

Long-Term Priorities

- A full conservation programme coordinating wildlife and ecology.
- Development of mainly forestry watershed management systems in selected catchments.
- Development of industrial plantations and investment scale programmes in agroforestry and fuelwood.
- Expansion of forest training to march capability to increase responsibility.

Implementation Strategy

The Department of Forestry in the Ministry of Agriculture, Forestry and Food Security in collaboration with the Conservation Society (SL).

8.2.2 Agriculture

Priority Actions for the Crop Production Sub-Sector: -

- Government should formulate legislations or enforce existing ones or even abolish savanna burning.
- Introduce support and promote sedentary farming and cattle raring in the country.
- Encourage and promote irrigated rice cultivation in all the ecologies. This involves very little or no burning.
- Use residues to make compost for use as organic manure in rice fields.

- Burn residues and use ash to fertilize irrigated as well as deep water rice fields and rain fed farms. Burning residues reduce emission but N_2O increases.
- Conduct research on the nutrient content of fodder feed to animals, inorder to determine the carbon and nitrogen contents.

Implementation Strategy

The Ministry of Agriculture, Forestry and Food Security will play a leading role for the
Agriculture sector in collaboration with other partners such as the FAO, Farmer Association,
NGO's etc.

8.2.3 Waste Management Sector

Priority actions in the Waste Management Sector: -

- Increase sensitization and education of the populace on the separation of garbage wastes.
- Aerobic treatment
- Recycling and manures small-scale industry to be encourage.
- Landfill/dump site management waste water treatment.

Implementation Strategy:

The ministry of Health and Sanitation, Youth and Sport and Freetown City Council and Town Councils.

8.2.4 Cross-Cutting Issues (Education, Training and Public Awareness, Research and Systematic Observations): -
Priorities Action on Cross Cutting Issues: -

- Incorporate climate change issues in the curricula at all levels of the Educational Strata of Sierra Leone.
- Use mass media techniques such as television/Video, radio and the print media etc.
- Develop educational and sensitization materials to enhance public awareness on climate change.
- Strengthen the climate base of the National Meteorological Department and other relevant data collection institutions countrywide.
- Capacity building in the meteorological department should be urgently addressed.
- Intensification of research in the areas of climate change.
- Support the effort of the National Climate Change Committee (NCCC).

Implementation Strategy

The Ministry of Education, Science and Technology, Ministry of Information and Broadcasting, the Universities (Freetown and Njala), NGO's drama groups etc should implement such strategies.

8.2.5 Coastal Zone of Sierra Leone

Priority Actions Include: -

- Establishment of a Coastal Management Board/Studies on Coastal erosion in Sierra Leone.
- Delineation of Flood and erosion hazard areas.
- Improvement on the quality of Topograhic data for the Coastal Zones.
- Strengthen the Monitoring of the Coast
- Development of programmes on Education and Research on the Coastal Zone of Sierra Leone.

Implementation Strategy

The Ministry of Marine Resources and Fisheries in Collaboration with NGO's, the Department of Oceanography, University of Sierra Leone will implement these strategies

8.2.6 Fisheries Sector: -

Priorities actions include: -

- Introduction of biological monitoring.
- Enforced fishing control measures in the country
- Promote aquiculture.
- Modify and strengthen fisheries management policies and institutions.
- Strengthen and expand catchment.

Implementation Strategy: -

The Ministry of Marine Resources in Collaboration with the Department of Marine Biology and Oceanography, FBC, University of Sierra Leone.

CHAPTER NINE

9.0: INTERNATIONAL COOPERTION IN CLIMATE CHANGE

In Article 3 paragraph 5 of the UNFCCC, Parties are called upon to cooperate in the promotion of a supportive and open international economic system that would lead to sustainable economic growth and development in all Parties, particularly developing country parties. Article 4 of the Convention specifically calls for cooperation of parties:

- In the development, application and diffusion, including transfer, of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of GHGs;
- In the conservation and enhancement, as appropriate, of sinks and reservoirs of all GHGs not controlled by the Montreal Protocol;
- In scientific, technological, technical, socio-economic and other research, systematic observation and development of data archives related to the climate system;
- In the full, open and prompt exchange or relevant scientific, technological, technical, socio-economic and social consequences of various response strategies; and
- In education, training and public awareness related to climate change.

Article 2, paragraph (b) and article 10, paragraphs (c), (d) and (e) of the Kyoto Protocol also strengthens these Convention commitments. Article 2(b) of the Protocol explicitly requests Annex I Parties to cooperate with other Parties to enhance the individual and combined effectiveness of their policies and measures adopted under Article 2 of the Kyoto Protocol.

9.1: Cooperation with Multilateral Agencies

Sierra Leone participated in the INC negotiations for the UNFCCC and all IPCC activities prior to and after the INC. Sierra Leone also cooperated and collaborated with the UNFCCC Secretariat, GEF, UNEP, and UNDP in the implementation of climate change activities. These activities are indicated in previous chapters of this NIC.

9.1.1: Cooperation with Bilateral Governments

At the bilateral level Sierra Leone cooperated with the Government of the Republic of The Gambia, Ghana, and Nigeria. This cooperation was very effective in building the capacity of the NCCU of Sierra Leone in terms of the acquisition and utilization of methodologies, particularly in the assessment of the impacts of climate change.

9.1.2: Future Cooperation Requirements

Past and existing bilateral and multilateral cooperation has contributed to Sierra Leone being able to participate in the climate change debate and process and thus meeting its commitments to the climate change family.

Public awareness and political commitment are no longer constraints in the implementation of climate change. However, existing scientific, technical, technological and financial capacity and the level of human resources development of the country have limited effective participation.

Within the available national capacity and assistance provided by bilateral and multilateral partners, Sierra Leone has been able to put together a strategy (see chapter 8) for the implementation of the UNFCCC. The implementation of this strategy and the Convention by Sierra Leone is dependent on the future cooperation other Parties to the Convention and its Protocol. It is particularly dependent on the availability of technical, technological and financial resources, and human resources required for the implementation of the Convention and the Protocol. Specifically, bilateral and multilateral cooperation and collaboration will be required in the following areas:

- **Re-orientation and development of national policies and programmes to take climate change fully into account in formulating a sustainable development path:** What is needed is to develop policies and measures with opportunities to facilitate sustainable development and strategies that make climate-sensitive sectors resilient to climate variability and change. The policies should lead to reduced pressure on resources and enhance adaptive capacity.

- **Enhance climate change education and awareness particularly at basic cycle in schools:** A sensitized population is capable of changing attitude towards building a better climate system for responding to climate change. This can be achieved by conducting training, education and public awareness campaigns at all levels of society particularly in schools. It will be necessary to develop educational materials and conduct extensive training on climate and climate change. School curricular should be re-oriented and developed to include climate and climate change education.

- **Rehabilitation of observation networks:** Long term and accurate data and information are prerequisite for climate change modeling. These are available from an extensive and reliable network of recording stations. Similar to many countries, the networks of observing systems have deteriorated during the past few years. Data and information gaps are

increasing and this will continue to lead to uncertainties in research and modeling results. Bilateral and multilateral cooperation are required to address this situation.

- **Further capacity building for Sierra Leoneans:** Members of the NCC have been trained in the assessment of vulnerability to climate change. The methodologies used are sectoral and the integration of the results proved difficult. Integrated assessment methodologies and analytical tools are available in the market but not in Sierra Leone. It will be necessary to introduce and build the capacity of Sierra Leoneans in conducting integrated assessment of vulnerability to climate change. The building of capacity should go beyond applying models from outside Sierra Leone but should be concentrated on building models for the Sierra Leonean environment and ecosystems.

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