**REPUBLIC OF SIERRA LEONE**

# SECOND NATIONAL COMMUNICATION ON CLIMATE CHANGE

## Executive Summary

The country has a surface area of about 72,325 square kilometers and 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. The country has a population of 4,976,871 based on the 2004 National Census and is growing at 2.5% per annum. Approximately 80-90 % of the population is in the rural areas.

The Second National Greenhouse Gas (GHG) inventories of emissions by sources and removals by sinks have been carried out to meet Sierra Leone's obligation under Articles 4.1 and 12 paragraphs (a) of the United Nations Framework Convention on Climate change (UNFCCC).

The United Nations Framework Convention on Climate Change (UNFCCC) seeks to stabilize concentration of greenhouse gases (GHGs) in the atmosphere and commits Parties to take measures to mitigate GHG emissions, in accordance with the principle of common but differentiated responsibility and taking into account their national priorities and aspirations. Inventories of GHGs provide the means for monitoring reductions of GHGs by Parties and are therefore important components of national communications.

The Intergovernmental Panel on Climate Change (IPCC) has developed guidelines for computing of GHGs (by parties) to enable their comparison. Sierra Leone used the 1996 IPPC guidelines, including for the selection of emission factors in all the sectors.

This inventory used 2000 as the base year. No specific surveys were conducted to generate data needed for the inventory exercise as the funds were inadequate for such an exercise.

Country activity data were collected to the extent possible. IPCC default factors were employed where country data were not available.

For the Second National Communication, the aforementioned reforms contributed to: (i) an improvement in some areas of the national statistics; (ii) building of national capacity and expertise; (iii) appropriate institutional framework; (iv) orientations of policies, in particular more specific policies in agriculture, forestry, land use and land use change and energy water sectors.

## National Circumstances

Sierra Leone is located in the Southern-Western part of the bulge of West Africa. It lies between latitudes 7° and 10º 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 $28^0$C. 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.

The mining industry is one of the most important in terms of employment, and contribution to the national economy. The minerals mined include; Diamond, Bauxite, Rutile, Gold etc. Mining has a lot of potential 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

The table below show 2000 emission levels for the most important greenhouse gases Sierra Leone.

**Greenhouse Gases Emission for the Base Year 2000**

The gross emissions of GHG in Sierra Leone for 2000 are presented in the table below:

## Table 2.5: Summary Report for 2000 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 2000** | | | | | | | | |
| ***1 Energy*** | **529.28** | | | | | | | |
| Fuel Combustion (Sector Approach) | 529.28 | | | | | | | |
| i. Energy Industries | | | | | | | | |
| ii. Manufacturing Industries and Construction | | | | | | | | |
| iii. Transport | | | | | | | | |
| **2 Industrial Processes** | | | | | | | | |
| i. Mineral Products | 111.2397 | | | | | | 000000957 | |
| **3 Solvent and Other Product Use** | **NOT ESTIMATED DUE TO LACK OF METHODOLOGY** | | | | | | | |
| **4 Agriculture** | | | | | | | | |
| i. Enteric Fermentation | | | 5.152 | | | | | |
| ii. Manure Management | | | 414.2 | | | | | |
| iii. Rice Cultivation | | | 15640.37 | | | | | |
| iv. Agricultural Soils | | | | | | | | |
| v. Prescribed Burning of Savannas | 129.36 | | 689.91 | 8.54 | 308.58 | 24.147 | | |
| vi. Field Burning of Agricultural Residues | | | | | | | | |
| vii. Other (please specify) | | | | | | | | |
| **5 Land-Use Change & Forestry** | | **-405,339,92** | **5,431** | **4,645** | **167,891** | **49,267** | | |
| i. Changes in Forest and Other Woody Biomass Stocks | | 1,066,501.5 | | | | | | |
| ii. Forest and Grassland Conversion | 5331300.6 | | 5,631 | 4,645 | 167,891 | 49,267 | | |
| iii. Abandonment of Managed Lands | | -44,798,789 | | | | | | |
| **6 Waste** | | | | | | | | |
| i. Solid Waste Disposal on Land | | | | | | | | |
| ii. Wastewater Handling | | | 11.81 | 31.29 | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **7 Other (please specify)** | | | | | | | | |

The economic sectors considered in the greenhouse gas inventories are Energy, Industrial Processes, Agriculture, Land Use Change and Forestry, and Waste. The GHG inventories of emissions by sources and removals by sinks covers carbon dioxide ($CO_2$), methane ($CH_4$) and Nitrous Oxide ($N_2O$) and the total $CO_2$, - equivalent from the sectors for the period 1995 – 2005. The greenhouse gases $CO_2$, $CH_4$, and $N_2O$ have been reported in accordance with the guidelines

$CO_2$, $CH_4$ and $N_2O$ have a direct effect on the climate, while $NO_x$, CO and NMVOC have an indirect effect by contributing to the formation of the ozone in the atmosphere which actively causes the green house effect.

Not all emission categories of the 1996 Revised Guidelines (IPCC, OECD.IEA, 1997) are reported on in this chapter of the National Communications. This shortcoming is due to the following:

Sub-category B: fugitive emissions from fuels of category 1: energy is also not reported. Estimation of fugitive emissions could not be conducted because there is no fuel produced in Sierra Leone at present. Exploratory activities offshore from the coast of Sierra Leone suggests that primary fuel has been found to exist but oil and gas activities such as extraction and oil refining are not conducted.

The bulk of the emissions from Category 2: Industrial Processes could not be estimated for all in this category save for, cement, lime/limestone. Metal, soda ash, adipic and nitric acid, pulp and paper, ammonia, carbide and glass production do not exist. Asphalt roofing, road paving with asphalt, and concrete plumise stone production are conducted but data is lacking and documentation of halocarbons and sulphur hexafluoride (SF6) from refrigeration assembly, operation and disposal could not be quantified due to inadequate labeling, documentation and age of the equipment that enter the country. Similarly, data on foam products, fire extinguishers, solvents, aerosols and propellants, and equipment containing SF6 are not readily available. Some study is necessary because the equipments are found in most public, commercial facilities and residential properties.

Category 3: solvent and Other Product Use has not been reported on because the methodology for this category is still being developed.

The details of the methodology and data sources are under the respective emission categories below.

**Emissions and removals of Greenhouse Gases in 2000**
**Carbon dioxide**

The total carbon dioxide emission (CO2) for the year 2000 is 574.061Gg $CO_2$. The distribution per major sectors is as follows:

The emissions from energy generation are fairly high in the country, amounting to 529.287Gg of $CO_2$ as Sierra Leone energy generation is based on diesel powered generators. Recently, with the commissioning of the Bumbuna Hydro Electric Power Station, $CO_2$ emission from the energy sector has been fairly reduced at least on a seasonal basis.

The Land Use, Land Use Change and forestry (LULUCF) sector is the least significant source of $CO_2$ emissions up taking 752,748Gg of $CO_2$, followed by the waste sector emitting 11.83. The industrial processes are however marginal amounting to 39.55 Gg of $CO_2$ mostly from cement production.

**Methane**

The total $CH_4$ emissions are 32,312.53 Gg. Agriculture is the most important source of $CH_4$ emissions (86.67%), followed by the LULUCF sector (5.631) and finally the waste sector (11.83).

The other sectors are not sources of $CH_4$ emissions.

**Nitrogen dioxide**

$N_2O$ emissions estimated at 13.91 Gg with 8.54Gg coming almost exclusively from the agricultural sector. The waste sector is also a source of emission (31.29Gg).

**Mitigation of 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.

**Adaptation to Climate Change**

Vulnerability and adaptation assessments were undertaken for the following sectors: agriculture, forestry, water resources, human health, coastal zones and human settlements and tourism.

**Existing & Future Climate in the Sierra Leone**

The annual average rainfall in Sierra Leone is 2746 mm based on data from the National Meteorological Office for1961-1990.

Various models were used to assess future climate change scenarios for Sierra Leone, such as the GCM, HADCM, UKTR, ECHAM. 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.

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 2746 mm which varied from 3659 mm at Bonthe in the south to 2618 mm at Kabala in the North

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.

There is an indication of consistent temperature warming across all seasons and scenarios. The projected 1.5◦-2.0◦ Celsius increase in temperature results in increased evaporation losses, decreased precipitation, and a continuation of rainfall decline.

**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 hydro climatic cycle using the monthly, spatially lumped and one dimensional water balance model, WATBAL.

In Sierra Leone, groundwater supplies most water demands (approximately 80% of production) and represents 84 percent of the country's exploitable water. The country's water sources are associated with major rock formations and their interrelationships. Existing stream flow data from the Sierra Leone Water Resources Authority indicate that several rivers are in deficit, which results in water lock offs and an overall limit in water supply. The Sewa River, Jong, and Mano areas are under stress. It is not clear whether Sierra Leone has enough storage to provide water supplies to adequately meet all demands during periods of below average rainfall. The monitoring of wells need some improvements so that the real trends may be better identified. Additionally, more work need to be done with data collection to make it more relevant to user needs.

However, initial analysis of the Freetown Municipality, indicates that increase in population coupled with increased deforestation, after the war in 2000 increased abstraction from the Guma dam could be the main cause of lower water supplies and not so much as a direct result of less rainfall. Significant issues associated with water resources management and vulnerability and the impacts of climate change are likely to present some pressure.

Proposed Elements of a Water Resources Adaptation Strategy for Sierra Leone

1. 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.
2. 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.
3. Effective monitoring and management of the watershed is considered must crucial as climate change is likely to affect the frequency of floods and draughts. Monitoring systems

will assist in coping with these changes and will be of immense benefit without climate change.

4. Increasing and maintaining investment in hydrological monitoring and water use through a national database. This will result in improved data collection and storage on a national scale.
5. Funding research into adopting a water resources and water supply planning method under climate Change. With appropriate methods in place, consistent regional and national planning can take place under a changing climate.
6. Developing appropriate modelling tools to assist strategic planning of water resources. There is an urgent need to develop a consistent set of appropriate modelling approaches and tools.
7. Investigate shifting focus from ground water to surface water storage for water supply reducing the reliance on vulnerable coastal aquifers, in terms of quality and quantity with the increased use of surface water reservoirs to maintain supplies.

**Agriculture**

Agriculture is the largest sector in the economy of Sierra Leone providing employment for over 65 percent of the labour force, and contributing about 35 to 47 percent of the Gross Domestic Product. Rice is the staple food crop in Sierra Leone, grown mainly by small-scale farmers under rain-fed conditions. The impact of climate change is already felt in the country, in changed rainfall patterns, strong winds, thunderstorms, landslides, heat waves, floods, and seasonal drought. Transporting agricultural produce continues to be a challenge in the country; most of the roads in remote areas are impassable during the rainy season.

The crop specific data required for the assessment of the impacts of climate change on agriculture was obtained from the Sierra Leone Agricultural Research Institute (SLARI).

In assessing the impacts of climate on the crop production sub-sector of agriculture climate change, socio-economic and crop production data and scenarios were input into the DSSAT3 biophysical model to run the simulation of impacts of climate change.

All of the scenarios show increasingly negative trends for net rice exports—though much less so in the case of the pessimistic scenario. All three scenarios show a general increasing trend in the world price for rice. Rice productivity needs to improve to meet domestic consumption demand; increasing production will also benefit farmers, through high world prices.

The scenarios for production and yield of cassava and other roots and tubers show an increase toward 2050, with only a slight increase in the area under cultivation. Net export of cassava and other roots and tubers is shown increasing up to 2030, followed by a decline up to 2050 for all the scenarios.

Groundnut production is shown to increase as a result of expansion in area under production; productivity is shown to decrease, probably due to climate change. Depending on the scenarios, net exports are shown to increase through 2020 and decline thereafter. With decreasing productivity, more area has to be brought under cultivation to meet the demand for groundnut as population increases, while increased land degradation forces farmers to use expensive inputs.

The following specific adaptation measures regarding agricultural policy measures are strongly urged to implement in order to mitigate the impact of current and future climate challenges:

- Support the establishment of adequate weather stations around the country in order to provide reliable and adequate weather data that will be useful to properly inform farmers.
- Provide adequate support to the Sierra Leone Agricultural Research Institute as well as Njala University to develop appropriate crop varieties and production practices that will enhance resilience to adverse weather conditions
- Develop and maintain seed banks to provide a variety of seed types that preserve biological diversity and enable farmers to make informed choices.
- Promote innovative and adaptive approaches such as irrigation and water harvesting, to protect farmers from variability in rainfall.
- Make provision for the construction of appropriate roads particularly feeder roads in the rural areas to be able to withstand increasing rainfall.
- Take appropriate measures to control rapid increase in population as well as providing appropriate infrastructure, social services and mechanization of agriculture in the rural areas to slow down massive movements of youths into urban areas.
- Raise awareness of the potential impact of climate change on the agricultural sector. Climate Change is not mentioned in the Agricultural Development Strategy 2005-2008.
- Develop modeling approaches and tools to allow assessment of impacts of climate change on export and domestic crops and meat production. Detailed crop/country/climate specific assessments are required to inform an adaptation programme and policy development.
- Develop regional links to fund and promote plant breeding programmes for common crops.
- Adaptation strategies include the development of crop varieties with increased temperature, drought and pest resistance.
- Review approaches to integrated pest management under climate change. Existing pest management strategies may require modification under climate change. Care must be taken that any changes to these strategies do not have negative impacts on the environment, for example, from increased pesticide use.

**Human Health**

Increased temperatures are also associated with increased episodes of diarrhoeal diseases, sea food poisoning, and increases in dangerous pollutants. Threats from higher temperatures may cause greater contact between food and pest species. Warmer seas contribute to toxic algae bloom and increased cases of human shell-fish and reef-fish poisoning. Such cases have been reported in Freetown in july-August 2011 and August 2012. Incidents of high temperature morbidity and mortality are projected to increase.

Due to water shortages, the impact expected on Sierra Leone would be loss of food production and the necessity to import and/or experience food shortages. This may lead to hunger and malnutrition. The leading causes of death in Sierra Leone are non-communicable diseases – respiratory and lifestyle diseases. Cerebrovascular (stroke) that is susceptible to heat stress is among the leading causes of deaths. The problem could be exacerbated by the design and type of construction

materials used in housing. Attention must be given to the design of buildings in order to reduce heat stress.

Asthma is active among young children and this is an increasing cause for concern. There is ongoing study to determine the actual incidence of asthma. There are also two climate related factors that are causing concern. The first is the fact that rising carbon dioxide levels could increase allergenic plant pollen. The second is the correlation between the outbreak of asthma affecting children and the concentration of the Saharan dust in Sahel Africa that could lead to increase of asthma. The water and sanitation sectors of the population are dependent on water. Sources that are contaminated have implications in the spread of diseases. Typhoid was associated with and the destruction of pit latrines.

Epidemiological surveillance including entomological surveillance behaviours that promoted proliferation of rival habitats and the promotion of behavioural change are considered priorities. If the health system is efficient the country can adapt.

Proposed Elements of a Health Adaptation Strategy for Sierra Leone Climate change must also be mainstreamed into the health system to recognise the likely impact of vector-borne diseases. Under-financing is a major problem that can affected staff training and the ability to conduct surveillance.

Climate change should be included in the mandate of the Disaster Management Department, ONS since extremes in climate change can lead to greater incidences of flooding. Other adaptation strategies included the proper identification and upgrading of shelters to meet the demands for the outbreaks of diarrhoeal diseases and other unhygienic conditions that may be worsened.

Short-term adaptation strategies for addressing vector-borne diseases include:

- Public education aimed at encouraging individuals to identify and eliminate current breeding sites and the symptoms of dengue;
- Surveillance in outbreak communities for the purpose of environmental sanitisation;

Overall recommendations for the health sector include:

- Public education in the management of stress;
- Elimination of taxes on electric fans;
- Increased public education in the areas of sanitation and food poisoning;
- Relevant agencies prepared for handling increases in the incidents of food poisoning;
- Public health inspections for mosquitoes, including pest and rodent eradication;
- Sustainable design standards for housing in areas subjected to high rainfall and strong winds, for example, roofs can reduce heat absorption by painting them white or silver; windows need cross ventilation; and more attention to be paid to the design of settlements.

Priority should be given to:

- Better water monitoring and management through improvements at the National Water Resources Authority;
- Improving the capabilities of DMD to warn of hazards;
- Improving data gathering ability and technical support staff of the Meteorological Office for monitoring and warning of air-borne type diseases;
- More collaboration between research institutions involved in pollution control;
- Support should be given to research institutions involved in environmental related health risks to run as many regional and statistical downscaling models as possible for calibration and inter-comparison purposes; the

- Safe water storage containers;

**Coastal Resources and Human Settlements and Tourism**

The most important measure for adapting to sea-level rise involves a development of setback guidelines. This could be related to the local risk of inundation from present and future storm events (i.e., site specific). Setbacks for structures on rocky coasts where there is storm-deposited debris should be determined by the position of the debris ridge formed by sandy and rocky debris accumulated over the past four millennia. Destroying this ridge for construction materials exposes communities and buildings behind the ridge to increased vulnerability from inundation and damage from moving debris.

The vulnerability of communities such as Kroobay, Moa wharf to extreme weather events and the susceptibility of escape roads to flooding require a major effort to re-engineer other arterial roads at low elevation as all-weather highways.

If the tourist industry is to survive through 2050, despite sea-level rise, increased ocean acidity and sea-surface temperatures, then identification of suitable offshore sand deposits should commence now to avoid the growth of unregulated sand replenishment schemes.

Continuing research is required on perfecting setback guidelines for Integrated Coastal Zone Management; identification of offshore carbonate sand deposits for beach nourishment; expansion of the programme of co-operative for fisher-folks; and satellite-based monitoring of changes in the health of the island's coastal ecosystems.

**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 has 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 and 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

Although it is generally agreed that the incidence of severe weather, there is controversy over the likelihood of a general increase in storm frequency. Thus, it was assumed that there would be no increase in storm frequency or severity over the rest of the century.

The impacts of these processes on the various kinds of coastline of Sierra Leone were assessed. On beaches, short term erosion are largely governed by the incidence of storms. Over longer periods, sea level rise will cause progressive retreat. Hard engineered structures such as sea-walls will probably lead to eventual disappearance of any beaches in front of them. Offshore breakwaters will be more useful in retaining near-shore sand supplies. On cliffs and rocky coasts, sea-level rise will bring the cliff top closer to sea-level and increase the frequency of overtopping of the cliff by storm waves and rock debris, including large boulders. Recession will be greatest for soft-rock cliffs, whereas fractured hard rock cliffs will be more prone to sudden collapse, as indicated in the in the Sierra Leonean examples.

Wetlands present a particular problem due to their proximity to sea-level and the micro-tidal regime around Sierra Leone. Small changes in sea-level will prompt progressive retreat and migration of wetland eco-zones, unless vertical accumulation rates of wetland debris keep up with sea-level rise. Most of the wetlands of the coast of Sierra Leone are fronted by a narrow beach which will retreat over the wetland, driven by storms and sea level rise. No data on the vertical accumulation rate of wetland sediments is available for Sierra Leone.

These impacts are likely to be exacerbated, and even overshadowed, by non-climate change factors, such as deforestation, increasing riverine floods from destruction of forest, industrial farming and from poor farming practices, leading to increased near-shore sedimentation and turbidity, increased chemical pollutants from agriculture and industrial wastes, and from increasing coastal population growth

The local tourism is dominated mainly by resort tourism and is location specific. The Freetown coast areas (i.e., Lumley, Tokeh, No. 2 Goderich) are the dominant areas for both stopover and cruise ship visitors. This is due to the coastal resources (white sand beaches, all inclusive hotels and sea ports and attractions) and infrastructural investments which have gone into these areas.

Two socio-economic scenarios were modelled; one without climate change variables (control scenario) and another with assumptions about a changed climate change. An independent model was also developed to examine visitor arrivals over time.

For the control scenario, visitor arrivals are expected to increase by 2050. For the scenario with a changing climate, the number of visitors may fall by 2050, resulting in declines in earnings.

Proposed Elements of a Tourism Adaptation Strategy for Sierra Leone

1. Raise stakeholder awareness of the workings of both tourism and environment;
2. Stakeholder identification of detailed programme and projects;
3. Set up a comprehensive performance framework with targets;
4. Provide more varied visitor attractions to a) put less pressure on existing natural resources and b) Stimulate more visitors;
5. Reflect social and environmental costs in the price of tourism products;
6. Improve environmental lobbying;
7. Implement infrastructural changes to protect the environment, e.g., groynes and levees, reforestation, and coastal zone management;
8. Implement education and sensitization programmes;
9. Intensify community tourism activities; and
10. Increase urban tourism.

**Coastal Resources and Human Settlements and Tourism**

The most important measure for adapting to sea-level rise involves a development of setback guidelines. This could be related to the local risk of inundation from present and future storm events (i.e., site specific). Setbacks for structures on rocky coasts where there is storm-deposited debris should be determined by the position of the debris ridge formed by sandy and rocky debris accumulated over the past four millennia. Destroying this ridge for construction materials exposes communities and buildings behind the ridge to increased vulnerability from inundation and damage from moving debris.

The vulnerability of communities such as Kroobay, Moa wharf to extreme weather events and the susceptibility of escape roads to flooding require a major effort to re-engineer other arterial roads at low elevation as all-weather highways.

If the tourist industry is to survive through 2050, despite sea-level rise, increased ocean acidity and sea-surface temperatures, then identification of suitable offshore sand deposits should commence now to avoid the growth of unregulated sand replenishment schemes.

Continuing research is required on perfecting setback guidelines for Integrated Coastal Zone Management; identification of offshore carbonate sand deposits for beach nourishment; expansion of the programme of co-operative for fisher-folks; and satellite-based monitoring of changes in the health of the island's coastal ecosystems.

**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: -

(3) The rise in sea levels expected from Climate Change would accelerate the rate of recession of sandy shores.
(4) 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 has 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 and 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

Although it is generally agreed that the incidence of severe weather, there is controversy over the likelihood of a general increase in storm frequency. Thus, it was assumed that there would be no increase in storm frequency or severity over the rest of the century.

The impacts of these processes on the various kinds of coastline of Sierra Leone were assessed. On beaches, short term erosion are largely governed by the incidence of storms. Over longer periods, sea level rise will cause progressive retreat. Hard engineered structures such as sea-walls will probably lead to eventual disappearance of any beaches in front of them. Offshore breakwaters will be more useful in retaining near-shore sand supplies. On cliffs and rocky coasts, sea-level rise will bring the cliff top closer to sea-level and increase the frequency of overtopping of the cliff by storm waves and rock debris, including large boulders. Recession will be greatest for soft-rock cliffs, whereas fractured hard rock cliffs will be more prone to sudden collapse, as indicated in the in the Sierra Leonean examples.

Wetlands present a particular problem due to their proximity to sea-level and the micro-tidal regime around Sierra Leone. Small changes in sea-level will prompt progressive retreat and migration of wetland eco-zones, unless vertical accumulation rates of wetland debris keep up with sea-level rise. Most of the wetlands of the coast of Sierra Leone are fronted by a narrow beach which will retreat over the wetland, driven by storms and sea level rise. No data on the vertical accumulation rate of wetland sediments is available for Sierra Leone.

These impacts are likely to be exacerbated, and even overshadowed, by non-climate change factors, such as deforestation, increasing riverine floods from destruction of forest, industrial farming and from poor farming practices, leading to increased near-shore sedimentation and turbidity, increased chemical pollutants from agriculture and industrial wastes, and from increasing coastal population growth

The local tourism is dominated mainly by resort tourism and is location specific. The Freetown coast areas (i.e., Lumley, Tokeh, No. 2 Goderich) are the dominant areas for both stopover and cruise ship visitors. This is due to the coastal resources (white sand beaches, all inclusive hotels and sea ports and attractions) and infrastructural investments which have gone into these areas.

Two socio-economic scenarios were modelled; one without climate change variables (control scenario) and another with assumptions about a changed climate change. An independent model was also developed to examine visitor arrivals over time.

For the control scenario, visitor arrivals are expected to increase by 2050. For the scenario with a changing climate, the number of visitors may fall by 2050, resulting in declines in earnings.

Proposed Elements of a Tourism Adaptation Strategy for Sierra Leone

1. Raise stakeholder awareness of the workings of both tourism and environment;
2. Stakeholder identification of detailed programme and projects;
3. Set up a comprehensive performance framework with targets;
4. Provide more varied visitor attractions to a) put less pressure on existing natural resources and b) Stimulate more visitors;
5. Reflect social and environmental costs in the price of tourism products;
6. Improve environmental lobbying;
7. Implement infrastructural changes to protect the environment, e.g., groynes and levees, reforestation, and coastal zone management;
8. Implement education and sensitisation programmes;
9. Intensify community tourism activities; and
10. Increase urban tourism.

**Impacts of Climate Change on Fisheries**

In assessing the impacts of climate change on 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 fish is under threat of either over exploration or adverse effects 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 450$M^2$/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.

**Climate change research and systematic observation systems in Sierra Leone**

Under the INC and NAPA projects, an initial assessment of Sierra Leone's systematic observation systems was conducted in conjunction with the national Meteorological Office. This assessment

comprised of interviews with key personnel, as well as visits to a number of locations where systematic observation systems are located.

The assessment focused on the needs and the requirements of the Meteorological Services, with a view to making recommendations for the improvement of the observation systems. More specifically, the following elements were carried out:

(i) A detailed assessment of the coastal, marine, and hydro meteorological systematic observation systems in Sierra Leone, describing: the types and locations of the equipment; the agencies responsible for the maintenance of the equipment; the scope of climate related data stored, including climate variables observed; the years for which data is available and frequency of data collection.
(ii) An assessment of the current coastal, marine, and hydro meteorological systematic observations systems in Sierra Leone.
(iii) An identification of the technological and capacity building requirements for the upgrade and improvements of the current systematic observation systems.

In order to achieve the goals and targets of the International Community on Research and systematic Observations, efforts should be made to address these issues of Research and Observations. 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 with a view to attracting qualified personnel into the service.

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

- 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.
- Providing 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 national and international institutions that are in the field of research in climate change.

**Technology Needs Assessment**

The technology needs assessment process consisted of a series of expert workshops with key sectoral experts present to discuss issues relating to technology in Sierra Leone. The first workshop focused on mitigation and energy issues, while the second workshop looked at adaptation issues as they relate to the coastal zone and water sectors in Sierra Leone. Both workshops used the initial national communication of Sierra Leone as the document of reference.

A number of issues were considered with regards to criteria for the transfer and development of technologies for mitigation for Sierra Leone. These included the overall integration with the current energy policy, and the linkage to development goals. In order for a technology to be suitable for Sierra Leone, it was agreed there a number of key criteria which have to be met. These are:

(i) Affordability and low cost,
(ii) Environmental and economic impact,
(iii) Social acceptability, and
(iv) Job creation potential.

A number of mitigation technology options were identified:

- Natural gas technology for electricity production, especially for the bauxite alumina industries;
- Methane extraction from waste landfills for electricity production;
- Renewable energy technologies including wind, small-scale hydro, cogeneration and biomass, Solar.

Adaptation technologies were considered for the coastal zone and water resources sectors. A number of issues were considered when criteria for the transfer and development of technologies for adaptation were considered. Stakeholder consultations and expert judgment were used to determine the criteria. It was noted that technologies for adaptation should be: cost effective, proven, flexible, aid in vulnerability reduction, and easy to use. Technologies for adaptation should also look at technologies in the broadest sense.

For improving coastal zone management, the following technologies were identified:

- Beach protection measures such as groynes and revetments;
- Reinstatement of the tidal gauge network (for obtaining data to feed into the geographic information system and aid in planning and project designs, thus ensuring vulnerability reduction occurs;
- Beach profiling (to aid improved data collection); and
- Regeneration of mangroves.

In the water sector, the following needs were noted:

- Improvement and rationalization of the hydrometric network;
- Additional river gauges and more automatic weather stations to aid in data collection and planning to reduce vulnerability;
- Additional flood warning systems; and
- Additional software such as water ware, river ware, and mike basin to aid in improvement of water management.

The main barrier to the transfer of technology to Sierra Leone is the high initial capital cost of technologies. There is a need for flexible financial measures in order for new technologies to be adopted. Attitudes, perceptions, and lack of information were also highlighted as a key barrier. In particular, lack of understanding about specific technologies and lack of political will prevent the transfer and adoption of potential technologies. Lack of data is a constraint, particularly with regards to vulnerability issues which prevents adoption and applications of technologies for adaptation. The lack of a central decision making entity to handle issues with regards to technology was also noted as a barrier.

**Education, Training and Public Awareness**

A number of baseline studies were conducted to obtain a better understanding of the level of education and understanding about climate change in sierra leone . A number of activities were undertaken, including:

(i) A project launch workshop. The objectives of this workshop were to: 1) aid in reconvening the National Implementation Coordinating Unit for climate change in Sierra Leone and 2) launch phase two by informing participants about climate change, regional concerns, climate change scenarios, and alternative energy options for Sierra Leone.

(ii) A Climate Change Workshops. Participants were sensitised on international issues related to climate change, particularly the Conference of Parties of the UNFCCC and the effect that climate change could have on energy, water resources, coastal resources and biodiversity.

Overall, the activities aided in facilitating national networks on climate change and promoting the integration of climate change concerns into the national development planning dialogue.

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

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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 GOSL/GEF/UNDP-00055945 entitled "Second National Communications to the United Nations Framework Convention on Climate Change (UNFCCC)", was established in January 2010 with the objective of building Institutional and Technical capacities in the country and to prepare the Second National Communications for the country.

In order to successfully implement the project, four (4) Technical expert teams were established, i.e. GHG Inventory, Mitigation and Vulnerability and Adaptation Analysis Study teams and a team to handle cross cutting issues. Implementation started with the GHG programme followed by the other three components.

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 Office in the Meteorological Department, Ministry of Transport and Aviation 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 this report.

My sincere gratitude also goes to the National Communications Support Programme of GEF/UNDP /UNEP in New York for reviewing the chapters of the Second National Communications.

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. Keith Wright, Ms. Mariatu Swaray and Mr. Helal Huddin 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. Libasse Bah, International Consultant from Senegal (ENDA), Professor Ogunlade Robert Davidson Local Consultant and Chairman of the writing team which prepared the SNC report, the reviewers (local and international) of the various sectors of the report, and all members of the Climate Change Project Office (CCPO)

Prepared by

Dr. Reynold G. Johnson
Project Coordinator

## ACRONYMS AND ABBREVIATIONS USED IN SNC REPORT

| | | |
|---|---|---|
| AML | - | Abandonment of Managed Lands |
| CCP | - | Climate Change Project |
| $CO_2$ | - | Carbon Dioxide |
| COP | - | Country of Parties |
| CEF | - | Carbon Emission Factors |
| CFC | - | Chloro Fluorocarbon |
| CFWB | - | Change in Forest and other Woody Biomass |
| $CH_4$ | - | Methane |
| CMB | - | Coastal Management Board |
| CO | - | Carbon Monoxide |
| COP | - | Conference of Parties |
| EF | - | Emission Factor |
| EI | - | Energy Industries |
| EJ | - | Exajoule |
| EPA-SL | - | Environment Protection Agency – Sierra Leone |
| FAO | - | Food and Agricultural Organization |
| FGC | - | Conversion of Forest Grassland (Forest and Grasslands Conversion) |
| GDP | - | Gross Domestic Product |
| GEF | - | Global Environmental Facility |
| Gg | - | Gigagrams |
| GHG | - | Greenhouse Gas |
| $H_2O$ | - | Water Vapour |
| HCFC | - | Hydro-Chlorofluorocarbon |
| HFO | - | Heavy Energy Oil |
| IPCC | - | Intergovernmental Panel on Climate Change |
| LUCUCF | - | Landuse, Landuse Change and Forestry |
| MAFFS | - | Ministry of Agriculture, Forestry and Food Security |
| MCI | - | Manufacturing and Construction Industries |
| MM | - | Millimeters |
| MTA | - | Ministry of Transport and Aviation |
| MT | - | Million Tonnes |
| 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 |
| NCSP | - | National Communications Support Programme |
| $O_3$ | - | Ozone |
| OECD | - | Organization for Economic Cooperation and Development |
| SNC | - | Second National Communications |
| S&T | - | Science and Technology |
| SSL | - | Statistics Sierra Leone |
| $SO_2$ | - | Sulphur Dioxide |
| $SF_6$ | - | Sulphur Hflexafloride |
| SWDS | - | Solid Wastes Disposal Sites |
| UNDP | - | United Nations Development Programme |
| UNEP | - | United Nations Environmental Programme |

| | | |
|---|---|---|
| UNFCCC | - | United Nations Framework Convention on Climate Change |
| VMT | - | Vehicle Miles Traveled |

## Background

### General Development Context

After the resolution of a brutal armed conflict that lasted for just over ten years (March 1991-January 2002), Sierra Leone has been enjoying a period of relative peace and bliss. This peace has been consolidated by the two general elections of 2002 and 2007, which ushered in two democratically elected governments. Since Sierra Leone's civil conflict officially ended in 2002, the country has moved consistently towards restoring national security and good governance; re-launching the economy; and providing basic services to the most vulnerable groups. A National Recovery Strategy in 2002, was followed by a long term sustainable development plan; "Sierra Leone Vision 2025" and Sierra Leone's first Poverty Reduction Strategy Paper for the period 2005 - 2007 (PRSP 1)[1] PRSP [1] reflected a move away from immediate post-conflict concerns and was constructed around three pillars of good governance, peace and security; food security and job creation; and growth and human development. PRSP 11, An Agenda for Change; Social and Economic Empowerment 2008-2012, emphasizes the need to develop an enabling environment to support the private and productive sectors of the economy and identifies four key enablers and drivers of growth. These include energy supply; agriculture (including fisheries); a national transportation network; and sustainable human development.

The post war years has seen rapid rehabilitation of war damaged infrastructure and vibrant civil society movements and a revived economy. The development of Sierra Leone is also been enhanced by certain government policies such as decentralization, health care, free health care for pregnant and lactating women, energy, mining, and agriculture. The implementation strategy in these policies is ensuring steady growth in the economy. The agenda for change launched by the Government of Sierra Leone is the new development paradigm which Sierra Leone is now operating which is designed to bring about both social and economic transformation of the country. Together with the joint vision document the development trends of Sierra Leone are clearly mapped out. Recently the United Nations dropped the last sanction against Sierra Leone and declaring Sierra Leone a safe and stable country, thus paving the way for investment in the country.

The civil war in the 1990s hampered the economy 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 base year suggested for this Second National Communications, the economy has been growing between 5.8 and 6.8% per annum, mainly due to reconstruction and more prudent economic policies.

In July 2008 and in accordance with the Rio commitment, Sierra Leone established the National Environmental Protection Agency. This Agency, which is under the supervision of the President's Office, is implementing the National Environmental Action Plan for sustainable Development (NEAP) which is made up of priority programs, including one related to climate change.

The implementation of this National Environmental Action Plan is coordinated by Environment Protection Agency-SL and serves as a framework for all policies related to environment and sustainable development Recently EPA-SL has embarked on an exercise to upgrade the NEAP.

Sierra Leone prepared its Initial National Communication (INC) with the support of SIL/02/G32 "Climate Change" funded by the Global Environment Facility (GEF) implemented by the Department of Meteorology under the Ministry of Transport and Communications. (now Ministry of Transport and Aviation).

A self-assessment of the Initial National Communication revealed that there was little involvement of stakeholders with relevant data. As a result, the development process for the SNC considered the involvement of a mix of stakeholders for the various components of the project

Following the publication of its Initial Communication, Sierra Leone carried out a certain number of activities including:

- Organization of several workshops for information sharing and awareness raising on climate change;
- Publication of articles in newspapers on climate change;
- Organization of several training workshops on Clean Development Mechanism (CDM) for Government entities, the Civil Society, NGOs and the Private Sector. These sessions made it possible to identify project ideas;
- Development of a National Adaptation Program of Action (NAPA) for Climate Change to help mitigate the adverse effects of Climate Change on the most vulnerable population with a view to promote sustainable development and fight against poverty in Sierra Leone;
- Implementation of the "Self-assessment of the Initial National Communication Project " which was aimed at identifying the shortcomings and weaknesses of the communication and making suggestions for improving the Second National Communication;
- Development and implementation of the National Self-assessment of Capacity Building Needs for managing global environment. The objective of this project was to assess the needs for capacity building and come up with a strategy and a plan of action to implement capacity building activities in connection with Conventions on Desertification Control, Biodiversity and Climate Change.

The content of this Second National Communication is defined by the provisions of Decision 17/COP'8 related to the preparation of the National Communication of countries that are not members of annex 1 of the Convention.

The Second National Communication (SNC) is being prepared with the support of GOSL/GEF/UNDP-00055945 "Climate Change" funded by the Global Environment Facility (GEF) implemented by the Department of Meteorology under the Ministry of Transport and Aviation.

**The SNC preparation Process/Institutional Arrangements**

At the national level, project sponsorship and coordination involve institutional arrangement ensuring the integration of the project at policy level and an operational structure to implement specific project activities.

**The National Implementing Organization**

The project is being executed through national Execution (NEX) modality with the different roles undertaken by the following institutions:

- Overall supervision on financial management – UNDP, Freetown
- Policymaking – Project Steering Committee
- Project Implementation – Meteorological Department, Ministry of Transport and Aviation (MTA)

**Sponsorship/ Coordination and integration of the project at policy level**

At policy level, the Institutional Framework offered by the following three sponsorship/Coordination entities will Endeavour to facilitate the integration of the SNC in to national development policies:

- The United Nations Development Programme (UNDP)
- Environnent Protection Agency- Sierra Leone (EPA-SL)
- The Meteorological Department, Ministry of Transport and Aviation (MTA).

**EPA-SL**

In 2008 in trying to address the growing national environmental problems and the weak management capacity in the various institutions, a decision was taken by the government to create an agency. The creation involved deployment of staff and changes in the legal and institutional reforms which impact on the management of all environmental and related concerns.

EPA-SL will accomplish general coordination and will ensure proper linkages and collaboration among the various public and private institution involved in the SNC preparation. As the Agency is the GEF operational focal point and recipient of all reports and project conclusions, EPA-SL will be in a position to effectively integrate the SNC into national development priorities as well as facilitate access of SNC technical teams to data-holding national institutions.

**Global Environment Facility (GEF) Focal Point**

EPASL- is the operational Focal Point for all GEF activities. The agency chairs the Project Steering Committee (PSC) and the PSC keeps the board abreast of project progress, and is instrumental in making the board understand the full scope of adaptation issues, thus mainstreaming the SNC into national development policies.

**The Basic Country Driven SNC Preparatory steps**

The conceptual framework of SNC project design is dominated by national stakeholder/participants at all levels. The various levels of the national institutional framework, used to conceptualize the process are as follows:

**SNC Task Force (TF):**

The SNC local consultants comprised of professionals from academia, research institutions the public, private and NGOs in Sierra Leone. The TF serves as the technical arm of the SNC process. For example, the TF carried out criteria development, and scoring and ranking of options for the SNC priority activities.

SNC Local Consultants were involved in the project development. The local consultants conceptualized and wrote the SNC document with the advice and consultation of local, sub-

national, national and international primary and secondary stakeholders, including UNDP/ UNEP task managers.

**National Stakeholders:**

The stakeholders in the SNC included key institutions from the whole country including those at the local level.

**The UNDP/UNEP National Communications Support Programme**

The National Communications Support Programme (NCSP) is a NDP/UNEP project, funded by the GEF, which provides technical and policy support to non-Annex I Parties for the preparation of national communications. The NCSP is based at the UNDP office in New York. The governments of Switzerland and the USA have co-financed NCSP activities. The NCSP also promoted the quality and comprehensiveness of the Second National Communication and the timeliness of their submission.

**Results of Nation-wide Consultations**

The second national communications (SNC) was informed by a series of nation-wide consultations in which all MDAs, CSOs parliamentarians; CBOs & NGOs, civil society and media were given the opportunity to make inputs. It was also supported by site based impact, vulnerability and adaptation studies result of which were incorporated into the SNC. The approach used in developing the SNC was through studies by various taskforces (a mix of individual consultants and MOUs between the project and data holding institutions like the Meteorological Department, SLARI and IMBO and the University for the Various Sectors identified in the Self Assessment Exercise (SAE). The results of the task forces and stakeholders consultation for the various components of the study are summarised below.

**Energy**

In the energy sector the need for a fair, equitable, sustainable supply and distribution of electricity for development was emphasized. However there was the overriding view that a shift from thermal power generation to cleaner modes would be welcomed, for example solar, hydro, ion-diesel, biogas, LPGs etc.

**Transportation**

Apart from electricity generation in the energy sector, transportation was considered to be the sector where energy products were mostly consumed. It was noted though transportation is a major challenge to the development of agriculture, yet still, emission control mechanisms should be put in place for vehicles of all types. It was thought that the emissions related to the improvement of road networks were temporal and diminished with time. The improvement of bulk public transport system (buses, rail) etc. were highlighted as mitigation measures.

**Agriculture**

In all agriculture was identified as the number one livelihood of the bulk of Sierra Leoneans. It was therefore suggested that a balance should be struck between agricultural development and emissions control from this sector through climate friendly agricultural practices. This sector was also identified to be most vulnerable to climate change, therefore government should endeavour to

ensure proper early warning system for farmers and timely input of agricultural materials to farmers to in order to increase the adaptive capacity to climate change

**Land Use and Land Cover Change**

Rapid urbanization, agriculture, developments of the mining sector and timber production were considered to be the major drivers of deforestation. The need for conservation practices to maintain carbon sinks therefore were underscored.

**Report Structure**

Chapter one of these documents sets the national circumstances, and in particular the aspects of development policies related to the major components of Climate Change Process with emphasis on the year 2000.

Then, chapter two is devoted to greenhouse gases inventories, in accordance with the methodology recommended by the Convention Secretariat and the IPCC. This inventory is complemented by tables providing details on calculations carried out.

Chapter three focuses on the capacity for mitigating the effects of greenhouse gas emissions. This capacity is related to social and economic development policies of the country.

Chapter four deals with Vulnerability and Adaptation to Climate Change and variability which requires external assistance.

Chapter five focuses on other Information considered Relevant to the Achievement of the Objective of the Convention.

Finally, chapter six deals with constraints and gaps and related financial, technical and capacity needs.

## Foreword

### By Honourable Samuel Sam-Soumana 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 Second National Communications (SNC) Report of Sierra Leone to the United Framework Convention of Climate Change (UNFCCC)

This report on the Second National Communications of Sierra Leone was prepared by Greenhouse Gas Inventory, Mitigation and Vulnerability Analysis teams in collaboration with Secretariat of the CCP and the UNDP and NCSP. 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 a climate change strategy for Sierra Leone.

The groups were ably assisted by Mr. Libasse Bah the International Consultant, of the Republic of Senegal 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 by a chapter by chapter review by the NCSP of GEF in New York and some of their comments are contained therein. Special thanks go to Gabriela Walker and Yamil Bunduki of UNDP, New York and of the National Communication Support Progamme, for coordinating and personally reviewing some chapters of the documents.

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 implementation.

With the preparation of this report Sierra Leone will be in the position to consolidate the establishment of a National Climate Change Secretariat responsible for climate Change activities locally and internationally.

# CHAPTER ONE
# NATIONAL CIRCUMSTANCES

## 1.1 GEOGRAPHY, CLIMATE AND DEMOGRAPHY

### 1.1.1 Location of Sierra Leone:

Sierra Leone is located in the southern-western part of West Africa and lies between latitudes 7(6degree 55minute) and 10 (10degree 00minute) degrees North of the equator and longitude 10(10degree 14minute) and 13(13degree 17minute) degrees West of the Greenwich Meridian. The country has a surface area of about 72,325 square kilometers and 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. The country has a population of 4,976,871 based on the 2004 National Census and is growing at 2.5% per annum. Approximately 80-90 % of the population is in the rural areas. (Fig.1.1).


**Figure1.1: Map of Sierra Leone**

### 1.1.2 Climate

Sierra Leone has a wet tropical climate, marked by distinct wet and dry seasons. The wet or rainy season is from May to October and the dry season from November to April. Both seasons may have some variations in their commencement and duration. The wet season is dominated by the southwest tropical maritime monsoon which is a mass of moisture-laden air that originates over the south-Atlantic ocean. The dry season is dominated by the hot dusty air of the Harmattan trade winds.

The mean annual rainfall over the country is about 3000mm and 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.

The temperatures are consistently high throughout the country, roughly averaging about 28 degree centigrade. The humidity, like the temperature is usually high as a result of the heavy rains coupled with high temperature and 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.

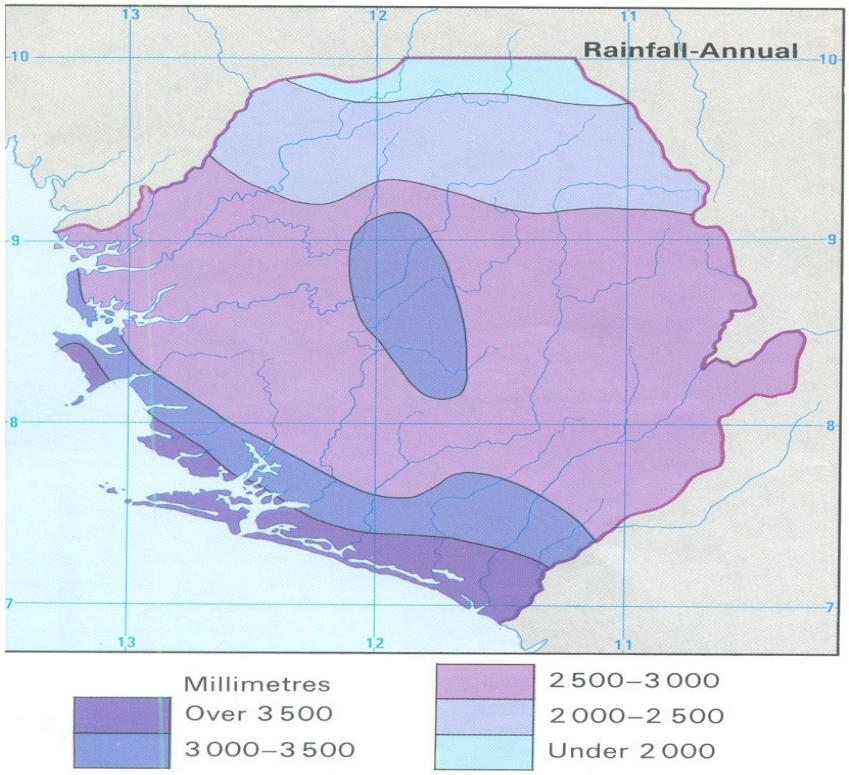



**Figure 1.2: Annual rainfall in Sierra Leone**

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.

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 Relief

The country is divided into four main physical regions, namely coastal plains, interior lowland plains, interior plateau, and hills and mountains (See Table One below).

The coastline or coastal plains is relatively gentle and comprised of estuarine swamps subject to

tidal flooding; coastal terraces; alluvial plains are subject to freshwater flooding during the rainy season. Beach ridges, fringe the alluvial plains on the seaward side (Allan 1990).

The interior lowland plains, the largest of the four physical regions extend from the coastal terraces in the west to the east of Sierra Leone, occupying approximately 43% of the total land area. They rise gently from the coastal terraces to elevations of 200m in the east, where they are separated from the plateaux by distinct escarpments.

At the edge of the lowland plains are the interior plateaux, which covers 22% of the total land area and made up of granite that run from the northeast of the country to the southeast. The plateau region seldom rises above 700m and is comprised of alluvial ironstone gravel in the southeastern region, while the northern end is comprised of weathered outcrops of granitic rocks. The eastern and southern parts comprise dissected hills. In the north and east of the country are found two of the highest mountains, with the Loma Mountains being the highest in West Africa, west of Mount Cameroon. The highest peak on the Loma Mountains is Bintumani, which rises to 1945m while Sankan Biriwa on the Tingi Hills, rises to 1805m. **118/119 USAID biodiversity report for Sierra Leone.**

The Freetown peninsula is made up of dissected mountainous Peaks with Sugar Loaf and Picket Hills being the highest.

West of the plateau region and interior lowlands, is the Freetown Peninsula, which is also made up of dissected peaks, with the two highest peaks being sugar Loaf and Picket Hills. The hills on the Freetown Peninsula are unique to this region, and found nowhere else in the sub-region. The rocks are resistant to erosion, resulting in dissected ridges of moderate to high relief. The high content of iron and aluminium results in the formation of laterites, either as a surface crust or as densely packed ironstone gravel.

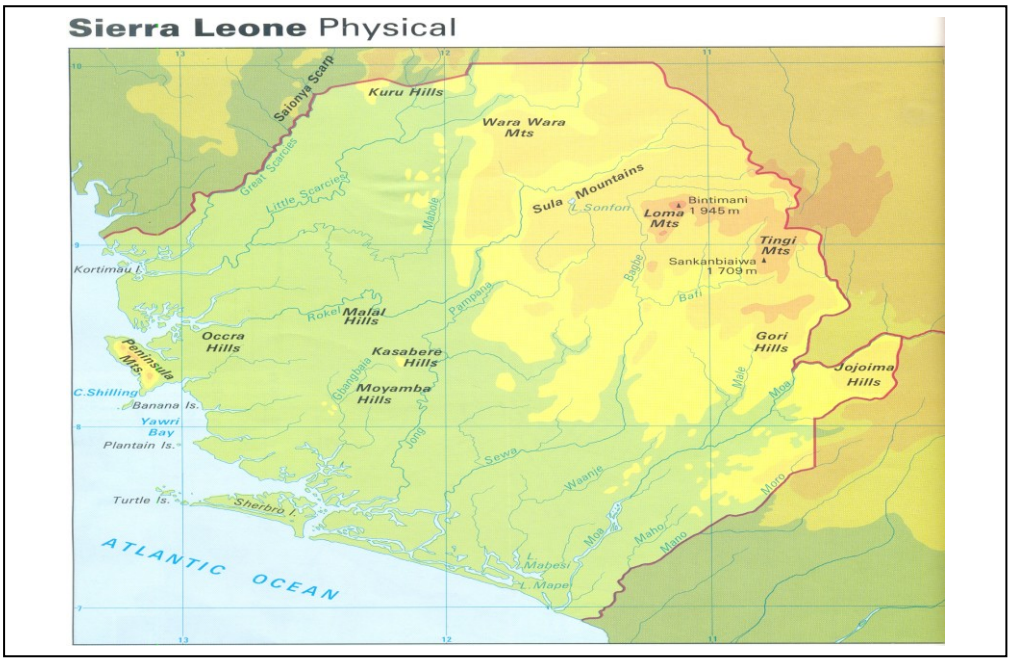



**Figure 1.3: Physical regions of Sierra Leone**

### 1.1.4 Water

The drainage system consists of a series of rivers that run from North to south including the Great Scarcies, Little Scarcies, Rokel, Jong, Sewa, Moa and Mano rivers

### 1.1.5 Population & Demography

In 2004, Serra Leone's population was estimated at 4,976,871 inhabitants living mostly in rural areas (%). This population derives most of its income from natural resources.

The population growth rate was 1.5% in 2004. Fertility index, representing the average number of children per woman (15 – 49 years old), was 6.1.

According to the trend scenario, based on national statistics, the population will reach 6.2 million inhabitants in 2014. Table 1.1 summarizes the evolution of the population in various districts of Sierra Leone since 1985.

**Table 1.1: Evolution of Sierra Leone Population from 1985 to 2004**

| Region | District | 1985 | | 2004 | |
|---|---|---|---|---|---|
| | | Population | Percent | Population | Percent |
| | Bo | 268671 | 7.6 | 462849 | 9.3 |
| | Bonthe | 105007 | 3.0 | 139352 | 2.8 |
| | Moyamba | 250514 | 7.1 | 263774 | 5.3 |
| South | Pujehun | 117185 | 3.3 | 228936 | 4.6 |
| | Kailahun | 233839 | 6.7 | 358335 | 7.2 |
| | Kenema | 337055 | 9.6 | 497687 | 10.0 |
| East | Kono | 389653 | 11.1 | 338427 | 6.8 |
| | Bombali | 317729 | 9.1 | 408103 | 8.2 |
| | Kambia | 186231 | 5.3 | 268751 | 5.4 |
| | Koinadugu | 183266 | 5.2 | 263774 | 5.3 |
| | Port Loko | 329344 | 9.4 | 452895 | 9.1 |
| North | Tonkolili | 243051 | 6.9 | 348381 | 7.0 |
| | Western Area Rural | 84467 | 2.3 | 174190 | 3.5 |
| West | Western Area Urban | 469776 | 13.4 | 771417 | 15.5 |
| **Sierra Leone** | | **3515812** | **100** | **4976871** | **100** |

#### 1.1.5.1 Population Trends in the major Urban Areas of Sierra Leone

Sierra Leone, like most other countries, has cities whose rates of growth have been remarkable over the years. This growth, however, if not carefully monitored, could become a troubling problem for Sierra Leone's policy makers. The cities monitored during this study are Freetown, Bo, Kenema, Makeni and Koidu-New Sembehun, which constitute Sierra Leone's major urban conglomerations.

The number of years for which these cities may have their populations doubled range from 14 years for Bo and Kenema to 25 years for Freetown and Makeni. This doubling of population in such short a time, could provide a major problem for Sierra Leone's urban planners. The consequences need

not be exaggerated, but, this population explosion would put tremendous pressure on the social services (that is to say, have adverse effects on housing, health, sanitation, water supply and electricity supply, just to mention a few).

It is imperative that Sierra Leone's policy makers begin to plan for this population explosion by building more houses, improve on health care provision and sanitation, and expand both water and electricity supply.

### 1.1.5.2 Population trends in Sierra Leone's major cities

Table 2.1 shows the population trends in Sierra Leone's major cities between 1963 and 2004, as determined by censuses conducted during the corresponding years. The population of Freetown has grown from 127,917 in 1963 to 772,873 in 2004. The percentage change in the population of Freetown between 1985 and 2004 alone was 62.1%. The population of Bo has grown from 26,613 in 1963 to 149,957 in 2004, with a percentage change in population of 150.9% between 1985 and 2004 alone. The population of Kenema has grown from 13,246 in 1963 to 128,402, with a percentage change of population between 1985 and 2004 of 144.7%. With regard to Makeni, the change in population between 1963 and 2004 was from 12,306 to 82,840, with the percentage change in population between 1985 and 2004 being 68.9%. Koidu-New Sembehun, located in Sierra Leone's predominantly diamond mining district Kono, has seen equally significant population shifts. Its population grew from 11,706 in 1963 to 82,899 in 2004. The percentage change in population for Koidu-New Sembehun between 1985 and 2004 is 0.5%, representing the lowest change in population between the major Sierra Leonean cities. The rate of population growth for each of these cities are Freetown (2.86%), Bo(4.96%), Kenema(4.82%), Makeni(2.80%) and Koidu-New-Sembehun(0.027%).

The population of Sierra Leone grew from 2,180,355 in 1963 to 4,976,871 in 2004. The percentage change in population of Sierra Leone between 1985 and 2004 alone was 41.6%, representing an annual rate growth is 2.18%

**Table 1.2 Population trends in the major cities of Sierra Leone**

| City | Population | | | | Percentage Change (1985 – 2004) | Rate of Growth (1985-2004) | Percentage of Total population |
|---|---|---|---|---|---|---|---|
| | 1963 | 1974 | 1985 | 2004 | | | |
| **Freetown** | 127,917 | 276,247 | 476,776 | 772,873 | 62.1% | 0.0286027 | 15.53% |
| **Bo** | 26,613 | 39,371 | 59,768 | 149,957 | 150.9% | 0.0496058 | 3.01% |
| **Kenema** | 13,246 | 31,458 | 52,473 | 128,402 | 144.7% | 0.0482250 | 2.58% |
| **Makeni** | 12,306 | 26,781 | 49,038 | 82,840 | 68.9% | 0.0279798 | 1.66% |
| **Koidu** | 11,706 | 75,846 | 82,474 | 82,899 | 0.5% | 0.0076453* | 1.67% |
| **Sierra Leone** | 2,180,355 | 2,735,159 | 3,515,812 | 4,976,871 | 41.6% | 0.0184594 | 100% |

**** Rate of growth of Koidu was taken between 1974 and 1985.***

Table 2.2 shows the population projections for Sierra Leone's major cities from 2004 to 2014. These projections are based on figures resulting from the 2004 Population and Housing Census. These projections suggest that the population for the major cities by 2014 would be Freetown (1,040,888), Bo (250,960), Kenema (212,130), Makeni (125,518) and Koidu-New Sembehun

(89,459). The Population of Sierra Leone is projected to be 6,348,350 by 2014.

**Table 1.3: Population projections for Sierra Leone's major cities**

| City | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Freetown** | 772,873 | 841,545 | 861,066 | 881,197 | 901,953 | 923,341 | 945,423 | 968,189 | 991,618 | 1,015,829 | 1,040,888 |
| **Bo** | 149,957 | 210,071 | 214,117 | 218,280 | 222,561 | 226,961 | 231,494 | 236,155 | 240,937 | 245,867 | 250,960 |
| **Kenema** | 128,402 | 177,204 | 180,658 | 184,213 | 187,869 | 191,626 | 195,498 | 199,479 | 203,565 | 207,778 | 212,130 |
| **Makeni** | 82,840 | 103,418 | 105,595 | 107,837 | 69,239 | 112,251 | 114,970 | 117,491 | 120,081 | 122,755 | 125,518 |
| **Koidu** | 82,899 | 83,533 | 84,171 | 84,815 | 85,463 | 86,177 | 86,775 | 87,439 | 88,107 | 88,781 | 89,459 |
| **Sierra Leone** | 4,976,871 | 5,094,500 | 5,216,890 | 5,343,200 | 5,473,530 | 5,607,930 | 5,746,800 | 5,890,080 | 6,037,660 | 6,190,280 | 6,348,350 |

The spectacular rate of growth of population in Sierra Leone's major cities is particularly evident from the time taken to double in size taking 2004 as the base year. As projected, Freetown's population would take 24.6 years to double in size, and this would be attained by 2028. Bo's population would take 14.3 years to double in size, attaining this by 2018. Kenema's population would take 14.7 years to double in size, attaining this by 2018. Makeni's population would take 25.1 years to double in size, and this would attained by 2029. Due to the extremely low growth rate for Koidu-New Sembehun (0.76%), it would take 91 years for its population to double, achieving this by 2095. Sierra Leone's population would take 37.9 years to double in size, and this would be achieved by 2044.

One should not fail to notice the relative short time required for Sierra Leone's cities to double in size. With years to doubling in population size of the major cities ranging from 14 years to 25 years, policy makers must begin to put policies in place to address the effects of this population explosion, as already scarce resources would be stretched to unbearable limits. The major social issues that would be significantly affected by this population explosion would be health, sanitation, housing, transportation, water supply and electricity supply. The consequences for failing to plan for this population explosion are catastrophic.

**Table 1.4: Doubling of population of Sierra Leone's major cities**

| City | 1985 | 2004 | Rate of growth | Years to doubling of population | Year in which population doubles |
|---|---|---|---|---|---|
| **Freetown** | 476,776 | 772,873 | 0.0286027 | 24.578572 | 2028 |
| **Bo** | 59,768 | 149,957 | 0.0496058 | 14.316885 | 2018 |
| **Kenema** | 52,473 | 128,402 | 0.048225 | 14.717045 | 2018 |
| | | | | | |
| **Makeni** | 49,038 | 82,840 | 0.0279798 | 25.118108 | 2029 |
| **Koidu** | 82,474 | 82,899 | 0.0076453 | 91.009666 | 2095 |
| **Sierra Leone** | 3,515,812 | 4,976,871 | 0.0184594 | 37.939297 | 2044 |

### 1.1.5.3 Population Dynamics

The population growth rate has been estimated at 2.7% (2009). The population is youthful with more than 40% under 15 years. Other social indicators estimated for 2009 are as follows: Maternal mortality rate (annual average) is estimated at 970/100,000(2009); Infant mortality rate/1000 live births (2009) is 192.3, Life expectancy at birth for men is 53 years and for women is 58 years

## 1.2 Natural Resources

Sierra Leone is endowed with a wide variety of natural resources, including large deposits of minerals, abundant fertile agricultural land, and a deep natural harbour. Poverty in Sierra Leone can only be overcome by harnessing these advantages to create an economic transformation of the nation, while ensuring that the benefits of this growth are shared widely and lead to the betterment of the lives of the people. Mining, tourism and land management are three key areas which have a significant impact on economic growth. In the mining sector we will focus on strengthening the legal and regulatory framework to ensure that returns benefit the population, while in tourism we will focus on improving the public image of Sierra Leone and building the necessary infrastructure. Land management will concentrate on ensuring clear ownership and use of land through the development of land management systems.

### 1.2.1 Land

The physiography was described by Dixey (1925) and Clarke (1966). Extensive land resource survey was also undertaken between 1975 and 1980 and Technical Reports were published. A brief summary of all these characteristics is produced.

#### 1.2.1.1 Arable Land

The total area of Sierra Leone is 72,300km2, of which 74.2 percent is arable or suitable for cultivation of crops on sustainable bases. This is shown in Table 1.

**Table 1.5 Arable (Effective) and Non-Arable Areas by Ecological Zones (Modified from FAO/LRSPTRI 1979)**

| Non-Arable Area | Total Area | % of Total |
|---|---|---|
| Hills and Rockland | 16,330 | **22.6** |
| Lowland Water areas | 1050 | **1.4** |
| Roads and Built up | 900 | **1.2** |
| **Arable Area** | | |
| Arable Uplands | 43020 | **59.5** |
| Arable Lowlands | 10,600 | **14.7** |
| Forest Reserves | 400 | **0.6** |
| **Total** | **72,300** | **100** |

The suitability of the arable lands for farming is controlled by factors such as climate, soils and topography.

### 1.2.1.2 Land Review of the Land use potentials and limitations

The land use potential in Sierra Leone is rated as very high by virtue of the latter's endowment with extensive natural resources of arable land, non arable land and water resources (surface, ground, and various forms of precipitation of which rainfall is most dominant). The land use types are many and diverse. Agriculture is the dominant land use on which more than two-thirds of the population (mainly rural) depends. It encompasses livestock rearing, Fisheries and food crop and tree crop production, forestry and wildlife production, timber production, mining industry, estate development and other forms of human activity.

All of the different land use types, have intensified over the years, due to the increase in population. In the past, all forms of land use were done on small scale and, there was not much disturbance to natural resources. Lately, due the increase in population, the use of the resources has intensified but with very little control and supervision. In fact there is now a new development in the form of large scale farming, mining, and utilization of forest resources. A type of land use has emerged in the form of farming for biofuel production, which involves the use of arable land for cultivation of crops like sugar cane and oil palm for biofuel. Thus, the pressure on land resources continues to grow.

### 1.2.1.3 Land Use Constraints.

Lack of well-articulated natural resources management system
High incidence of unsuitable land use practices (e.g. shifting cultivation, bush burning, poor soil management, traditional technology, forest destruction biodiversity loss).

Increasing risks of land degradation arising from unsuitable land use practices
Food shortages (Level of agricultural production records less than 1% annual growth rate compared to about 2.6% population growth rate (2003 data;) about 60% of total food needs produced and about 44% of rice consumption requirement (2002) aging rural population (out-migration of youths to better life in cities and towns) underutilization of arable land (predilection of farmers 80% of the population) with low productive subsistence farming using only 8% of the estimated 5.36 million ha of arable land in any year). Wastage of forests (e.g. by clearing for agriculture, shifting cultivation, logging, mining, uncontrolled bush fires, charcoal making, firewood collection.

Population redistribution (caused by the civil war) and related land use and land tenure problems.

### 1.2.2 Water

Adequate amount of water exists in Sierra Leone from rainfall, surface and underground. The mean annual rainfall ranges between 400mm along the coast and 200m in the northeast. The duration of the wet season varies from 9 months, stating in March in the East to 7 months, starting in May in the north and west and ending in November.

Compared to other larger river systems in Africa, the drainage basins of Sierra Leone are small. There are nine major rivers and five of these originate in the country. Most of the flow in the rivers during the dry season comes from ground water storage that recharges the channels. According to occurrence, most of the ground water comes from sedimentary and igneous rocks. In the soft sedimentary rock, good ground water potential and depth to water have been found to be shallow, about 6 meters below ground level. Ground water potential in the hard rocks depends on the weathering depth and the amount of rainfall in that area. Ground water has been found to occur around 8 – 10m below ground level on average with a seasonal fluctuation of 3 – 5m.

Access to improved water supplies in the country is in the form of pipe-borne water, boreholes or wells. These are distributed unequally between rural and urban areas. In rural communities, the main water sources are from shallow wells, rivers, lakes and swamps. Government merely pays lip service to the development of rural water supplies. Until recently, much of the effort has come from NGOs who provide rural areas with hand-dug wells some of which are fitted with pumps.

The average minimum per capita consumption of improved water for the rural population measured in litres per day is as low as 2 in the dry season and 20 in the wet season. During the dry season, most of the rivers, streams and swamps dry up and women and children have to travel long distances in search of water.

### 1.2.3 Soil

Soils in Sierra Leone, according to d'Hoore Classification (1964) are ferrigneous (lateritic) and hydromorphic. They are described in details by Odell et al (1967, 1964). Generally, they are referred to as Ultisols, Oxisols, Entisols and Lnceptsols, either characterized by an argillic horizon, often weakly developed or often slightly altered.

Steep slopes characterized by very shallow, gravely and low water holding capacity Hydromorphic soils occupy 17% of the land area. Limiting factors for crop production on these soils include low soil reduction and flooding. Upland lateritics soils occur on the remaining 0% of land area. These soils are also shallow, often gravely and liable to erosion.

### 1.2.4 Vegetation

The vegetation was part of the larger tropical rainforest belt, which originally covered the interior plateau and the hills of the eastern region and the Freetown peninsula.

The two kinds of closed high moist tropical forests include the evergreen forest and the secondary forest. The kinds of forests contain a wide range of tree species. Others include Forest Re-growth, Savannah Wood lands,. Mixed Tree Savannah, Montane Grassland and Rock Outcrops, Upland Grasslands Complex, Lophira Vegetation, Coastal Tree Savannah Mangrove Swamp Forests, Aquatic Grasslands, Freshwater Swamp Forest and undifferentiated Swamps.

### 1.2.5 Mineral Resources

Expanding industrial mining is already recognized as significant for development with World Bank estimates suggesting that the sector could bring in up to USD 370 million in export revenues by 2015. Moreover, it is estimated that direct employment in industrial mines could exceed 38,000 with an additional 300,000 people deriving livelihoods indirectly if the development of the mining sector continues apace. Currently, the major operations that are ongoing or in the development stages include Sierra Rutile (mineral rutlile), Koidu Holdings (kimberlite diamonds), African Minerals (iron ore) and London Mining (iron ore). However, the expansion of the sector will have to be conducted in a fashion that is sustainable and equitable and, even then, may have only quite localized development effects.

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.

### 1.2.6 Energy Resources

In 2008, Sierra Leone's energy consumption was estimated at 1410toe[2]. Most of the consumption is c oncentrated in the household sub-sector, where biomass, in the form of fuel wood and charcoal is used for cooking and kerosene is used for lighting. Traditional biomass (fuel wood and charcoal) account for over 80 per cent of total energy used in the country, while modern energy services, electricity, petroleum products, including LPG, and non-biomass renewable, still represent only a small percentage. Almost 80 per cent of the electricity used is in the industrial and mining sub-sectors, and about 50 per cent of petroleum products used is in the transport sub-sector.

The over-reliance on traditional biomass for energy contributes significantly to deforestation and land degradation with negative consequences on climate change, agriculture and water resources. The huge potential for the use of agricultural wastes which is estimated could provide over 2000 GWh of electricity annually, remains untapped.

## 1.3 Economic and Social Development
## Sectoral Trends, Policies and Initiatives

The moderate economic gains Sierra Leone achieved between 1966 and 1970 with average annual growth rates of around 4% declined to 2.1% between 1971 and 1980. They experienced further decline to an 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 programs and weak export prices in the face of higher import prices. The impact of the Structural Adjustment Program (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, escalating prices on the staple food reversed any gains that these policies may have achieved. 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. The overall benefits of this program are yet to be realized by the majority of peoples. This situation worsened during the rebel war as a result of devastation of the economy and the social infrastructure of the country. Production in the agricultural, mining and industrial sector was badly disrupted. As output and exports declined, external debt increased 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 dropped 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 impact of the war. However, there has been a steady rise in growth rates from 2001 to 2004. The growth rate has increased from 3.0% in 2001 to 5.4% in 2002. This trend continued to 6.3% in 2003 with a growth rate of 6.5% in 2004. It is 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. The improvement reflects on the increase in GDP per capita rising from US$142 in 2000 to US$160 in 2002, and to US$210 in 2004.

### 1.3.1 Economic policies and Trends

Sierra Leone is a small open economy that has suffered prolonged deterioration and an accompanying low standard of living despite its significant resource endowments. The average annual growth rate of real GDP fell continuously: from 4% per annum in 1966-70, to 2.1% 1971-80, then to decline of 0.07% per annum (8-89), and an accelerating decline of 1.5% per annum from

[2] Tonnes of oil equivalent

1990 to 1998. Gross domestic Product per capita declined from US$380 in 1980 to US$237 in 1990 and to about US$142 in 2000.

### 1.3.2 Patterns of Growth

Before 2000, Annual economic growth averaged about 4 percent and 3.5 percent in the 1960s and 1970s, but declined to 1.5 percent in the 91980s, because of misguided economic policies, indiscipline in the public sector mismanagement and other problems Efforts to introduce macroeconomic stabilization and structural reforms to redress economic decline and restore growth were abruptly disrupted by armed conflict in the 1990s, plunging the economy further into decline, with GDP falling by an average of 4.5 percent per annum between 1990 and 2000. During this period most of the country's revenue was spent on military expenditure. At the same time, Sierra Leone has to cope with displaced citizens as well as an influx of Liberian refugee's equivalent to 5% of the indigenous population.

Growth after 2000. There has been a broad improvement in economic performance in the initial years after conflict, as Figure 2.1 and Table 2.1 show. The cessation of hostilities and eventual restoration of security across the country strengthened confidence, which facilitated economic recovery during 2000-2004. Economic activity was initially spurred by the countrywide reconstruction and rehabilitation work, and then the broad recovery in agriculture, mining (mainly diamonds), manufacturing, construction and services. Real GDP rose sharply by 18 percent in 2001, further increased by 27.5 percent in 2002, between 7 and 9 percent annually from 2003 to 2005, and was projected to continue at about this rate in 2006 and the medium term.

### 1.3.3 Economic Growth in 2008 was lower than Projected but Inflation Decelerated

During the last quarter of 2008, the economy came under pressure from slowing global demand and falling export prices, particularly for diamond and bauxite. Real GDP is estimated to have reached 5.5 percent in 2008, compared to a projection of 6.4 percent. On the positive side, growth was solid in agriculture and the service sector. Inflation remained in the double digits with average CPI inflation reaching 14.8 percent in 2008, fueled notably by higher international food and fuel prices. However, inflationary pressures subsided toward the end of the year due to the steep decline in import prices (mainly for oil), leading to a fall in end-period inflation to 12.2 percent, compared with 15.7 percent programmed

Sierra Leone's medium-term policy agenda focuses on reducing poverty by stimulating economic growth while preserving macroeconomic stability.

The policies to achieve these objectives are elaborated in the second-generation Poverty Reduction Strategy Paper (PRSP), which was finalized and endorsed by Parliament in May this year.

### 1.3.4 Poverty Reduction Strategy Paper (PRSP), Agenda for Change

Sierra Leone developed its first Poverty Reduction Strategy in the form of an Interim Poverty Reduction Strategy in 2001. This was designed to address the challenges of transition from war to peace by focusing on three key areas: restoring national security and good governance; re-launching the economy; and providing basic services to the most vulnerable groups. This was complemented in 2002 by a National Recovery Strategy based on district and local recovery plans that emphasized the consolidation of state authority, peace-building, promotion of reconciliation, enforcement of human rights, resettlement, reintegration and the rebuilding of communities.

Subsequently, a long-term sustainable development plan entitled "sierra Leone vision 2025" was published in 2003, which provided a long-term framework for development planning and management. This was followed by the first full Poverty Reduction Strategy Paper (PRSP-1), which was developed for the 2005-2007 period. PRSP-1 reflected a move away from immediate post-conflict concerns and was constructed around three pillars: the first pillar focused on good governance, peace and security; the second on food security and job creation; and the third on growth and human development.

Upon embarking on the second PRSP process, a review was undertaken of PRSP -1 to highlight the achievements and lesson learned from its planning and implementation.

Furthermore, a diagnostic study was conducted to identify drivers of growth in Sierra Leone. Based upon these finding, it was clear that only economic growth could provide the basis for poverty reduction in Sierra Leone, and consequently the focus of the second PRSP (PRSP-11) should be on the promotion of transformational economic growth. The diagnostic study and analysis of the poverty profile has helped to identify the key sectors which will form the strategic priorities for PRSP.11. In order to generate a sustainable rate of economic growth, PRSP-11 also emphasises the need to develop an enabling environment to support the private and productive sectors of the economy, and identifies four key enablers and drivers of growth. Finally, PRSP-11 has sought to strengthen the implementation process to ensure that strategies are rolled out and implemented effectively by the ministries, departments and agencies

### 1.3.5 Energy Development Plan

The Energy Policy formulated by the Ministry of Energy and Water Resources has as one of its objectives, improvement of energy efficiency in all sectors. The National Strategic Plan developed from the Policy outlines the strategies that will be adopted to meet the objective and will include the formulation of an Energy Efficiency and Conservation Act, and the introduction of measures at urban and rural levels to overcome barriers to improved energy efficiency and reduces emissions of GHG's. As a result, a project has been proposed which will involve launching awareness campaigns to sensitize consumers and encourage ownership in domestic and industrial/commercial sectors. Smaller communities will also be included and the project will cover households in 100 villages' country-wide. There will be activities to promote the development and introduction of improved wood, charcoal, and kerosene stoves.

In 2002, total electricity production was 142GWh, but this dropped to only 45GWh in 2007. Even though the availability has increased since 2007, as a result of the introduction of emergency measures by the government supported by World bank and UNDP funding, total electricity production in 2008 was 157GWh (which represents 24 KWh per capita), or only 3.4 percent of the projected 4,660 GWh required for a population of 5.4 million to meet basic human needs.[3]

Other policy objectives in place include the expansion of and the development of hydropower and solar power that will reduce the current dependency on fossil fuels and reduce the cost of importation of the fuels and also reduce our overall emissions of GHGs. The transmission lines for these schemes will be linked up eventually to form part of the national grid.

[3] This is based on a calculation of 100W electricity supply capacity per capita. It should be noted that this 100Watts per capita is only about one tenth of the level required to support a Western European living standard with modern energy sources and energy efficient converter. SOURCE: Energy and Basic Human needs, updated September 23, 2008, UNDP, 2002 - REDDY.

A Solar Street Lighting Project to install solar street lighting in Freetown and all district headquarter towns has already started.

The country has recently signed up to join the West African Power Pool (WAPP) Project involving a grid network which will initially run from Nigeria to Cote d'Ivoire, but will eventually cover all ECOWAS states. When fully implemented, the network will facilitate the transport of power between states in the sub-region; providing power to countries where there are shortages from those countries with spare capacity.

Sierra Leone also aspires to join the West African Gas Pipeline (WAGP) project which now provides natural gas from Nigeria to Benin, Togo and Ghana, and is expected to run up to Senegal. Efforts are under way to ensure connection to this pipeline, in order to have access to this valuable source of energy to augment and diversify the country's sources of energy.

Because of the high cost and lack of access to electricity supply, biomass fuels in the form of firewood, charcoal and bio-waste will continue to be the main energy source for the foreseeable future by the majority of the population. The government has recognised the damage this is doing to the country's forests and ecosystem and is examining various options for energy supply among which is the use of liquefied petroleum gas (LPG) in the domestic sector. Only two companies, Safecon and National Petroleum market LPG in the country and there are a number of issues relating to the use of LPG:

Public perception of safety problems related to its use.
Canisters are not readily available and connections from bottle to equipment are not standardized.
Marketing companies cite cost, shipping, storage during shipments, storage at depot and inland transportation as serious setbacks.
Consumers also complain about high cost of purchasing.

Therefore there is need for major changes to the supply, distribution and pricing; and one of the main challenges will be to ensure that many Sierra Leoneans can afford to use LPG.

#### 1.3.5.1 Petroleum

The sub sector plays an important role in the economy. In excess of 200,000 tons of petroleum products are imported annually, representing in monetary terms about 26% of all imports into the country.

Sierra Leone's on-off off-shore petroleum exploration which dates back to the 1970's appears to have finally paid off when petroleum was recently discovered in 2009. The find is being assessed for commercial viability. Meanwhile government is looking at the institutional, legal and contractual issues to ensure that exploitation of the resource benefits the entire population. Government is acutely aware that the existence of oil and other natural resources can be one of 'mixed blessing' as it has often been demonstrated in the case of Nigeria.

### 1.4 The Agricultural Development Plan

The agricultural sector in Sierra Leone has been exhaustively described in several documents including the report on the initial national communication on climate change in 2006.

#### 1.4.1 Livestock sector

Almost 90% of Sierra Leone's cattle are in the Northern Province and owned by the Fula ethnic group who represent about 5% of the country's population. Cattle rearing are distinctly concentrated

in the savannah woodland and the Transitional Rain Forest-savannah woodland particularly in the northern most areas with rainfall less than 2500mm and shorter rainy season. Also this area is adjacent to the cattle producing area of the neighbouring Republic of Guinea and shares similar climatic conditions. Sheep ownership is more widespread, but goats are more widely distributed and are found all over the country. Pigs and poultry are also widely distributed.

Poultry mostly comprise domestic fowl, although there are smaller numbers of Guinea fowl and Muskovy ducks (Table…). Almost all rural households raise a few chickens. However, commercial poultry production is concentrated in the urban areas particularly around the capital city, Freetown largely due to the effective demand for poultry products in the city. Similarly, pig rearing is also more common in the western area and in the Port Loko, Bo and Moyamba districts. The relative low pig population may not be un-disconnected with the high Muslim population (60%) in the country.

Open grazing is generally practiced with cattle driven away in search of fresh field by herd boys during the day and kept in wooden fence enclosures during the night. During the dry season when fresh grass is scarce, cattle are let loose for about three to four months until the rains commence and fresh grass is again abundant, then they are gathered and controlled. There is high risk of crop damage by cows during the dry season often causing conflicts among families in the villages.

**Table 1.6… Number and distribution of livestock by category and by district in 2005**

| District | Category of Livestock | | | | | | |
|---|---|---|---|---|---|---|---|
| | Cattle | Sheep | Goat | Pig | Chicken | Ducks | Guinea Fowl |
| Kailahun | 0 | 2623 | 5,901 | 0 | 471,006 | 15,736 | 0 |
| Kenema | 1905 | 6349 | 13,333 | 0 | 464,747 | 68,569 | 1,587 |
| Kono | 1322 | 5289 | 17,631 | 0 | 163,966 | 15,868 | 0 |
| Bombali | 3934 | 7377 | 9,836 | 0 | 318,680 | 11,803 | 0 |
| Kambia | 1127 | 20,292 | 24,049 | 0 | 324,665 | 27,055 | 939 |
| Koinadugu | 4299 | 9,674 | 18,631 | 0 | 176,274 | 8,599 | 0 |
| Port Loko | 10096 | 35,966 | 58,050 | 2,524 | 636,028 | 22,715 | 3,155 |
| Tonkolili | 1603 | 12,826 | 19,239 | 0 | 487,382 | 153,910 | 2,672 |
| Bo | 729 | 2,917 | 3,889 | 2,917 | 268,322 | 34,998 | 0 |
| Bonthe | 0 | 1,446 | 9,640 | 0 | 150,390 | 23,137 | 603 |
| Moyamba | 675 | 9,445 | 43,179 | 10,795 | 415,597 | 64,768 | 1,124 |
| Pujehun | 0 | 3,304 | 5,507 | 0 | 286,385 | 44,059 | 918 |
| W/Area | 0 | 1,144 | 1,716 | 17,159 | 171,594 | 17,159 | 0 |
| **S. Leone.** | **25,691** | **118,651** | **230,601** | **33,395** | **4,281,036** | **508,378** | **10,999** |

**Source: MAFFS, V. A. M. Report, 2005**

### 1.4.2 Fisheries Development Plan

Along its coastline of 507 km and the continental shelf area of 25,600 km2, Sierra Leone is rich with marine resources. It is also well endowed with inland waters (rivers, lakes and floodplains)) which support a large number of aquatic organisms. Fishing is carried out largely by local canoes which exploit the inshore waters and the three large estuaries in the north-west and south of the country. There are an estimated 20,000 full time fishermen operating with some 6000 boats of different sizes and designs. The level of boat motorization is about 16% (MAFFS/MAMR, 2004). A variety of fishing gears are in use (Ring nets, Drift nets, Beach seines, Cast nets, Hook and line).

The bulk of the fish produced by the artisanal sector is consumed locally. Fish production from 1994 to 2002, is shown in Table 1.7

The Government of Sierra Leone exploits this resource in partnership with foreign governments and companies who mainly provide the vessels. Fish export from the country is made up of fish products manufactured by industrial fishing trawlers operating off shore. Foreign owned vessels fish in Sierra Leone waters through joint arrangements with Sierra Leonean nationals. They comprise demersal, pelagic and shrimp trawlers as well as purse seine vessels fishing for Tuna and Herrings. The absence of home based industrial fishing vessels and basic infrastructure and facilities to catch and process fish, limits the country's ability to maximize benefits from the resource

**Table 1.7 Artisanal and Industrial Marine Fish production (MT) in Sierra Leone**

| Category | Year | | | | |
|---|---|---|---|---|---|
| | 1994 | 1996 | 1998 | 2000 | 2002 |
| Artisanal | 47,000 | 47,000 | 47,000 | 46,000 | 53,000 |
| Industrial | 18,000 | 17,000 | 13,000 | 14,000 | 14,000 |
| **Total** | **65,000** | **64,000** | **60,000** | **60,000** | **67,000** |

Source: MFMR

### 1.4.3 Wetlands

The Ramsar Convention on Wetlands defines wetlands as "areas of marsh, fen, peatland, or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish, or salt, including areas of marine water the depth of which at low tide does not exceed six metres".

Sierra Leone's wetlands fall into two main categories; namely, the saline coastal mangrove swamps and the freshwater swamps.

### 1.4.4 Agriculture and Forestry

Since 2007, government has doubled its efforts in the fight to achieve food security and reduce poverty in the country especially in the rural areas. This is being achieved with support from the donor community such as the World Bank, the African development Bank (ADB), the Islamic Development Bank (IDB), the Japanese government (JICA), Peoples Republic of China, to mention just a few. A few of the areas of

### 1.4.5 The Food Security Drive

The drive for food security in Sierra Leone, gathered momentum immediately after the declaration of the food security pledge by former President Kabbah on the 19$^{th}$ of May 2002, with the declaration in place, several important actions, ideas and policies were put in place to guide the various stakeholders in their efforts to ensure the achievement of a sustainable food security in Sierra Leone. Two of such actions worth mentioning here are the Food Security policies and Food Security pillars.

### 1.4.6 Food Security policies and pillars

These include: Land development policy, pricing policy, Livestock policy, Forest conservation policy, Fisheries policy, Support services policy and a Decentralization policy.

## 1.5 Biodiversity

Sierra Leone comprises of a range of ecosystems, which have historically contained a wide array of plants and wildlife though this number has been reduced substantially over the last two centuries. The war also had a significant impact on the country's ecosystems given the lack of government management and the increased rebel activity and management and the increased rebel activity and population displacement that occurred primarily in forested areas. While current data are incomplete, Sierra Leone contains extensive biodiversity in terms of species richness and endemism, especially in areas covered by rainforest. Although estimates vary wide, the country has some 15,000 species alone. Sierra Leone also contains approximately species that are either endangered or vulnerable to extinction. Other mammals such as elephants and hippos have been considerably reduced in number. Biodiversity in the country remains threatened by agricultural practices, deforestation, mining, infrastructure and urban development.

## 1.6 Waste

The present policy direction on waste management is to properly manage available old solid waste dump sites to more efficiently collect and dispose of garbage particularly in the major cities of the country.

The Waste Management policy objectives are to preserve and improve the health and quality of life of all Sierra Leoneans through sound environmental management. Problems addressed include poor sanitation, waste management and disposal.

The management of the sewage system lies officially under the authority of the Water and Sanitation Department of the Ministry of Energy and Water Resources (MEWR). However, in the frame of the decentralization process started in 2004, a "Supervisory and Coordinating Role" - which includes the operation and maintenance of sewage and the management of solid waste - was handed over from the MEWR to the Freetown City council (FCC). Later under the authority of FCC, the sewage clearing and maintenance service is delegated to a private operator: the Sewage and Sanitary Division of Sanitary Products and Allied Company Limited (SDSPAC).

As for the tariff setting, the situation is rather complex:

Each new connection is subject to a connection fees to be paid directly to Freetown City Council (and not to the MEWR as it used to be);

Many studies on waste management have revealed that waste disposal in the entire country especially large provincial towns is based on the model in Freetown and has changed very little since colonial times. Based on the Public Health Ordinance of 1960 and its subsequent amendments, the Local Governments are the de jure authorities responsible for the implementation of waste management service in their respective communities.

In 1980 the waste management responsibility for Greater Freetown was transferred to the Environmental Health Division (EHD) of the Ministry of Health and Sanitation (MOHS). From 1980-1993, the physical collection, transportation and disposal of waste from designated points in Freetown were contracted out to a local waste management contractor. However, in 1993 the entire operation of waste collection, transportation and final disposal was handed over to the EHD of the MOHS. Ten years after (in 2003) waste management in Greater Freetown was transferred to the Ministry of Youth and Sports (MOYS) with both the Freetown City Council and EHD acting as partners. By 2005 waste management had been transferred to the Freetown City Council in line with the decentralization policy.

The legislative framework for the management of health care waste is currently under review.

### 1.7 Youth & employment

Sierra Leone currently faces high unemployment among the youth. Unfortunately many of these were unable to complete their education due to the interference of the civil war. Although employment is currently available in Sierra Leone, it is often only for those who are highly skilled and educated. Thus, the unemployed low and semi-skilled youth, particularly in the urban areas of Sierra Leone, remain a risk since they need but are unable to find stable, long-term employment. Short term employment increases the risks to climate change.

### 1.8 Gender

Low educational participation of the girl-child and low literacy rates among women in Sierra Leone remains a constraint. Throughout the world, those countries which have focused on educating women and girls have had stronger economic development over a longer period of time. This is particularly related to the health of children of well-educated women, as well as the higher likelihood of these children completing their education, thus giving greater growth and development in the future. For continued development into the future, it is essential to ensure that women and girls receive a good education, since this will severely impact the future of Sierra Leone and reduce risks due to climate change.

### 1.9 Exogenous Risks

Uncertain political and economic situations in any neighbouring country could disrupt Sierra Leone's economic development. If terms of trade are disrupted for Sierra Leone's exports, this could handicap the country Sierra Leone is dependent on oil and other petroleum products. If the international price of oil were to continue to increase, it would damage the economy, in terms of supplying power in the short term, as well as in the transportation of goods, since the majority of goods travel by road.

If climate change and environmental changes cause weather patterns to shift, Sierra Leone must be aware of potential changes in climate and how agriculture in particular can be adapted to thrive in a new environment.

With a Crude Death Rate of 20/1000, Sierra Leone remains one of the sub-Saharan countries with the highest death rates. The under-5 mortality rate of 297 for males and 271 for females is the highest in Africa. Life expectancy is still low, at 48.4 years according to the 2004 census. This, however, reflects an increase over time. Malnutrition among children aged under 5, estimated at 27.2 percent in 2003, is one of the highest in the region. Overall, 70 – 80 percent of the population of Sierra Leone lives on less than $ 2 a day. Population is concentrated in the district headquarter towns as well as in the Western Area. Under the high and medium variants, the population of Sierra Leone will double between 2030 and 2040; while under the low variant, the population doubles after 2040. Higher population growth can adversely affect resources and development in post war Sierra Leone.

# CHAPTER TWO
# GREENHOUSE GASES INVENTORIES

## 2.0 Introduction

The Second National Greenhouse Gas (GHG) inventories of emissions by sources and removals by sinks have been carried out to meet Sierra Leone's obligation under Articles 4.1 and 12 paragraph (a) of the United Nations Framework Convention on Climate change (UNFCCC).

The United Nations Framework Convention on Climate Change (UNFCCC) seeks to stabilize concentration of greenhouse gases (GHGs) in the atmosphere and commits Parties to take measures to mitigate GHG emissions, in accordance with the principle of common but differentiated responsibility and taking into account their national priorities and aspirations. Inventories of GHGs provide the means for monitoring reductions of GHGs by Parties and are therefore important components of national communications.

The Intergovernmental Panel on Climate Change (IPCC) has developed guidelines for computing of GHGs (by parties) to enable their comparison. Sierra Leone used the 1996 IPPC guidelines, including for the selection of emission factors in all the sectors.

This inventory used 2000 as the base year. No specific surveys were conducted to generate data needed for the inventory exercise as the funds were inadequate for such an exercise.

Country activity data were collected to the extent possible. IPCC default factors were employed where country data were not available.

Sierra Leone prepared its initial communication in 2006 taking 1990 as a base year. For the Second National Communication (SNC), 2000 has been selected as base year. However, since that year many reforms have come into effect that have a direct impact on the results of the present national communication. Main developments include:

- Development and adoption of Poverty Reduction Strategy Paper (PRSP) 2005-2007;
- Sierra Leone Vision 2025
- Decentralization with the election of town councillors in 2004;
- Population and Housing Census 2004
- Development of the National Adaptation Programme of Action (NAPA) document
- Development and adoption of Poverty Reduction Strategy Paper (PRSP) Agenda for Change 2008-2012;
- Supporting Sierra Leone: A Joint Vision of the United Nations Family

In the Mining and Energy sector, some legal and regulatory documents were also revised, namely the new Mining Act and the just adopted new Petroleum Act 2011 in order to make investments more attractive in these sectors in addition to the adoption of a new Forest Act.

For the Second National Communication, the aforementioned reforms contributed to: (i) an improvement in some areas of the national statistics; (ii) building of national capacity and expertise; (iii) appropriate institutional framework; (iv) orientations of policies, in particular more specific policies in agriculture, forestry, land use and land use change and energy water sectors.

The table below show 2000 emission levels for the most important greenhouse gases Sierra Leone.

**Table 2.1 Greenhouse Gases Emission for the Base Year 2000**

The gross emissions of GHG in Sierra Leone for 2000 are presented in the table below:

## Table 2.2: Summary Report for 2000 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 2000** | | | | | | | | |
| ***1 Energy*** | **529.28** | | | | | | | |
| Fuel Combustion (Sector Approach) | 529.28 | | | | | | | |
| iv. Energy Industries | | | | | | | | |
| v. Manufacturing Industries and Construction | | | | | | | | |
| vi. Transport | | | | | | | | |
| **2 Industrial Processes** | | | | | | | | |
| ii. Mineral Products | 111.2397 | | | | | | 000000957 | |
| **3 Solvent and Other Product Use** | **NOT ESTIMATED DUE TO LACK OF METHODOLOGY** | | | | | | | |
| **4 Agriculture** | | | | | | | | |
| viii. Enteric Fermentation | | | 5.152 | | | | | |
| ix. Manure Management | | | 414.2 | | | | | |
| x. Rice Cultivation | | | 15640.37 | | | | | |
| xi. Agricultural Soils | | | | | | | | |
| xii. Prescribed Burning of Savannas | 129.36 | | 689.91 | 8.54 | 308.58 | 24.147 | | |
| xiii. Field Burning of Agricultural Residues | | | | | | | | |
| xiv. Other (please specify) | | | | | | | | |
| **5 Land-Use Change & Forestry** | | **-405,339,92** | **5,431** | **4,645** | **167,891** | **49,267** | | |
| iv. Changes in Forest and Other Woody Biomass Stocks | | 1,066,501.5 | | | | | | |
| v. Forest and Grassland Conversion | 5331300.6 | | 5,631 | 4,645 | 167,891 | 49,267 | | |
| vi. Abandonment of Managed Lands | | -44,798,789 | | | | | | |
| **6 Waste** | | | | | | | | |
| iii. Solid Waste Disposal on Land | | | | | | | | |
| iv. Wastewater Handling | | | 11.81 | 31.29 | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **7 Other (please specify)** | | | | | | | | |

The economic sectors considered in the greenhouse gas inventories are Energy, Industrial Processes, Agriculture, Land Use Change and Forestry, and Waste. The GHG inventories of emissions by sources and removals by sinks covers carbon dioxide ($CO_2$), methane ($CH_4$) and Nitrous Oxide ($N_2O$) and the total $CO_2$, - equivalent from the sectors for the period 1995 – 2005. The greenhouse gases $CO_2$, $CH_4$, and $N_2O$ have been reported in accordance with the guidelines

$CO_2$, $CH_4$ and $N_2O$ have a direct effect on the climate, while $NO_x$, CO and NMVOC have an indirect effect by contributing to the formation of the ozone in the atmosphere which actively causes the green house effect.

Not all emission categories of the 1996 Revised Guidelines (IPCC, OECD.IEA, 1997) are reported on in this chapter of the National Communications. This shortcoming is due to the following:

Sub-category B: fugitive emissions from fuels of category 1: energy is also not reported. Estimation of fugitive emissions could not be conducted because there is no fuel produced in Sierra Leone at present. Exploratory activities offshore from the coast of Sierra Leone suggests that primary fuel has been found to exist but oil and gas activities such as extraction and oil refining are not conducted.

The bulk of the emissions from Category 2: Industrial Processes could not be estimated for all in this category save for, cement, lime/limestone. Metal, soda ash, adipic and nitric acid, pulp and paper, ammonia, carbide and glass production do not exist. Asphalt roofing, road paving with asphalt, and concrete plumise stone production are conducted but data is lacking and documentation of halocarbons and sulphur hexafluoride (SF6) from refrigeration assembly, operation and disposal could not be quantified due to inadequate labeling, documentation and age of the equipment that enter the country. Similarly, data on foam products, fire extinguishers, solvents, aerosols and propellants, and equipment containing SF6 are not readily available. Some study is necessary because the equipments are found in most public, commercial facilities and residential properties.

Category 3: solvent and Other Product Use has not been reported on because the methodology for this category is still being developed.

The details of the methodology and data sources are under the respective emission categories below.

**Table 2.3 National Greenhouse Gas Inventories of Emissions by Sources and Removals by Sinks of all Greenhouse Gases, 2000 (Gg)**

| GHG Source and Sink Categories | $CO_2$ Emissions | $CO_2$ Removals | $CH_4$ | $N_20$ | $NO_x$ | CO | NMVOC | $SO_2$ |
|---|---|---|---|---|---|---|---|---|
| Total (Net) GHG emissions by source and removal by sinks | | | | | | | | |
| All energy (fuel Combustion) | 529.28 | | | | | | | |
| 1.1 fuel combustion | 529.28 | | | | | | | |
| 1.2 Biomass burned for energy (Non-CO2 emissions) | | | | | | | | |
| | | | | | | | | |
| Industrial Processes | | | | | | | | |
| Mineral Production | | | | | | | | |
| 1.1 Cement Production | 39.55 | | | | | | | 0.02373 |
| 2.2 Lime Production | 0.0497 | | | | | | | |
| 2.3 Limestone use | 0.000072 | | | | | | | |
| 2.5 Soda Ash & Sodium Bicarbonate | | | | | | | | |
| | | | | | | | | |
| Food Industry | | | | | | | | |
| Bread | | | | | | | 0.47 | |
| Confectionary | | | | | | | 0.000382 | |
| | | | | | | | | |
| Beverages) | | | | | | | | |
| Beer | | | | | | | 0.0000000318 | |
| Guinness | | | | | | | 0.0000000015 | |
| Soft drinks | | | | | | | 0.00000005 | |
| | | | | | | | | |
| Chemical Industry | | | | | | | | |
| 2.9 calcium Carbide Use | | | | | | | | |
| Metal Production | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2.11A Iron and Steel | | | | | | | | |
| 2.11B Aluminium | | | | | | | | |
| | | | | | | | | |
| Agriculture | | | | | | | | |
| 4.1 Enteric Fermentation | | | 5,15207 | | | | | |
| 4.2 Manure Management | | | 185,4 | | | | | |
| 4.3 Rice Cultivation | | | 1,5640.31 | | | | | |
| 4.4 Prescribed burning of Savannas | | | 689,91 | 8,54 | 308,58 | 24,147.01 | | |
| 4.4 Field burning of Agricultural Residues | | | | | | | | |
| 4.5 Agricultural Soils | | | | | | | | |
| | | | | | | | | |
| Land use Change and Forestry | | -405,309,52 | 5,631 | 4,645 | 167,891 | 49,267 | | |
| 5.1 Changes in forest and other woody biomass stock | | -1,066,503 | | | | | | |
| 5.2 Forest and Grassland Conversion | 5,331,300 | | 5,631 | 4,645 | 167,891 | 49,267 | | |
| 5.3 Abandonment of managed lands | | -44,798,789 | | | | | | |
| | | | | | | | | |
| Waste | | 11.81 | 31.29 | | | | | |
| 6.1 Solid Waste Disposal Sites (SWDSs) | | 0.88 | | | | | | |
| 6.2 Domestic & Commercial | | | | | | | | |
| 6.3 Industrial Waste Water handling | | | 10.92 | | | | | |
| 6.4 Human Waste (Indirect $N_2O$) | | | 0.01 | | | | | |

## 2.1 Emissions and removals of Greenhouse Gases in 2000

### 2.1.1 Carbon dioxide

The total carbon dioxide emission (CO2) for the year 2000 is 574.061Gg $CO_2$. The distribution per major sectors is as follows:

The emissions from energy generation are fairly high in the country, amounting to 529.287Gg of $CO_2$ as Sierra Leone energy generation is based on diesel powered generators. Recently, with the commissioning of the Bumbuna Hydro Electric Power Station, $CO_2$ emission from the energy sector has been fairly reduced at least on a seasonal basis.

The Land Use, Land Use Change and forestry (LULUCF) sector is the least significant source of $CO_2$ emissions up taking 752,748Gg of $CO_2$, followed by the waste sector emitting 11.83. The industrial processes are however marginal amounting to 39.55 Gg of $CO_2$ mostly from cement production.

### 2.1.2 Methane

The total $CH_4$ emissions are 32,312.53 Gg . Agriculture is the most important source of $CH_4$ emissions (86.67%), followed by the LULUCF sector (5.631) and finally the waste sector (11.83).

The other sectors are not sources of $CH_4$ emissions.

### 2.1.3 Nitrogen dioxide

$N_2O$ emissions estimated at 13.91 Gg with 8.54Gg coming almost exclusively from the agricultural sector. The waste sector is also a source of emission (31.29Gg).

## 2.2 Sector Emissions

### 2.2.1 The Energy Sector

In Sierra Leone, energy sector activities that contribute directly to the emission of GHGs have been identified as electricity production, transportation, domestic consumption of energy, industrial, forestry and agricultural processes and waste generation and disposal. The emissions consist of direct GHGs from energy consumption (Carbon Dioxide ($CO_2$), Methane ($CH_4$), Nitrous Oxide ($N_2O$), Nitrogen Oxides ($NO_x$), Carbon Monoxide (CO) and Non Methane Volatile organic Compounds (NMVOC)) and Sulphur Dioxide ($SO_2$). Emissions from energy systems are calculated from fuel combustion, including fuel wood. It is assumed that all fossil fuel imported and all wood fuel gathered are consumed. Details of the methodologies can be found in the National Inventory (NCC, 2002).

Since the INC, Sierra Leone continues to depend on expensive imported petroleum fuel for nearly 60% of her energy requirements. The main sources of energy for power generation are the Hydroelectric Power (HEP), Heavy Fuel Oil (HFO), and diesel with petroleum fuels accounting for about 70-80% of this present energy requirement.

### 2.2.1.1 Emissions of Greenhouse Gases from Energy Sector

In the Common Reporting Framework (CRF) from the 1996 IPCC Revised Guidelines the Energy Sector is divided in two main categories (1A Fuel combustion activities; 1B Fugitive emissions from fuels) that also can be broken out in different subcategories. Emissions in this sector were determined for the category 1A.

### 2.2.1.2.1A. Fuel Combustion Activities – $CO_2$ and Non – $CO_2$ Emissions

### 2.2.1.3 $CO_2$ Emissions from Stationary Sources

It is important to note that accounting for carbon is based mainly on the supply of primary fuels and the net quantities of secondary fuels imported into the country. This is to avoid the problem of double counting.

### 2.2.1.4 $CO_2$ Emissions from Mobile Sources

The road transport sector generally accounts for majority of the mobile source fuel consumption. Depending upon the category, activity data includes information such as fuel consumption, fuel deliveries, and vehicle miles traveled (VMT). Emission estimates from highway vehicles are usually based on VMT and emission factors by vehicle type, fuel type, model year and control technology. Since these data are not currently available in Sierra Leone, GHG emissions from road transport will be calculated and reported separately but not included in this inventory.

### 2.2.1.5 Non-$Co_2$ Emissions from Stationary Sources

These emissions consist primarily of $CH_4$ from natural gas systems, petroleum systems, and coal mining. Smaller quantities of $CO_2$, CO, NMVOCs and NOx are also emitted in this process. Therefore, since detailed information for the calculation of non-$CO_2$ GHG emissions from stationary the fossil fuel sources in Sierra Leone are not available, they are not included in this inventory.

### 2.2.2 1B Fugitive Emissions from Fuels

According to the Revised 1996 IPCC Guidelines, in Fugitive Emissions should be considered the following categories: I) CH4 Emissions from Coal Mining and Handling, II) CH4 Emissions from Oil and Natural Gas Activities, III) Emissions of Ozone Precursors and SO2 from Oil Refining (Tier 1 or Tier 2). According to the IR those emissions not occurred in the country in 2000.

Fugitive emissions mainly result from mining and processing of coal, oil and natural gas. Coal reserves are currently not in existence in Sierra Leone. However, exploration activities for oil and natural gas are underway and until this is realized, fugitive emissions will not be included in the inventory of Sierra Leone's GHG emissions.

#### 2.2.2.1 Biomass-Based Fuels

Biomass includes trees, timber wastes, wood chips, rice husk, etc. Sierra Leone enjoys a wealth of energy resources which are viable particularly biomass and hydroelectric. Approximately 80% of Sierra Leone's primary energy is derived from domestic biomass while crude oil and its by-products supply the remaining 20%, namely: kerosene, cooking gas and other petroleum products

#### 2.2.2.2 Inventory Data Sources

Primary country activity data for apparent fuel consumptions were collected to the extent possible from the National Petroleum Unit. Data for vehicle population in the transport sector was collected from the Sierra Leone Road Transport Authority. Simple extrapolation techniques were used where data gaps were encountered. IPCC default factors were employed where country data were not available.

### 2.2.3 Methodology

The methodology used here is based on the 1996 IPCC Guidelines for National GHG inventories recommended for use by parties to the UNFCCC in preparation for national communications with regards to inventories. The energy sector worksheets in the IPCC workbook were duly completed

Appropriate emission estimation methodologies in accordance with 1996 IPCC Guidelines to evaluate GHG emissions were used. Care was taken to the extent possible to avoid double counting of emissions. This was achieved by only considering total imports of the various categories of fuel types instead of considering consumptions in the various energy sub-sectors (e.g. industrial, residential, and transport sectors).

#### 2.2.3.1 Selection of Conversion Factors

The apparent fuel consumptions in Metric tonnes (MT) were recorded and the values converted to a common energy unit Terajoules (TJ) by multiplying with the appropriate conversion factors for each fuel type. The apparent fuel consumptions were then converted into carbon content in tonnes by multiplying with the appropriate default values of Carbon Emission Factors (CEF) given in Table 1-2 of the IPCC Guidelines. The Carbon content in tonnes was converted to Gigagrammes of carbon (Gg C). The carbon stored was calculated using the recommended steps outlined in the IPCC Reference Approach Guidelines. Correction was made for incomplete combustion by using appropriate default values for the "fraction of carbon oxidized". The actual carbon emission from each fossil fuel is multiplied by the factor (44/12) to obtain the total amount of $CO_2$ emitted from that fossil fuel. That is, to convert the carbon oxidized to $CO_2$ emissions, we multiply the actual carbon oxidized by the ratio of the molecular weight of $CO_2$ to carbon (44/12). The sum of $CO_2$ from all the fossil fuels gives the total national $CO_2$ emissions from fossil fuel combustion.

Table 2.4: Default conversion factors

| Products (tons) | Conversion factors ($TJ/10^3t$ |
|---|---|
| Gasoline | 44.8 |
| Diesel Oil | 43.33 |
| Jet Kerosene | 44.59 |
| Kerosene | 44.75 |
| Fuel Oil | 40.19 |
| Lubricants | 40.19 |
| LPG | 47.31 |
| Avgas | 44.8 |
| Bitumen | 40.19 |
| Lignite | 15.49 |
| Biomass | 18.84 |

Source: Manual IPCC, 1996 revised version

### 2.2.3.2 Selection of Emission Factors

Additional surveys indicate that in Sierra Leone industries neither measure pollution nor analyze gas emission.

Default emission factors were therefore selected as follows:

**Table 2.5: Default Emissions Factors**

| Type of fuel | Emission factors tc/TJ | Carbone stored | Oxidized fraction of carbon |
|---|---|---|---|
| Gasoline | 18.9 | 0 | 0.99 |
| Kerosene | 19.5 | " | " |
| Kerosene oil | 19.6 | " | " |
| Diesel Oil | 20.2 | " | " |
| Fuel Oil | 21.1 | " | " |
| LPG | 17.2 | " | " |
| Lubricants | 20.0 | 0.5 | " |
| Bitumen | 22.0 | 1 | " |
| Lignite | 27.6 | 0 | 0.98 |
| Solid Biomass | 29.9 | " | 0.90 |

Source: IPCC, 1996 revised version

### 2.2.3.3 Choice of Method for Calculating Greenhouse Gas Emissions

The choice of method is country-specific and is determined by the level of detail of the activity data available. The "bottom-up" approach is generally the most accurate method for those countries whose country energy consumption data are reasonably complete. For least developed countries like Sierra Leone, where required activity data are incomplete or in most cases not available, the "top-bottom" or "Reference Approach" method is preferred. That is, only import data by fuel-type are used.

### 2.2.4 Results of Estimation of Emission from the Energy Sector Due to Fuel Combustion

The calculated energy Sector GHG emission inventory results by fuel-type and their respective percentage emissions for the stated period are given below;

**Figure 2.1: $CO_2$ Emissions (Gg) By Fuel Type - 2000**

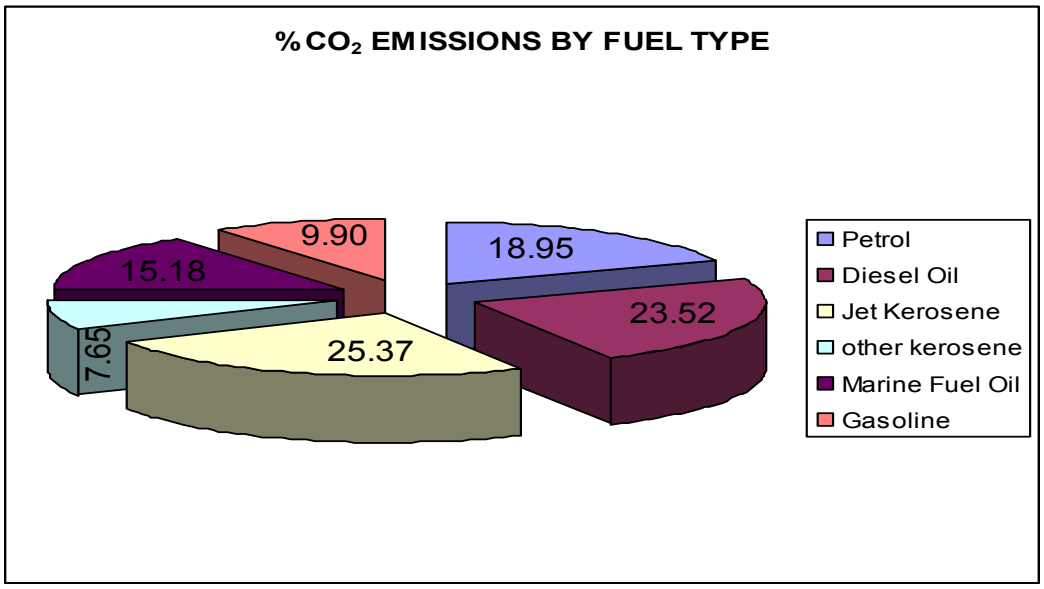



**Table 2.6 $C0_2$ Emissions (Gg) – 2000**

| YEAR | $CO_2$ EMISSIONS ($GgCO_2$) |
|---|---|
| 1995 | 476.98 |
| 1996 | 294.06 |
| 1997 | 134.56 |
| 1998 | 334.57 |
| 1999 | 227.78 |
| 2000 | 529.28 |

### 2.2.5 Data gaps, expertise, sustainability and recommendations

The expertise already developed during the development of the INC was used for this inventory of the SNC.

Due to the lack of country-specific emission factors and coefficients, default values provided in the IPCC Guidelines are used in this inventory.

It is recommended that the inventory team should as a matter of priority, develop country specific emission factors and coefficients where found necessary. This aspect is a national priority and the National Communications Support Programme in New York and UNDP have understood it that way and that Sierra Leone should be included in the Regional Project on the Improvement of Inventories through the development of regional and national emission factors.

### 2.2.6 Difficulties

Informal hydrocarbons importation channels are not subjected to the formal channels hence difficulties in even the apparent consumption of the country. Only a regular consumption survey will ensure reliable estimates;
Increase in the price of hydrocarbons on the international market which increase the previous structure grounds;
Lack of data on auto-producers due to the low keeping of energy statistics either as a result of lack of interest or for reasons of supply in a parallel market;
Disregard by many private operators of the energy sector's challenges and the challenges related to climate change particularly the opportunities that the Clean Development Mechanism (CDM) offers;
Existence of too little official figures on energy data, which tends to prove that this sector is hardly considered at the strategic level by vocational and statistical institutions;
Confidentiality of energy data for security grounds (army) or taxation (deductible expenses);
Low prioritization of the sector in the various development policies and strategies in the tools and instruments equal to the related challenges;
Shortage of energy statistics professionals in institutions due to the lack of motivation from the latter to gain such skills;

### 2.2.7 Recommendations

Fine-tune data to make a better assessment of emissions through the sector method; conduct a survey following a relatively less expensive methodology to establish a baseline case with more elaborate collection tools and;
use this survey to make a better assessment of the technical characteristics of production tools in anticipation of mitigation measures.

## 2.3 Industrial Processes Sector

### 2.3.1 Introduction

In the IPCC 1996 Guidelines, the Industrial Processes Sector includes seven main categories: 2A Mineral Products, 2B Chemical Industry, 2C Metal Production, 2D Other Production, 2E Production of Halocarbons and Sulphur Hexafluoride, 2F Consumption of Halocarbons and Sulphur Hexafluoride, 2G Other, with the corresponding subcategories. This structure is based on the coding and naming as defined in the Common Reporting Framework of the IPCC Guidelines and used by the UNFCCC.

The Industrial Processes sector in Sierra Leone is relatively small, and the main GHG emissions reported are derived from the categories 2A Mineral Products (2A1 Cement production, 2A2 Lime Production, 2A3 Limestone and Dolomite Use, 2A6 Road Paving With Asphalt) and 2D Other Production (2D2 Food and Drink). Most of the categories of this sector do not occur in the country. For example soda ash production, glass production, chemical industry, metal production, glass production and

production of halocarbons and SF6 do not exist. Other categories were not estimated due the unavailability of activity data (e.g. consumption of halocarbons and SF6).
The industrial sector in Sierra Leone is underdeveloped. Sierra Leone Brewery Limited produce beer, stout, malt and mineral water. Various cottage industries exist and these process and produce food on relatively small scale. Therefore, only emissions from beverage and food production are assessed for the Industrial Processes category. These activities are not related to energy but chemically or physically transform materials. During these processes Non-methane Volatile Organic Compounds (NMVOC) are released.

The manufacturing industry in Sierra Leone consists mainly of processing raw materials and light manufacturing for the domestic market, small-scale manufacturing (beverages, textiles, cigarettes, footwear); petroleum refining, small commercial ship repair[4]. Most of these activities are developed in the Western Area, particularly in Freetown.

The Wellington Industrial Estate area, covering 46 hectares just east of Freetown, was developed in the 1960s by the government to encourage industrial investments. Its factories produce a variety of products, including cement, nails, shoes, oxygen, cigarettes, beer and soft drinks, paint, and knitted goods[5]. Timber for prefabricated buildings is milled, and another factory produces modern furniture.

Small factories outside the industrial area process tuna and palm oil. In 1992, the oil refinery in Freetown closed due to lack of capital for crude oil imports; in 1994 the facility was sold to Unipetrol of Nigeria but has since close down. Its production capacity in 2002 was 10,000 barrels per day

**Table 2.7. Production of Manufacturing Establishments, 2000–07 (In units indicated)**

| Products | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|---|
| Food and beverages | | | | | | | | |
| Biscuits (*1000 kilograms) | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Confectionery (*1000 kilograms) | 382 | 500 | 1,032 | 1,505 | 2,724 | 2,074 | 1056.8 | 1424.73 |
| Beer and stout (*1000 crates) | 188 | 401 | 915 | 771 | 942 | 1,012 | 832.1 | 780.11 |
| Spirits (*1000 litres) | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Soft drinks (*1000 | 1,429 | 1,701 | 1,872 | 1,113 | 1,584 | 1,908 | 2088.75 | 2431.7 |

[4]https://www.cia.gov/library/publications/the-world-factbook/print/sl.html
Sierra Leone Adding Value through Trade for Poverty Reduction. A Diagnostic Trade Integration Study (Sierra Leone DITIS), October 2006. (http://www.daco-sl.org/encyclopedia/1_gov/1_2/mti/DTIS_FinalNov06.pdf )/

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| crates) | | | | | | | | |
| Household products and construction | | | | | | | | |
| Matches (cartons) | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Washing soap (metric tons) | 493 | 149 | 460 | 492 | 268 | 417 | | |
| Cement (*1000 bags) | 1,593 | 3,108 | 2,883 | 3,390 | 18,046 | 18,045 | | |
| Nails (cases) | 0 | 0 | 0 | 0 | 0 | 0 | | |
| Paint (*1000 litres) | 394 | 318 | 744 | 725 | 169 | 135 | 649 | 713.6 |
| Miscellaneous | | | | | | | | |
| Cigarettes (*1000000 sticks) | ... | ... | ... | ... | ... | ... | | |
| Acetylene (*1000 cubic feet) | 100 | 91 | 99 | 114 | 12 | 219 | 291.33 | 191.45 |
| Carbon dioxide (*1000 cubic feet) | 49 | 0 | 26 | 2 | 0 | 0 | | |
| Oxygen (thousands of cubic feet) | 721 | 547 | 1,131 | 1,609 | 428 | 966 | 791.64 | 423.85 |
| Salt (metric tons) | 3,970 | 1,833 | 1,821 | 1,005 | 0 | 0 | | |
| | (Annual percentage change) | | | | | | | |
| Beer and stout | … | 113.0 | 128.1 | -15.7 | 22.0 | 7.0 | | |
| Soft drinks | 81.5 | 19.0 | 10.1 | -40.5 | 42.0 | 20.0 | | |
| Cigarettes | ... | ... | ... | ... | ... | ... | | |
| Sources: BSL Bulletin, Bank of Sierra Leone; and data provided by the Sierra Leonean authorities | | | | | | | | |

Greenhouse Gas (GHG) emissions of industrial processes includes emissions of all green house gases from industrial activities that are not related to energy. These industrial activities involves the chemical and physical transformation of materials resulting in the release of carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), hydro fluorocarbons (HFCs), per-fluorocarbons (PFCs), sulphur hexafluoride ($SF_6$), and Non-Methane Volatile Organic Carbons (NMVOCs).

#### 2.3.1.1 Description of Emission Sources in the Industrial Sector

The sub-sections below describe the various industrial activities that have been documented for this inventory exercise. Also, the mode of action resulting to the type of emission has been discussed.

### 2.3.1.2 2A1 Cement Production – CO2 and SO2

Cement is a material used to bind other materials together. It contains calcium, iron, aluminum, silicon and oxygen in varying proportion according to the type of cement. Cement production constitutes significant amount of $CO_2$ emission. It is made by roasting a powdered mixture of calcium carbonate (limestone), silica (sand) or aluminosilicate mineral (kaolin) clay or shale and iron oxide at a temperature of about 850 - 1500$^{o}$C in a rotating kiln. The following chemical reaction occurred during the production process.

$CaCO_3 + heat \rightarrow CaO + CO_2$

As the materials pass through the kiln, they loose water and carbon dioxide and ultimately form a "clinker" in which the materials are partially fused. The "clinker" is then grounded to a fine powder after the addition of a small amount of calcium sulphate (gypsum). Cement reacts in the presence of water to form a hydrated colloid of large surface area, which subsequently undergoes re-crystallization and reaction to bond to itself resulting to bricks or stone.

### 2.3.1.3. 2A2 Carbon dioxide ($CO_2$) Emission from Lime Production

Lime production in Sierra Leone is done locally in a non-mechanized manner in non-formal small-scale industry mainly by residents along the coastal areas in different parts in the country. It involves three main processes: preparation of the calcareous shell, calcination and hydration. Producers of the lime collect calcareous shell from Oyster and other mollusc. Unwanted materials are first removed from the shells (i.e. cleaning) and then the shells are packed with wood to be burnt. Limestone - mostly calcium carbonate present in the shell - is heated at high temperatures using wood to decompose the carbonate thus producing solid calcium oxide (CaO) and carbon dioxide ($CO_2$) at the end of the chemical cycle shown below. The $CO_2$ is driven off and is emitted to the atmosphere.

$CaCO_{3(s)} + heat \rightarrow CaO_{(s)} + CO_{2(g)}$

Unlike standard large-scale industries where, depending on product requirement (e.g. metallurgy, pulp & paper, construction materials, effluent treatment, water softening, pH control and soil stabilization), high calcium carbonate is processed in a manner to produce high percent and quality quicklime, this local lime produced is mainly for construction purposes and is not of very high quality (pers. obs.). Following the burning process, the lime is sieved to separate the burnt shell (lime) from the unburnt shell. The unburnt shell is recycled until the burning process is complete. The products are hydrated and after further processing, bagged for sale.

### 2.3.1.4 2A3 Limestone and Dolomite Use – Carbon dioxide ($CO_2$) Emission

Lime is a basic raw material used by a wide variety of industries including construction and agriculture. In some of its uses, limestone is sufficiently heated during the process to generate $CO_2$ as a by-product as described in the previous sections.

### 2.3.1.5 2A5 Asphalt Roofing - Non Methane Volatile Organic Carbons (NMVOCs)

Asphalt roofing production produces NMVOCs emissions and can also produce CO emissions in dependence of the production process used. Those emissions were not reported in the IR and apparently do not occur in the country.

### 2.3.1.6 2A6 Road Paving With Asphalt – Non Methane Volatile Organic Carbons (NMVOCs)

Asphalt road surfaces are composed of compacted aggregate and asphalt binder. Asphalt is a sticky, black and highly viscous liquid or semi-solid present in crude petroleum. NMVOC from asphalt is emitted during production and road surfacing operations. The emissions of NMVOC depend on the type of asphalt (slow, medium or rapid cure) and the amount of diluents. Asphalt is not produced in Sierra Leone, hence emissions are those resulting from road paving with asphalt.

### 2.3.1.7 2D2 Food and Drink – NMVOCs

Non Methane Volatile Organic Carbons (NMVOCs) emissions from food production
Based on data availability and industrial production contribution within Sierra Leone, the food production industries in Sierra Leone that have been are important to this study include those that produce the following products: flour and confectionary.

**Flour Production**

Flour is a white or brown powder that is made by grinding grains. White flour is produced in Sierra Leone by the Seaboard West Africa factory at Cline Town in the eastern part of Freetown. The flour produced is usually used to make bread, cakes and pastry. The technology involved is modern and involves the transformation of wheat to flour in large-size flourmill. The transformation involves several physical and chemical changes that resulted in NMVOCs emissions.

**Confectionary Production**

Confectionary is produced by only one industry. It involves the preparation of toffee-like products consisting of milk powder, chocolate liquor, sugar, flavours, etc. It is moulded or cut into the desired size and shape. The technology used in production is standard with the use of modern equipment.

**Biscuit Production**

Biscuits are made from good quality mill flour using chemical leavening agents and other optional ingredients. There is one plant in the country producing biscuits using modern equipment and technology.
NMVOCs are emitted during various stages in food processing especially during the heating of fats and oils and foodstuffs containing them, baking of cereals, flour and beans, fermentation in bread making, cooking of vegetables and meat and the drying of residues

Non Methane Volatile Organic Carbons (NMVOCs) emissions from drink production

Drink production includes both alcoholic and non-alcoholic beverages. In Sierra Leone, basically three types of beverages are being produced. These include beer, hard liquor (spirits) and soft drinks. NMVOCs are emitted during the production of the beverages

Beer production involves the use of malt and malt adjuncts along with hops for alcoholic fermentation followed by classification, carbonation and bottling. Hard liquor is manufactured from industrial alcohol that is treated to make it neutral. Flavour concentrates are added and the product allowed maturing to reduce hardness.

### 2.3.1.8 2F Consumption of Halocarbons and SF6

Sierra Leone will, as appropriate, provide information on anthropogenic emissions by sources of hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF6). However, these emissions were not estimated due the unavailability of activity data.

### Solvent and Other Product Use Sector

This sector covers mainly NMVOC emissions resulting from the use of solvents and other product containing volatile compounds. Also includes evaporative emissions of GHG arising from other types of product use for example, $N_2O$ emissions from medical use. When the solvents and other products are, or are produced from petroleum products, the carbon in the NMCOC emissions will be included in the $CO_2$ inventory if the Reference Approach for $CO_2$ emissions from energy is used.

Sierra Leone did not report emissions from this sector because the methodology for this category is still being developed. Hence these emissions were not estimated and reported in the sectoral and inventory reporting tables.

### Methodology and Data Sources

The general methodology employed to estimate emissions for each industrial process as recommended by IPCC involves multiplying product/material produced or consumed by a default emission factor ( due to country specify values) per unit of production/consumption expressed mathematically as:

$EMISSION_{ij} = A_j * Ef_{ij}$ .....(1)

where:

$EMISSION_{ij}$ = the process emission tonnes) of the greenhouse gas from an industrial sector

$A_j$ = the amount of produce of processing material in industrial sector j ( tones/yr)

$Ef_{ij}$ = the emission factor associated with gas i per unit of activity in industrial sector j (tonne/tonne).

Country activity data for industrial processes as well as consumption of industrial

products were collected to the extent possible. In virtually all circumstances, adequate data was not available to calculate local/country emission factor for the various industrial sector. Consequently, recommended IPCC default values were employed in all circumstances where country-specific (local) values were not available.

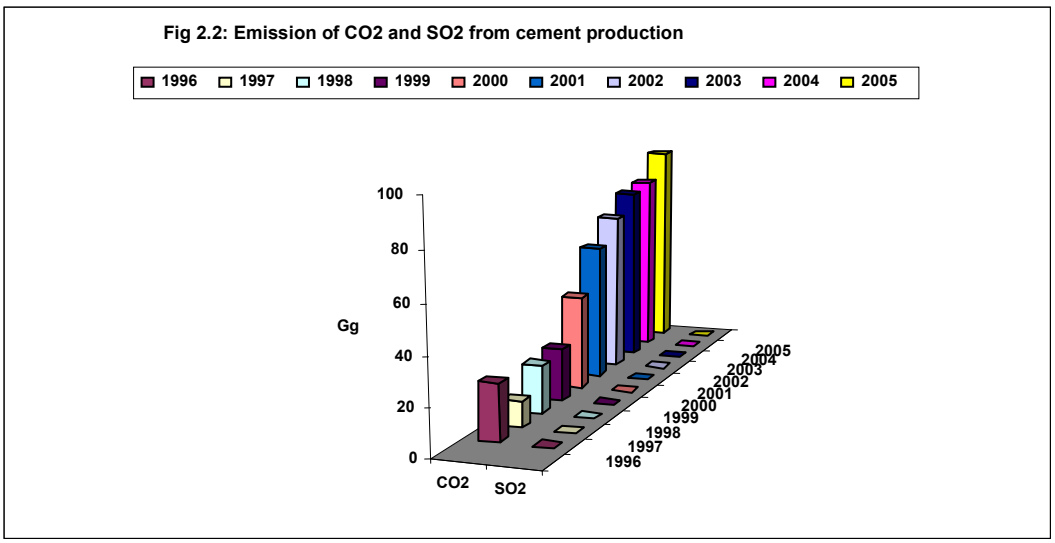
### 2.3.2 Results of estimation of emissions from industrial processes

#### 2.3.2.1 Emissions from Cement Production

The following tables give results of various GHGs emissions from the different industrial processes considered in this study.

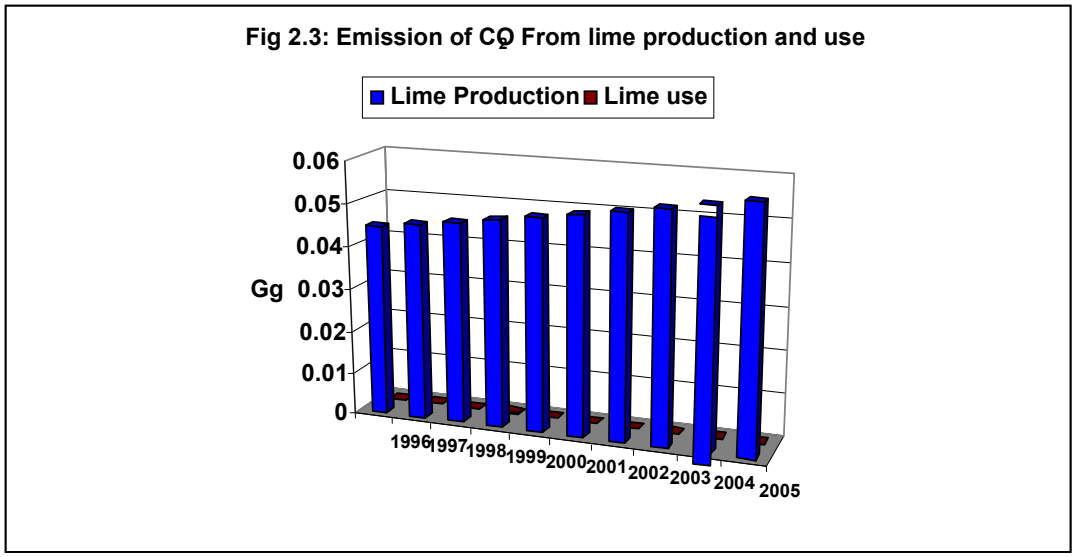
**Table 2.8: GHG emission from cement production**

| Year | $CO_2$ emissions (Gg) | $SO_2$ emissions (Gg) * $10^{-3}$ |
|---|---|---|
| 1996 | 24.09 | 14.45 |
| 1997 | 11.05 | 6.63 |
| 1998 | 20.36 | 12.21 |
| 1999 | 21.99 | 13.20 |
| 2000 | 39.55 | 23.73 |
| 2001 | 56.63 | 33.98 |
| 2002 | 66.03 | 39.62 |
| 2003 | 73.53 | 44.12 |
| 2004 | 75.53 | 45.49 |
| 2005 | 86.07 | 51.64 |
| TOTAL | 474.83 | 285.07 |




***Greenhouse Gas emissions from Lime Production and Use***

| Table 2.9: GHG emission from lime production and Use | | |
|---|---|---|
| **Year** | **$CO_2$ emissions (Gg) from Lime Production** | **$CO_2$ emissions (Gg) from Lime Use $*10^{-6}$** |
| 1996 | 0.0447 | 64.11 |
| 1997 | 0.0459 | 65.81 |
| 1998 | 0.0471 | 67.55 |
| 1999 | 0.0484 | 69.34 |
| 2000 | 0.0497 | 71.17 |
| 2001 | 0.0510 | 73.05 |
| 2002 | 0.0524 | 74.99 |
| 2003 | 0.0538 | 76.97 |
| 2004 | 0.0552 | 79.00 |
| 2005 | 0.0567 | 81.10 |
| **TOTAL** | **0.1014** | **723.08** |



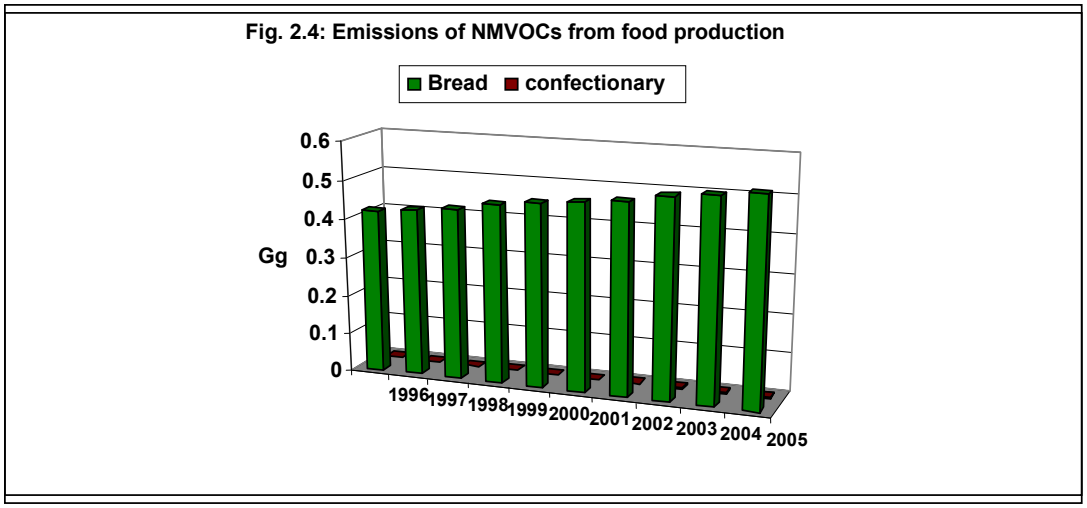

### 2.3.2.2 Greenhouse Gas emissions from Road Paving

| Table 2.10: GHG emission from road paving with asphalt | |
|---|---|
| **Year** | **NMVOC emissions (Gg)** |
| 1996 – 2005 | 49, 300, 000. 00 |
| **Total** | **49, 300, 000. 00** |

### 2.3.2.3 Greenhouse Gas emissions from Food Production

**Table 2.11: GHG emission from Food Production**

| Year | $CO_2$ emissions (Gg) from Bread | NMVOC emissions (Gg) from Confectionery |
|---|---|---|
| 1996 | 0.42 | 0.000344 |
| 1997 | 0.43 | 0.000353 |
| 1998 | 0.44 | 0.000362 |
| 1999 | 0.46 | 0.000372 |
| 2000 | 0.47 | 0.000382 |
| 2001 | 0.48 | 0.000500 |
| 2002 | 0.49 | 0.001030 |
| 2003 | 0.51 | 0.001505 |
| 2004 | 0.52 | 0.002724 |
| 2005 | 0.53 | 0.002074 |
| **TOTAL** | **4.75** | **0.009648** |

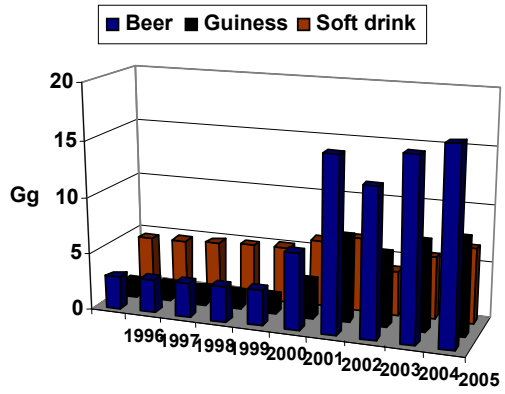



### 2.3.2.4 Drink Production

Data on beer production in 2000, 2001 and 2002 supplied by Statistics Sierra Leone. The tables below show emission results from drink production (beer, Guinness, malt and spirit) for the period under review.

| Table 2.12: GHG emission from Production of Beverages | | | |
|---|---|---|---|
| **Year** | **NMVOC emissions (Gg) $*10^{-8}$ from Beer** | **NMVOC emissions (Gg) $*10^{-8}$ from Guinness** | **NMVOC emissions (Gg) $*10^{-8}$ from Soft drinks** |
| 1996 | 2.86 | 1.40 | 4.51 |
| 1997 | 2.93 | 1.44 | 4.62 |
| 1998 | 3.01 | 1.48 | 4.75 |
| 1999 | 3.10 | 1.52 | 4.87 |
| 2000 | 3.18 | 1.56 | 5.00 |
| 2001 | 6.78 | 3.33 | 5.95 |
| 2002 | 15.45 | 7.61 | 6.55 |
| 2003 | 13.03 | 6.38 | 3.90 |
| 2004 | 15.90 | 7.84 | 5.54 |
| 2005 | 17.08 | 8.42 | 6.68 |
| **TOTAL** | **83.3** | **40.97** | **52.37** |

**Fig. 2.5: Emission of NMVOCs (* $10^{-8}$) from drink production**




### 2.3.2.5 Emissions of NMVOC from Alcohol Beverage Production

In 2000 Sierra Leone Brewery Limited produced about 0.97 Hecto litres of Beer, about 0.446 Hectolitres of Guinness and about 1.429 Hectolitres of soft drinks. Production of these quantities of beverages resulted to emissions of about 3.18 for Beer, $1.56*10^{-8}$, for Guinness and $5.00*10^{-8}$ NMVOC for the soft drinks. Thus, in 2000, a total of $9.74*10^{-8}$ of NMVOC were produced due to production of beverages at Sierra Leone Brewery Limited.

### 2.3.2.6 Emissions of NMVOC from Bread and Other Food Production

Emissions from the production of bread and other food items. Bread production is responsible for 0.47 $CO_2$ of the emissions while production of meat, poultry and production of cakes has combined emission of about 0.000382 of NMVOCs.

### 2.3.3 Conclusions and recommendations

Presently, only the alcohol Beverage and Food Production sub-modules of the industrial sector of Sierra Leone can be assessed. Data on all other sub-modules are not readily available. An attempt was made to collect data on other sub-modules but this ended up being a useless exercise for this Inventory development process.

The data have not been properly recorded or not recorded at all. Some of the equipments are so old that labels have faded or non-existent. The Industrial Processes category is likely to be a big emitter because most of the equipment used is obsolete. These include used refrigerators, freezers, air conditioners, and compressor units that are leaking even at the time of importation.

It is recommended that a complete data gathering and collection study should be conducted for the Industrial processes category in Sierra Leone. Since this the second time this category is being assessed in Sierra Leone historical, data needs to be assembled in the data bank. Based on the collected data, it will be possible to extrapolate emissions for past year.
All emissions factors used are those from the 1996 Revised IPCC Guidelines on the development of National GHG emission (IPCC, OECD, IEA, UNEP, 1997).
The trend for the GHGs emitted from 1996 to 2005 shows a fairly general increase with some irregularities. It could be noted that data obtained by projection from existing data increased regularly during the pe gap years. Data supplied directly from offices/industries show an irregular trend. Consequently, the emissions from these data follow the same pattern.

Of the various GHGs investigated, NMVOC accounted for about 98% of the total emission with $CO_2$ accounting for the remaining 2%. Virtually all of the 98% of NMVOC was due to road paving with asphalt. This is consistent with observations from several other national communications. The significantly low emission from the mineral, chemical, drink and food industry points to the low level of development in Sierra Leone. With little or no industry whose activities involve processing of raw materials, the statistics obtained justifies the significantly low emission from these activities. Table 4.13 shows summary report of sectoral emission of industrial processes.

**Table 2.13 Overall emissions from industrial processes**

| | $CO_2$ | NMVOC |
|---|---|---|
| Cement | 474.83 | |
| Lime production and use | 0.1021 | |
| Road Paving with asphalt | | 49, 300, 000 |
| Food | | 4.7597 |
| Drinks | | 0.0000018 |

### 2.3.4 Uncertainties

Uncertainties in emission estimates for the various industrial processes are due in part

to inherent statistics obtained from sources from which data were obtained. In most cases, suggested emission factors from IPCC rather than country specific emission factors were used. Therefore uncertainties exists as to the precise accuracy of the emission factor used as these emission factors are not in any way ideally suited for the Sierra Leone situation. Also, for specific cases, such as lime, uncertainty exists in the assumed production and imports respectively as well as carbon dioxide produced from production and use. In other cases, uncertainty exists where available data that falls outside the period of investigation has to be extrapolated to the year under review. Such would have imparted some degree of uncertainty in the production and hence emission estimates.

The year 1999 was the time the civil conflict reached its peak in the capital Freetown. It is therefore not surprising that most institutions contacted for data were unable to produce data possibly due to lost data from their system.

In comparison to inventory results for the first National Communication on Climate Change Sierra Leone, emissions from the Second National Communication on Climate Change Sierra Leone was much higher reflecting increasing industrial activities.

In all categories where $SO_2$ emission occurs, emission is significantly lower (<1%) compared to carbon dioxide and NMVOCs.

## 2.4 Agriculture sector

### 2.4.1 Introduction

In accordance with the IPCC 1996 Guidelines the Agriculture sector considered greenhouse gas emissions from seven categories: 4A Enteric Fermentation; 4B Manure Management; 4C Rice Cultivation; 4D Agricultural Soils; 4E Prescribed Burning of Savannas; 4F Field Burning of Agricultural Residues and 4G Other.

Emissions in this sector were determined for the categories 4A, 4B (CH4) and 4C. The emissions from the categories 4B (N2O), 4D and 4E7 were not estimated due the unavailability of data, and the emissions from the category 4F were not estimated because its contribution to the emissions was considered insignificant.

The agriculture module of the inventory will consider green house gas emissions from enteric fermentation and manure management, flooded rice fields, prescribed burning of savannas, field burning of agricultural residues and agricultural soils, subject to availability of the relevant data in the primary, secondary and/or default status.

The sector of agriculture has recently received a boost in budgetary allocations from 1.6% in 2007 to 7.6% in 2009 and to more than 10 %, including salaries and interest rates, in 2010; and, it is mainly characterized by pastoral and farming activities that

are now transforming from the subsistent level to a more intensively mechanized and large scale based farming as a result of the introduction of the new agricultural commercialization policy of the present government. This increasing investment in the agricultural sector is quite likely to increase levels of production and subsequently the relative quantum of emissions from the sector, especially methane ($CH_4$) from the rice sub-sector, and carbon dioxide ($CO_2$) and other noxious gases ($NO_X$) from the slash and burn culture of virgin bolilands, grassland-savannahs and forests, inland valley and mangrove swamps and farm bush clearing.

The sector of agriculture accounts for almost 40% of Sierra Leone's GDP, of which livestock and crops (not including tree crops) represent 3.15 % and 32.39 %, respectively. On a sub-sectoral basis, the contributions of crops and livestock to GDP growth of the agricultural sector were estimated at 3.02% and 0.42 %, respectively, for 2008[6].

The agriculture sector includes pastoral and farming activities. Three main livestock production systems exist in Sierra Leone. These include:

Pastoral production: as part of pastureland management. Pastoralists move over long distances, from one region to another or from one country to another Agro-pastoral production: this system is used in the intermediate zone where farming is the main activity of the agro-pastoralists, and cattle breeding makes up their secondary activity. It integrates the urban and peri-urban farming systems which involves supplementary feeding;

Intensive production: in this system, animals are confined and generally used for meat production. This type of cattle farming is called fattening: animals raised in pastureland are given high nutritive feed over a long period time, which enable them to quickly put on weight just before being slaughtered.

Crop production is extensive; it is poorly mechanized and uses little inputs and heavily dependent on rainfall. Cereals are the main crop and staple food as they represent 80% to 90% of caloric intake of the population in the country. In addition to cereal crops (millet, sorghum, maize, and so on), there are tubers (cassava, sweet potatoes and potatoes), cash crop (groundnut, cotton, tiger nut, sugar cane and tobacco) and finally vegetable crops (onion, tomato, hot pepper and pepper). Land areas used for cereal production have not changed much over time and represent more than 80% of the total surface areas devoted to these types of crop. As regards cash crops, land areas used for cowpea production are progressively approaching those used for millet and sorghum. This shows the importance of this crop for the population.

#### 2.4.1.1 Description of categories of sources

#### 2.4.1.1 4A Enteric Fermentation – CH4

Methane emissions (CH4) from cattle enteric fermentation occurs during the normal digestion process. The quality of methane gas from enteric fermentation is much

[6] MAFFS, (2009). Agricultural statistical bulletin. Vol. 1, pg 10-12.

higher than that of N2O from manure management. This is the second most significant source of emission after manure management.

#### 2.4.1.2 4B Manure Management – CH4

Methane emissions from manure management are due to animal waste decomposition. In Sierra Leone, the predominance of extensive cattle breeding greatly contributes to emissions of large quantities of methane gas produced under anaerobic conditions. Therefore, manure management is a source of nitrous oxide emission ($N_2O$). Based on $N_2O$ high conversion rate in $CO_2$ equivalent, manure management is the main source of emission in the subsector of agriculture in general and in particular in the livestock component.

#### 2.4.1.3 4B Emissions from Animal Waste Management Systems – $N_2O$

Three main livestock production systems exist in Sierra Leone. These include pastoral production, agro-pastoral production and intensive production. In the inventory 2000 the $N_2O$ emissions from this category were not estimated apparently due unavailability of data.

#### 2.4.1.4 4C Rice Cultivation – CH4

This source category of emissions is accounted for by methane produced in anaerobic decomposition of organic material in flooded rice fields from where the methane escapes to the atmosphere mainly by diffusive transport through the rice plants. The level of emissions is dependent on the rice species, number and duration of harvests, soil type, temperature, irrigation practices and fertilizer usage. The seasonally integrated $CH_4$ flux depends upon the input of organic carbon, water regimes, soil type, time and duration of drainage inter-alia.

#### 2.4.1.5 4D Agricultural Soils – $N_2O$

According to the IPCC 1996 Guidelines, in the category "N2O Emissions from Agricultural Soils" should be considered the following emissions: I) Direct emissions of N2O from agricultural soils (excluding effects of grazing animals, II) Direct soil emissions of N2O from animal production, III) Indirect emissions of N2O from nitrogen used in agriculture. These last ones include indirect emissions from atmospheric deposition of NH3 and NOx, and indirect emissions from leaching.

In the inventory 2000 the N2O emissions from this category were not estimated due to lack of adequate data. Organic soils are not sources of gas emissions in the country as the areas they occupy are marginal.

In Sierra Leone, soils are generally poor in minerals and organic matter. From the agro-geological perspective, soils are categorized as follows: (i) gross mineral soils; (ii0 little mature soils; (iii) sub-arid soils; (iv) ferruginous tropical/sandy soils; (v) hydromorphic soils and (vi) vertisols.

There are very few hydromorphic soils and vertisols (categorized as organic soils) which can directly produce $N_2O$.

When used, agricultural soils may produce or absorb nitrous oxide, carbon dioxide and/or methane. The main emissions are nitrous oxide ($N_2O$) and include: (i) direct emissions from agricultural soils; (ii) emissions from animal production and (iii) emission linked to the use of inorganic fertilizers in agriculture.

Cultivated areas are the main source of nitrous oxide emission ($N_2O$). Annual quantities produced vary from one year to another and are quite low. This variation is attributable to the annual variations in the amounts of inorganic fertilizer used, and to the production of grain legumes and other rain-fed crops. As the land areas covered by organic soils are marginal, their contribution is very marginal.

#### 2.4.1.6 4E Prescribed Burning of Savannas - Non-$CO_2$ Gases

Savannahs are tropical and subtropical formations with continuous grass coverage. Alternating wet and dry seasons control the growth of the savannahs with most of the growth occurring in the wet season.

Man-made and/or natural fires frequently occur during the dry season, resulting in nutrient recycling and re-growth. The burning of savannahs results in immediate emissions of carbon dioxide ($CO_2$) into the atmosphere. However, the $CO_2$ released into the atmosphere is reabsorbed during the next vegetation growth period and is therefore discounted as emissions. This same process also releases gases other than $CO_2$ and they include methane ($CH_4$), carbon monoxide (CO), Nitrous Oxide ($N_2O$) and other oxides of nitrogen (NOx). Unlike $CO_2$, emissions of this type should be accounted for because they are anthropogenic.

Cattle herders customarily burn areas of bush and grass in successive stages to produce feed for the animals, especially in the dry season, as a common practice in Sierra Leone. Burning usually begins after the end of the rainy season and ends only in the beginning of the next rainy season. The burning of old vegetation results in the growth of a new one, including grass much need as feed for cattle. Therefore, huge fires are set on the grasslands of Sierra Leone in the dry season every year and this result in the emission of $CO_2$ into the atmosphere.

#### 2.4.1.7 4F Field Burning of Agricultural Residues – Non-$CO_2$ Gases

Crop residues are increasingly used by producers for other purposes (cattle feeding, fuel, etc.) and are therefore collected after harvesting. Hence, burning of crop residues is not very common in Sierra Leone. This activity is a source $N_2O$, $NO_x$ and CO emissions even if the quantities burnt on-site are not very significant.

#### 2.4.1.8 Livestock Production

The relative contribution of the livestock sub-sector into the growth of the agricultural sector of Sierra Leone, as indicated above, reflects a minor fraction both in terms of production and growth.

Emissions from this sub-sector are therefore not anticipated to be significantly high.

The rearing of cattle in Sierra Leone is free range. It is based on animals feeding on grasses and other vegetation from the wild and involves movement of herders from one site to the other – a practice that often causes clashes and disputes as cattle sometimes invade cultivated field crops – with long distances being cover by nomadic groups at times.

Further to the above mode of feeding for cattle on wild grasses, the herders have an alternative mode based on the mixture of termite earth and loose salt (mostly local salt) to provide the necessary mineral salts required for normal growth of cattle.

**2.4.1.9 Data Sources**

A number of widely different estimates are abound for cattle population in Sierra Leone but the PEMS Division of the MAFFS has recently published data (tab.1) that could be used for the purpose of inventorying even though it could be fraught with anomalies due to constant migration of cattle in and out of Sierra Leone across the Guinea border along the north, north-western and north-eastern boundaries. The data on cattle for instance shows a dynamics of cattle heads rising from 94,800 (in 2000) to 156,989 (in 2003) and finally to 226,064 (in 2005). The dynamics of production for other types of livestock besides cattle is also given in table 1 above for a comprehensive inventorying of GHGs from enteric fermentation.

**2.4.1.10 Analysis of the Data**

An estimate of GHGs emissions from enteric fermentation was carried out for the First National Communication using the available data with some projections made from the recorded livestock population growth rates in existence then. That estimate might have been questioned by critics because of the likely impact of the 10 years war on dynamics of livestock population growth rate that should have been expected to decline. The current data indicates a trend in favour of the latter expectation and that gradually increases towards the end of the war. A sharp increase in growth rates and GHG emissions level is observed thereafter from 2002 to 2008 for almost all categories of livestock (see emissions data in the appendices).

The current calculation of GHGs emissions for livestock (enteric fermentation, manure management), rice cultivation from flooded fields and prescribed burning of savannah (for 1995 only due to data availability) is founded on much more reliable data that has been built on the efforts of the MAFFS, INGOs, NGOs and donor partners of Sierra Leone such as the DFID, EU, FAO, UNDP, UNIDO and others who have worked together in promoting farmers' resettlement, rehabilitation and commercialization initiatives to boost food security.

As a result it is now clearly evident that Sierra Leone manages cattle, sheep, goats, pigs, poultry and rabbits in various parts of the country (Tab. 1). Based on available data and projections that could be made from that said data, enteric fermentation is not a key source category of emissions. So too are the other categories of emissions

sources from Agriculture in Sierra Leone – with the exclusion of agricultural soils for which data has not been provided by MAFFS. If projections are made on the basis of production for the different types of livestock raised in the country over the thirteen year period – 1995 to 2008 - given in table 1, the following data would be obtained (tab. 2, 2a and Fig. 1).

### 2.4.1.11 Methodology

The inventory methodology used is from the 1996 revised version of the IPCC/OECD/IEA inventory guidelines.

### 2.4.1.12 Enteric Fermentation and Manure Management

Methane from enteric fermentation is derived from the digestive process by which carbohydrates are broken down by micro-organisms in the digestive tracks of livestock into simple molecules for absorption into the blood-stream. The amount of methane released in the process depends on the type, age and weight of the animal. It lso depends on the quantity and quality of the feed consumed. Methane from manure management, on the other hand, is produced as a result of its decomposition under anaerobic conditions in dairy farms, beef feedlots, piggery and poultry farms.

$N_2O$ emissions are also derived from manure management during storage, in which case some manure nitrogen is converted to $N_2O$. This source category (i.e. manure management) also accounts for emissions of $N_2O$ resulting from manure handling prior to its addition to the soil. However, manure related $N_2O$ emissions from soils are considered as agricultural soil emissions.
Emissions are calculated on the basis of IPCC guidelines by applying an emission factor – EF – (derived from a specific table) to the number of animal heads of each livestock type in the country to produce a total for enteric fermentation. Default emission factors are provided but it is recommended to use national emission factor, where available. The EF for this estimate is derived from tables 4-1 to 4-6 of the jointly produced IPCC workbook[7].
From the IPCC manual,
**Emissions of CH4 = EF * Population ÷ $10^3$ (to express in Gg)**
Where:
Emissions = Methane emissions from enteric fermentation, in t/yr or Gg $CH_4$ per year;
EF = Emissions factor for the specific population, Kg/head/year; and,
Population = the number of animal heads.

[7] IPCC, OECD, IEA, (1997). Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Workbook.

**Table 2.14 Results of Estimation of emission from Agriculture Sector**

The following results were obtained for the year2000:

| | |
|---|---|
| MODULE | AGRICULTURE |
| SUBMODULE | METHANE AND NITROUS OXIDE EMISSIONS FROM DOMESTIC LIVESTOCK ENTERIC FERMENTATION AND MANURE MANAGEMENT |
| WORKSHEET | 4-1 |
| SHEET | 1 OF 2 METHANE EMISSIONS FROM DOMESTIC LIVESTOCK ENTERIC FERMENTATION AND MANURE MANAGEMENT |
| COUNTRY | 0 |
| YEAR | 0 |

| | STEP 1 | | | STEP 2 | | STEP 3 |
|---|---|---|---|---|---|---|
| Livestock Type | A Number of Animals | B Emissions Factor for Enteric Fermentation (kg/head/yr) | C Emissions from Enteric Fermentation (t/yr) | D Emissions Factor for Manure Management (kg/head/yr) | E Emissions from Manure Management (t/yr) | F Total Annual Emissions from Domestic Livestock (Gg) |
| | | | C = (A x B)/1000 | | E = (A x D)/1000 | F =(C + E)/1000 |
| Dairy Cattle | 94800 | 36 | 3,412.80 | 1 | 94.80 | 3.51 |
| Non-dairy Cattle | | | 0.00 | | 0.00 | 0.00 |
| Buffalo | | | 0.00 | | 0.00 | 0.00 |
| Sheep | 109400 | 5 | 547.00 | 0.21 | 22.97 | 0.57 |
| Goats | 127950 | 5 | 639.75 | 0.22 | 28.15 | 0.67 |
| Camels | | | 0.00 | | 0.00 | 0.00 |
| Horses | | | 0.00 | | 0.00 | 0.00 |
| Mules & Asses | | | 0.00 | | 0.00 | 0.00 |
| Swine | 6020 | 1 | 6.02 | 2 | 12.04 | 0.02 |
| Poultry | 1193000 | 0.5 | 596.50 | 0.023 | 27.44 | 0.62 |
| **Totals** | | | 5,202.07 | | 185.40 | 5.39 |

**Table 2.15. Emissions of ch4 (gg) from enteric fermentation for 2000 to 2005**

| GHG Sources/Sinks Category | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|
| **Cattle** | 3.412800 | 3.924720 | 4.709664 | 5.654604 | 6.781932 | 8.138304 |
| **Sheep** | 0.547800 | 0.656400 | 0.787680 | 0.945215 | 1.134260 | 1.361110 |
| **Goats** | 0.639950 | 0.767700 | 0.921240 | 1.105490 | 1.326585 | 1.591905 |
| **Chickens** | 0.545500 | 0.681875 | 0.852344 | 1.065429 | 1.331787 | 1.664734 |
| **Ducks** | 0.051000 | 0.063750 | 0.796875 | 0.996095 | 0.124115 | 1.556395 |
| **Pigs** | 0.006020 | 0.007525 | 0.009406 | 0.011756 | 0.014697 | 0.18372 |
| **Rabbits** | ND | ND | ND | ND | ND | ND |
| **TOTAL** | 5.15207 | 6.10197 | 8.077209 | 9.778589 | 10.713376 | 14.330820 |

Fig.2.6 Methane (CH4) Emissions from Enteric Fermentation

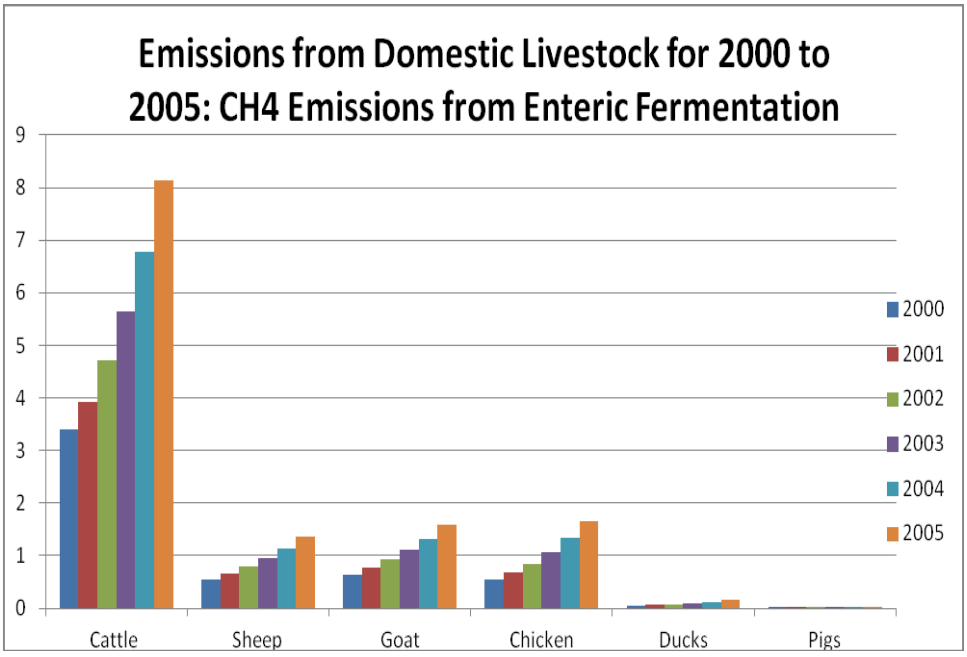
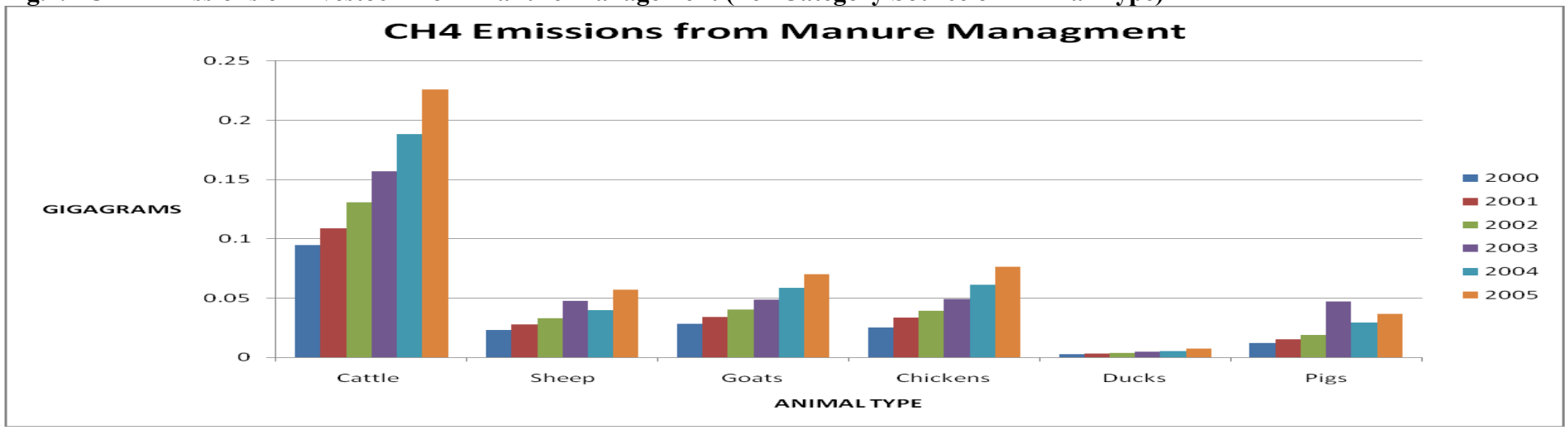


**Table 2.16: Emissions of $CH_4$ (t/yr) From Manure Management for the period 1995 to 2005**

| GHG Sources/Sinks Category | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cattle** | 214.2 | 190.4 | 166.6 | 142.8 | 122.4 | 94.8 | 109.0 | 130.8 | 157.0 | 188.4 | 326.1 |
| **Sheep** | 55.6 | 49.4 | 43.2 | 37.0 | 31.8 | 23.0 | 27.6 | 33.1 | 39.7 | 47.6 | 57.2 |
| **Goats** | 63.8 | 56.7 | 49.6 | 42.5 | 34.2 | 28.2 | 33.8 | 40.5 | 48.6 | 58.4 | 70.0 |
| **Poultry** | 58.0 | 51.5 | 45.1 | 38.6 | 33.1 | 27.4 | 34.3 | 3.7 | 53.4 | 67.0 | 83.7 |
| **Pigs** | 22.7 | 20.2 | 17.6 | 15.1 | 13.0 | 12.0 | 15.1 | 18.8 | 23.5 | 29.4 | 36.7 |
| **TOTAL** | **414.2** | **368.1** | **322.1** | **7836.4** | **234.5** | **185.4** | **219.8** | **226.9** | **322.2** | **390.8** | **573.7** |

The same formula above was applied using different emissions factors (from Tab. 4-4 of the Workbook) for manure management for the various categories of livestock.

**Fig.2.7 CH4 Emissions of Livestock from Manure Management (Per Category Source or Animal Type)**



### 2.4.2.1 Emissions from enteric fermentation

From table 2.15 a total of about 5.15207.are produced through enteric fermentation in livestock and from table 2.16 about 185.4 $CH_4$ are produced from manure management. This converts to a total of 5.39 Gg, $CH_4$ from livestock production in Sierra Leone in 2000..

### 2.4.2.2 Emissions from Manure Management

As shown at the bottom of table 2.16 manure deposited by livestock that are grazing extensively in pastures produces about, **185.4**, **t/yr** of $CH_4$ per year.

### Total Emissions from Livestock

Total Annual $CH_4$ Emissions form Livestock = $\Sigma CH_4$ from all categories of livestock for enteric fermentation + $\Sigma CH_4$ from Manure Management
Where:
$\Sigma CH_4$ = total methane emissions from enteric fermentation and manure management of all categories of livestock in t/yr or Gg $CH_4$/year (i.e. t/yr divided by $10^3$).
For example:
The Total Annual Emissions from domestic livestock in 2000 is therefore = 5.15207 + 185.4 = 5.39 **Gg of $CH_4$**
The same could be done and concluded for the other categories of sources of emission in the 10 year series above.

Note: n/d = Not determined.
Due to lack of adequate data and/or the intensive data collection required in the execution of the higher tiers [of the methodology], only tier 1 of the same has been applied here – i.e. higher tiers of the methodology have not been considered in the calculations.

**Fig. 2.8 Total CH4 Emissions for Domestic Livestock (Per Category Source or Animal Type)2000**

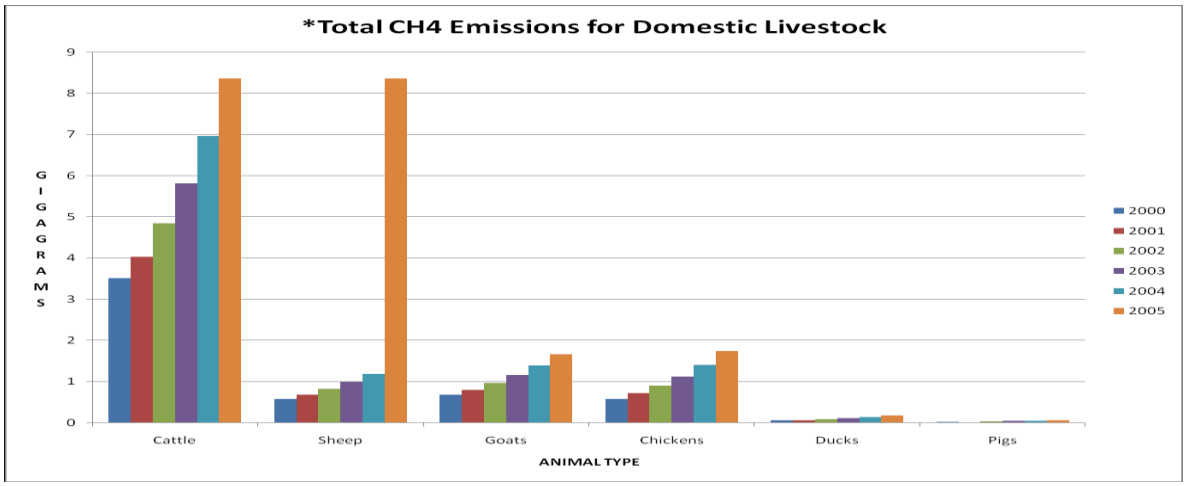



**Figure 2.8 TOTAL EMISSIONS FOR DOMESTIC LIVESTOCK-2000**

**Table 2.17: Summary table for total emission from domestic livestock 1995-2005**

| Year | Emissions from Enteric Fermentation | Manure Management | Total Emissions Domestic Livestock (Gg) |
|---|---|---|---|
| 1995 | 11,754.54 | 414.16 | 12.17 |
| 1996 | 10,448.48 | 368.14 | 10.82 |
| 1997 | 9,142.42 | 322.13 | 9.46 |
| 1998 | 7,836.36 | 276.11 | 8.11 |
| 1999 | 6,666.80 | 234.46 | 6.90 |
| 2000 | 5,202.07 | 185.40 | 5.39 |
| 2001 | 6,101.88 | 219.71 | 6.32 |
| 2002 | 6,508.89 | 226.97 | 6.74 |
| 2003 | 8,879.11 | 322.44 | 9.20 |
| 2004 | 10,713.77 | 390.78 | 11.00 |
| 2005 | 16,530.06 | 573.76 | 17.10 |

### 2.4.2.3 Emissions from Rice cultivation

IN 2000, $CH_4$ emission from rice cultivation was estimated based on data on large-scale irrigation scheme and areas under rain-fed rice, contained in the ONAHA 2005 report.

**Data**

Only data on land areas under irrigated rice production has been considered. This area amounted to 12,118 hectares in 2000. Water management regime considered for the two types of rice production are the permanent flooding for large-scale irrigation scheme and the rain flood for rain-fed rice respectively.

**Methodology**

The current resources of the Project and the support provided by the MAFFS in data collection have not been adequate enough to achieve the intensive data collection required for the execution of this tier of the methodology. Nevertheless, methane emissions from cultivated rice fields are calculated in this exercise with the use of available national data and the application of reasonable technical assumptions. A more generalized approach has been applied instead and where possible default data from the IPCC Guidelines Workbook has been adapted to Sierra Leone's GHG emissions from the Agricultural sector to account for emissions from the wet or lowland (irrigated, rain-fed and deep water) rice fields.

| | |
|---|---|
| **MODULE** | **AGRICULTURE** |
| **SUBMODULE** | **METHANE EMISSIONS FROM FLOODED RICE FIELDS** |
| **WORKSHEET** | **4-2** |
| **SHEET** | **1 OF 1** |
| **COUNTRY** | **0** |
| **YEAR** | **0** |

| Water Management Regime | | | A Harvested Area (1000 ha) | B Scaling Factor for Methane Emissions | C Correction Factor for Organic Amendment | D Seasonally Integrated Emission Factor for Continuously Flooded Rice without Organic Amendment ($g/m^2$) | E $CH_4$ Emissions (Gg) |
|---|---|---|---|---|---|---|---|
| | | | | | | | E = (A x B x C x D)/100 |
| Irrigated | Continuously Flooded | | 16638.7 | 1 | 1 | 20 | 3,327.74 |
| | Intermittently Flooded | Single Aeration | | | | | 0.00 |
| | | Multiple Aeration | 16638.7 | 1 | 1 | 20 | 3,327.74 |
| Rainfed | Flood Prone | | 33277.4 | 1 | 1 | 20 | 6,655.48 |
| | Drought Prone | | 8319.35 | 1 | 1 | 20 | 1,663.87 |
| Deep Water | Water Depth 50-100 cm | | 3327.4 | 1 | 1 | 20 | 665.48 |
| | Water Depth > 100 cm | | | | | | 0.00 |
| **Totals** | | | **78,201.55** | | | | **15,640.31** |

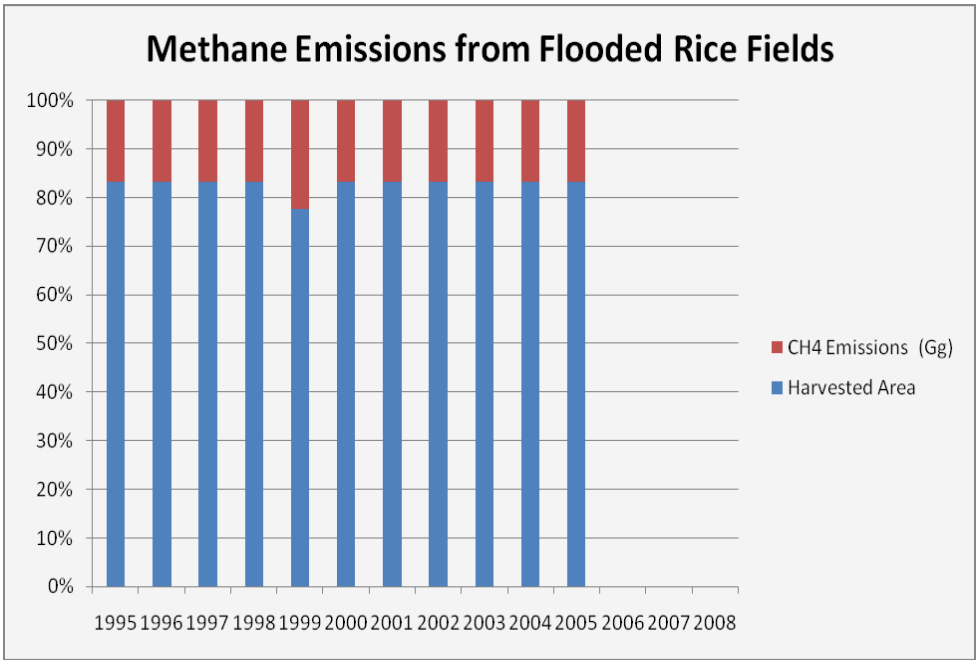


Figure 2.9 Methane emissions from flooded rice fields

**Table 2.18 Methane Emissions from Flooded Rice Fields**

| Year | Harvested Area | CH4 Emissions (Gg) |
|---|---|---|
| 1995 | 157,585.00 | 31,517.00 |
| 1996 | 184,099.00 | 36,819.80 |
| 1997 | 20,821.00 | 4,164.20 |
| 1998 | 154,301.00 | 30,860.20 |
| 1999 | 116,654.00 | 33,330.80 |
| 2000 | 78,201.55 | 15,640.31 |
| 2001 | 121,659.50 | 24,331.90 |
| 2002 | 161,272.40 | 32,572.04 |
| 2003 | 162,860.20 | 32,572.04 |
| 2004 | 200,581.90 | 40,116.38 |
| 2005 | 201,117.40 | 40,223.48 |

**Methodology for Emissions of methane from rice fields**

Emissions of methane from rice fields can be represented as follows:

$$\mathbf{Fc = EF * A * 10^{-12}}$$

Where:

- Fc = estimated annual emissions of methane from a particular rice water regime and for a given organic amendment, in Tg/yr or Gg;
- EF = methane emission factor integrated over integrated cropping season, in $g/m^2$;
- A = annual harvested area cultivated under the conditions specified above.

It is given by the cultivated area (converted into $m^2$) times the number of cropping seasons per year, i.e., in $m^2$/yr with 1000 ha = $10^7$ $m^2$.

**Table 2.19: $CH_4$ Emissions from Rice Cultivation in Sierra Leone for the Period 1995 to 2005 (in Gg)**

| Year | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Irrigated (continuously flooded rice fields).** | 6700 | 7834 | 886 | 6566 | 4964 | 3327.74 | 5177 | 6862.44 | 6930.2 | 8535.4 | 8558.14 |
| **Irrigated (Intermittently flooded rice fields with multiple aeration).** | 6700 | 7834 | 886 | 6566 | 4964 | 3327.74 | 5177 | 6862.44 | 6.930.2 | 8535.4 | 8558.14 |
| **Rainfed (flood prone) fields.** | 13420 | 15668 | 1772 | 13132 | 9928 | 6655.48 | 10354 | 13725.68 | 13860.4 | 17070.8 | 17116.4 |
| **Rainfed (drought prone) fields.** | 3355 | 3917 | 443 | 3283 | 2482 | 1663.87 | 2588.5 | 3431.4 | 3465.2 | 4267.7 | 4279.1 |
| **Deep water (Water Depth 50cm to 1m)** | 1342 | 1566.8 | 177.2 | 1313.2 | 992.8 | 665.48 | 1035.4 | 1372.56 | 1386.04 | 1707.08 | 1711.64 |
| **Total** | **31517** | **36819.8** | **4164.2** | **30860.2** | **23330.8** | **15640.31** | **24331.9** | **32254.48** | **32572.04** | **40116.38** | **40223.48** |

Assumptions:
Scaling for rice areas cultivated in each ecology is as follows (expressed in percentage of the total cultivated area): Irrigated continuously flooded is 10%; Irrigated intermittently flooded – multiple aeration – is 10%; Rain-fed (flood prone) is 20%; Rain-fed (drought prone) is 5%; and, Deep Water (50 – 100 cm depth) is 2%.

The number of cropping seasons adopted for irrigated/flooded, Rain-fed and Deep Water fields = 1, respectively for the following reason: (i) conditions of the civil war could not have allowed the practice of multiple cropping seasons; (ii) a study conducted for IFAD last year revealed that a majority of small holder farmers rarely do multiple cropping seasons these days because of increasing problems with pests (birds and rodents, especially) and changing climate/weather patterns and their negative impact on agricultural production[8].

Emission factor (EF) used in the calculations = 20 – the global arithmetic mean;

Scaling factors were obtained from the IPCC jointly produced Workbook

**Results**

**Rice cultivation**

In 2000, $CH_4$ emission from rice cultivation was estimated based on data on areas under rain-fed rice, contained in the Agricultural Bulletin.

In 2000 (base year), for the agriculture/livestock sector, the two main sources of emissions are cattle enteric fermentation and agricultural soils, with 53.42% and 43.27% respectively.

Table 2.19 shows that out of a total of about 15640.31 of the CH4, emissions from rice production activities 6655.48 come from the deep water fields, 3327.74 come from activities in irrigated rice fields.

**Prescribed Burning of Savannah**

**methodology**

A number of users of the draft Guidelines, especially in Africa, have suggested that savannahs should be divided into woody and grassland savannahs, if possible. For woody savannahs, the above-ground biomass densities prior to burning would be higher and the fraction oxidized should be lower as much as the standing woody biomass would not be burned. Over time, savannahs can degrade significantly as a result of human intervention and thus resulting in long-term loss of carbon in above-ground biomass and soils. In addition to the information requested in the Workbook, the annual carbon loss should be accounted for, if this occurs.

In the methodology, carbon released and other GHGs are estimated using the notation below and then a nitrogen-carbon ratio is applied to estimate total nitrogen content. The resulting estimates of emissions are converted to total weight using standard factors. Due to lack of the requisite data GHG emissions from prescribed burning has been calculated for the 1994/1995 planting season only, on the basis of the available data from MAFFS i.e. Table 6 below.

Areas cleared for cultivation of rice in the upland ecology of North and North/Central Sierra Leone are assumed to have been savannah grasslands whereas those cleared on Boli and riverine ecologies, which are predominantly grasslands are considered under the same category too. The data on burnt areas of upland rice (75,790 ha), Boli/Boliland (21,836 ha) and riverine (6,897ha) ecologies is derived from table 2.20 below.

**Table 2.20 Data on burnt areas of upland rice**

| | |
|---|---|
| Fraction of total savannas burned annually | 0.70 |
| Above ground biomass density | 6.00 tons dry matter/ha (average) |
| Fraction of dry matter actually burned | 0.95 |
| Fraction of above ground biomass that is living | 0.55 |
| Fraction oxidized | 0.90 |
| Carbon fraction | 0.45 |

The following relationships were used in the estimation.

Quantity of Biomass =Area of savannas burnt * Average biomass density * Fraction of exposed biomass that actually burns.

Carbon released = Quantity of biomass burned * Fraction oxidized * Carbon fraction

**Total Carbon Released (t C) = Biomass Burned (t dm) x Fraction Oxidized [Fraction that is Dead x Carbon Content of Dead Biomass (t C/t dm)] + Fraction that is Live x Carbon Content of Live Biomass (t C/t dm)**

**Table 2.21: Area (HA) and Production (MT) of Rice Per Ecology Per Region and District 1994/95**

| REGION/ DISTRICT | UPLAND | | IVS | | MANGROVES | | RIVERINE | | BOLI | | TOTAL | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AREA | PROD. | AREA | PROD. | AREA | PROD. | AREA | PROD. | AREA | PROD. | AREA | PROD. |
| **SOUTH/ WEST** | **28,834** | **37,809** | **9,737** | **26,130** | **17,160** | **39,199** | **6,551** | **14,982** | **5,419** | **6,806** | **67,701** | **124,926** |
| Moyamba | 23,302 | 30,562 | 8,592 | 22,932 | 11,724 | 26,778 | 4,687 | 10,719 | 4,419 | 6,806 | 53,724 | 97,797 |
| Bonthe | 5,532 | 7,247 | 1,145 | 3,198 | 5,436 | 12,421 | 1,263 | 4,263 | - | - | 13,977 | 27,129 |
| **SOUTH** | **26,055** | **24,788** | **12,272** | **27,666** | **-** | **-** | **-** | **-** | **-** | **-** | **38,357** | **52,454** |
| Bo | 17,720 | 15,771 | 10,295 | 22,932 | - | - | - | - | - | - | 28,015 | 38,091 |
| Pujehun | 8,365 | 9,017 | 1,977 | 3,198 | - | - | - | - | - | - | 10,342 | 14,363 |
| **EAST** | **28,878** | **18,232** | **17,126** | **19,160** | **-** | **-** | **-** | **-** | **-** | **-** | **46,004** | **37,390** |
| Kailahun | 7,720 | 5,558 | 9,006 | 8,141 | - | - | - | - | - | - | 16,726 | 13,699 |
| Kenema | 21,158 | 12,674 | 8,120 | 11,019 | - | - | - | - | - | - | 29,278 | 23,693 |
| **NORTH /CENTRAL** | **24,797** | **25,537** | **20,288** | **34,556** | **-** | **-** | **-** | **-** | **6,097** | **5,609** | **51,182** | **65,702** |
| Tonkolili | 8,858 | 7,972 | 6,336 | 8,801 | - | - | - | - | 6,097 | 5,609 | 21,291 | 22,382 |
| Kono | 15,939 | 17,565 | 13,952 | 25,765 | - | - | - | - | - | - | 29,891 | 43,320 |
| **NORTH** | **28,650** | **27,924** | **24,560** | **33,640** | **-** | **-** | **-** | **-** | **7,469** | **7,173** | **60,679** | **68,737** |
| Bombali | 18,884 | 17,279 | 8,702 | 16,480 | - | - | - | - | 7,102 | 6,818 | 34,688 | 40,579 |
| Koinadugu | 9,766 | 10,645 | 15,858 | 17,158 | - | - | - | - | 367 | 355 | 25,991 | 28,158 |
| NORTH/ WEST | **22,343** | **20,694** | **11,141** | **22,926** | **27,153** | **48,905** | **346** | **775** | **2,851** | **2,120** | **63,834** | **95,420** |
| Port Loko | 12,015 | 10,573 | 7,187 | 14,654 | 5,858 | 9,483 | - | - | 1,369 | 697 | 26,429 | 35,579 |
| Kambia | 10,328 | 10,121 | 3,954 | 8,272 | 21,295 | 39,422 | 346 | 775 | 1,482 | 1,423 | 37,405 | 28,158 |
| **WESTERN AREA** | **463** | **425** | **132** | **268** | **-** | **-** | **-** | **-** | **-** | **-** | **595** | **693** |
| **SIERRA LEONE** | **160,050** | **155,409** | **95,256** | **164,346** | **44,313** | **88,104** | **6,897** | **15,757** | **21,836** | **21,708** | **328,352** | **445,324** |

**Source: PEMSD/DAF**

**Table 2.22: Emissions from Prescribed Savannah Burning for the 1994/95 Planting Season (in Gg)**

| Ecology GHG Emissions | Upland | Boliland | Riverine | Total Carbon Released (Gg C) | Total Nitrogen Content | Emissions from Savannah Burning (Gg C) |
|---|---|---|---|---|---|---|
| Carbon Released (Gg C) | 93,798.65 | 27,024.51 | 8,535.81 | 129,358.97 | 776.15 | 129,358.97 |
| $CH_4$ | - | - | - | - | - | 689.91 |
| CO | - | - | - | - | - | 24,147.01 |
| $N_2O$ | - | - | - | - | - | 8.54 |
| $NO_x$ | - | - | - | - | - | 308.58 |

### 2.4.2.4 Emissions from Savannah burning (bushfires)

Net CO2 released from the burning of savannah is considered to be zero because most of the grasses that regenerate during the following wet season absorb the CO2. Other gases such as CH4, $CO_2$, $N_2O$ and $NO_x$ are emitted due to incomplete burning and other factors such as temperature.

**Results**

From table 2.22, 35%.of the emissions from Prescribed Burning of Savannah are CO,5% represent emissions of CH4, and emissions of $NO_x$ represent about 40%. Emissions of $N_20$ are insignificant. It should be noted that only three years of data were available for savannah burning.

### 2.4.2.5 Emissions from Agriculture Residue Burning

Similar to the burning of savannas, crop residue burning is not thought to be a net source of $CO_2$ but is a significant source of $CH_4$, $CO_2$, NOx and $N_20$. However only one survey has been carried out on crop residue burning, and to establish a trend that will be usable with limited bias, more surveys should be conducted as crop production varies with climate.

**Results**

Emissions of trace gases due to burning of agricultural residues are mainly in the form of CO representing about 65% of the total emissions, while emissions of CH4 and NOx contributed about35%. Emissions of $N_20$ were comparatively insignificant.

### 2.4.2.6 Emissions of Non-$C0_2$ trace gases from Agricultural Soils

Emissions from this source category are usually the highest from agriculture for obvious reasons. Unfortunately, treatment of this source category has not been possible due to lack of data, which we strongly believe could have been produced by MAFFS if more effort was made by the Agricultural Extension and PEMS divisions.

Organic soils are not sources of gas emissions as the areas they occupy are marginal. Regarding prescribed burning of savannah and field burning of agricultural residues; emissions do not vary much from one year to another and are low. This small variation may be linked to the fact, on the one hand, that these activities are decreasing because farmers are increasingly using harvested agricultural residues as domestic fuel and, on the other, these residues are not taken into account.

### 2.4.3 Constraints in the development of the inventory for the agriculture sector

Data on flood duration and water depth in rice production ecology should be determined. Local emission factors and coefficients to be used in the calculation of emissions from rice production should be developed locally or in collaboration with other regional institutions.

Only one survey has been carried out on crop residue burning, and to establish a trend that will be usable with limited bias, more surveys should be conducted as crop production varies with climate.

There is no country specific data on savannah burning. Figures used were adopted from the INC covering the period 1990, 1991 and 1993. Default conversion factors from IPCC guidelines were used.

Annual fertilizer import figures were used in the calculations because it could not be determined how much of such quantities were actually applied on the soil. There are no organic (Histosols) soils in Sierra Leone. All other values used in the calculations were obtained from the 1996 Revised IPCC guidelines as default values.

**Difficulties**

Absence of monitoring of farm clearing;
Low monitoring capacity of bush fires in the country;
Total lack of data on some sub sectors such as the use of biomass (notably agricultural residues) as fuels;
Absence of conversion factors concerning the dry weight of some foodstuff (vegetables for example);
Inexistence of reliable data on the land areas occupied by organic soils even though they are very few in Sierra Leone.

**Recommendations**

Integrate into the next agricultural and livestock censuses the concerns related to the agricultural sectors inventories; set up an efficient monitoring mechanism of the progression of cultivated areas and bush fires.

## 2.5 Emissions of Greenhouse Gases from Land-Use Change and Forestry

### 2.5.1 Introduction

In the IPCC 1996 Guidelines the Land-Use Change & Forestry sector looks at greenhouse gas emissions and removals from five categories: 5A Changes in Forest and Other Woody Biomass Stocks; 5B Forest and Grassland Conversion; 5C Abandonment of Managed Lands; 5D CO2 Emissions and Removals from Soil and 5E Other.

66. According to the information provided in sectoral report, CO2 emissions and removals in this sector were determined for the categories 5A, 5B and 5C. The emissions from the category 5D CO2 Emissions and Removals from Soil were not estimated due the unavailability of activity data.

According to IPCC, OECD, IEA (1997) land-use changes that result in alterations in the amount of biomass on the land produce a net exchange of GHGs between the atmosphere and the land surface. Biomass is a shorthand for organic material, both above ground and below ground and both living and dead, e.g. tree crops, tree litter, roots, etc. the primary land-use changes that result in GHG emissions and uptake are conversion of forests to non-forest (e.g. conversion of forests to pasture or cropland) and conversion of non-forests to forests (e.g. establishment of plantations).

When forests are cleared, most of the carbon in the cleared biomass is released to the atmosphere as $CO_2$. Clearing by burning (e.g. biomass burning) releases other gases in addition to $CO_2$, which are by-products of incomplete combustion. These include $CH_4$, CO, $N_20$ and $NO_x$. $CO_2$ emissions from land clearing may not imply a net release of $CO_2$ to the atmosphere but emissions of these gases are net transfers from the biosphere to the atmosphere.

Land-use changes also result in GHG emissions through the disturbance of forest soils. When forests are converted to croplands, an average of about …….of the soils carbon is released as $CO_2$, primarily through oxidation of organic matter. Loss of forests may also result in increased net $CH_4$ emissions to the atmosphere since forest soils are a natural sink of $CH_4$ , i.e. forest soils absorb atmospheric $CH_4$.

The total land area in Sierra Leone is 72,300 $km^2$. Of this, 60,650 $km^2$ is classified as upland and 11,650 $km^2$ as lowland. It is estimated that some 53,620 $km^2$ (5.36 million ha) are suitable for crop production (i.e. 74.2% of total land area). The remaining 18,860 $km^2$ (25.8 %) of the country is described as non-arable land, which includes rocky land, towns, rivers and creeks (MANR/FAO, 1992).
Sources of Data

Data on total land area used for production of major crop types in the country for different ecologies as well as on yield studies and production of other major food crops were obtained from the Planning, Evaluation, Monitoring and Statistics Department (PEMSD) of the Ministry of Agriculture, Forestry and Food Security (MAFFS). Data on National GIS database of total land area on various land-use types was obtained from M.Sc.

Thesis (Kamara, 2010) whereas data on forest products and plantations were obtained from the Forestry division of the Ministry of Agriculture, Forestry and Food Security, the FAO Book (2005) and from M.Sc. Thesis (Conteh, 1997). Default values for the different categories of forest types were obtained from the 2006 IPCC guidelines. For instance, an average annual growth rate of 13.5 tonnes dry matter per hectare and 0.015 kilotonnes dry matter per one thousand trees was used as default value for plantations and forest trees and cash crops respectively. The method for calculating the net changes in biomass stocks is shown in the following equations:

Methodology

The method described in the revised 1996 Intergovernmental Panel on Climate Change (IPCC) manual of inventory guidelines was used to estimate the net carbon dioxide fluxes and other GHG emissions from the above land-use practices. Country activity data were collected to the extent possible and IPCC default factors were used where country data were not available riod investigated. This is due to the 2.6% growth applied to data for the

#### 2.5.1.1 5A Changes in Forest and other Woody Biomass Stocks – CO2

The following methods were used for the estimation of emissions under the *"changes in forest and other woody biomass stocks"* category.

Hectares of land in particular category (e.g. plantation) × average annual growth per hectare in biomass (IPCC default value) = gross annual growth increment (total biomass increment being the sum of all relevant categories)

Total harvest by category (including fuelwood gathering) × expansion ratio to treat slash (IPCC default value) = gross annual biomass loss

Total annual growth increment – total annual biomass loss = annual biomass change (positive or negative)

For non-forest trees such as village and farm trees, accounting was done on the basis of numbers of trees (in thousands) rather than for hectares of land.

Calculations were initially done in tonnes of dry biomass, which was then converted to carbon for estimating $CO_2$ emission. A general default value of 0.5t C/t dry biomass (IPCC, 2006) was used for all biomass conversions.

#### 2.5.1.2 5B Forest and Grassland Conversion – $CO_2$ and Non $CO_2$ Emissions

Emissions of carbon dioxide due to forest and grassland conversions were calculated through a sequence of steps involving the determination of the following:
the net change in aboveground biomass carbon;
the portion of this change that is burned in the first year (either on- or off-site) versus the amount left to decay over a longer time period; for the burned portion, loss to the atmosphere versus long-term storage in charcoal current emissions from decay of biomass cleared over the previous decade current releases of carbon from soils due to conversions (decomposition of soil organic matter)

The net $CO_2$ flux is calculated from the equation below:

Average annual land cleared over the period (default of 10 years) × Average quantity of aboveground dry biomass per hectare remaining on site as slash but not burned (either oxidized or converted to charcoal) × Carbon content of dry biomass
=
$CO_2$ flux in the inventory year from historical land clearing of the aboveground vegetation

### 2.5.1.3 5C Abandonment of Managed Land – $C0_2$

Emissions from Abandonment of Managed Lands were determined from the following expression.

Total area abandoned (over the previous 20 years including the inventory year) × Average annual uptake of carbon in the aboveground biomass (IPCC default value)

Biomass carbon gained

### 2.5.1.4 5D CO2 Emissions and Removals from Soil – $C0_2$

As no data was available for the Soils category, emissions were not assessed.

### 2.5.2 Results of Estimation of Emission from Land-Use Change and Forestry

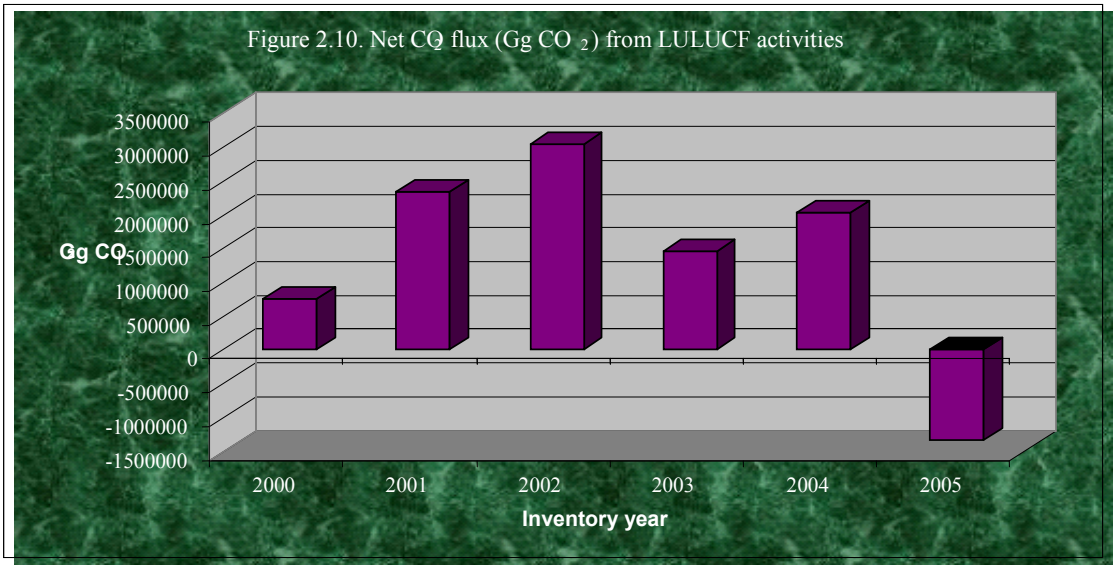
$C0_2$ emissions and sequestration by LULUCF activities in Sierra Leone

The results of the second greenhouse gas inventory of emissions by sources and removals by sinks related to LULUCF are summarized in the Tables and figures that follow. The results indicate that the LULUCF sector has evolved into a major $CO_2$ emission source with a potential to become an important $CO_2$ sink as noted in 2005, depending on the dynamics of the various land-use activities (Table 3 and Fig. 3).

In Table 3, the net flux (emission or removal) of $CO_2$ (Column 1) is due to emissions from Changes in forests and other woody biomass (Column 2), emissions from forest and grassland conversion (Column 3) and removals from abandonment of managed lands (Column 4). The emissions due to changes in forests and other woody biomass stocks and forests and grasslands conversions are shown in Figure 4 below.

Table 2.23. Total $CO_2$ removal (Gg) from the LULUCF sector of Sierra Leone

| Year | Column 1 | Column 2 | Column 3 | Column 4 |
|---|---|---|---|---|
| | Total $CO_2$ uptake/removal [Column= (Column 2 + Column 3 + Column 4)] | $CO_2$ emissions from Changes in Forest and other woody biomass stocks | $CO_2$ emissions from Forest and Grassland Conversion | $CO_2$ removals from Abandonment of Managed Lands |
| 2000 | 752748.7 | 1066501.5 | 5331300.6 | -5645053.3 |
| 2001 | 2336792.1 | 1900376.1 | 6765401.7 | -6328985.7 |
| 2002 | 3048731.2 | 2661336.1 | 8072770.6 | -7685375.5 |
| 2003 | 1466477.9 | 2771930.7 | 8280046.2 | -9585499.0 |
| 2004 | 2031946.8 | 3419216.8 | 9369871.9 | -10757142 |
| 2005 | -1342727.6 | 3417217.5 | 9387475.8 | -14147420.8 |




### 2.5.2.1 $CO_2$ Emissions from Changes in Forest and Other Woody Biomass Stock

The estimated total $CO_2$ emissions by the country's sources (changes in forest and other woody biomass stocks $1.06 \times 10^6$ Gg and forest and grassland conversion $5.33 \times 10^6$ Gg) (Fig. 4 below) amounted to $6.24 \times 10^7$ Gg.

### 2.5.2.2 Emissions from Forests and Grasslands Conversion

A total of $2.7 \times 10^6$ Gg non-$CO_2$ trace gases were estimated to have been emitted during the period considered in this inventory. Oxides of nitrogen ($NO_x$) accounted for 73.8 percent of the total non-$CO_2$ trace gas emissions related to forests and grassland conversion, CO emissions represent 21.7 percent, nitrous oxide ($N_2O$) 2.5% and methane ($CH_4$) constitutes 2.0% of the total emissions (Figure 7).

### 2.5.2.3 5C Emissions from Abandonment of Managed Lands

The total $CO_2$ removal by abandonment of managed lands (Fig. 5 below) was estimated at $-5.41 \times 10^7$ Gg. This gives the net $CO_2$ emission in the land-use change and forestry sector as $8.29 \times 10^6$ Gg. The sector is therefore a significant source of $CO_2$ emissions in Sierra Leone. These two land-use activities have resulted into significant emissions of $CO_2$, to the extent that they far outweigh the $CO_2$ sequestration due to abandonment of managed lands and hence the net $CO_2$ emission due to LULUCF.

Emissions of carbon dioxide were due mainly to two major land-use practices. These are forest and grassland conversions and changes in forests and other woody biomass stocks (Figure 4). This is mainly due to the fact that these are activities that often result in removal of sink materials (plants/vegetation). For example, when forests or swamps are cleared either for the purpose of mining or for crop cultivation, the cleared vegetation is either burned down or left to rot often aerobically, both of which processes lead to $CO_2$ release. When forests or farm-bushes are cleared for agricultural purposes and are re-growing, the biomass before conversion (estimated mean value of 20 tonnes dm/ha) is in most cases greater than that after conversion (10 tonnes dm/ha) and hence the observed net $CO_2$ emissions in this sub-category. Furthermore, current data suggests that there has been a gradual increase in commercial

harvest activities for the different purposes including logging and traditional fuel wood consumption following the reduction in hostilities in 2000 and the final declaration of the end of the war in 2002. This commercial harvest of forest products (timber, fuel wood etc.) have apparently become more important than the traditional practice of growing non-forest trees such as fruit trees and cash crops in determining the net $CO_2$ flux in this sub-category. This escalation in logging activities resulting in the deforestation of vast areas of forest lands led to the imposition of a ban on timber exportation in 2009 by a presidential decree.

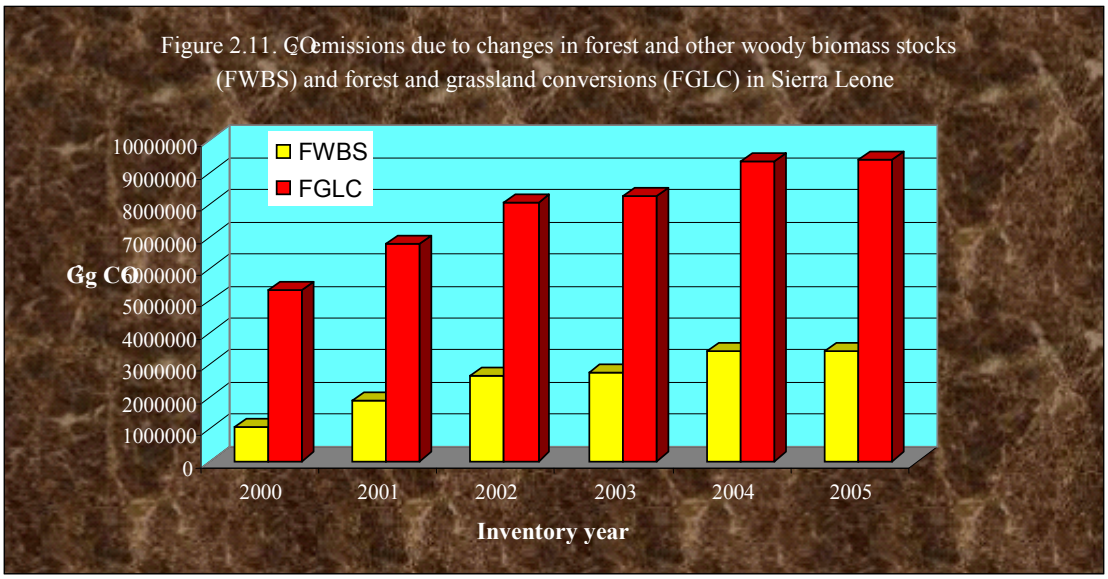
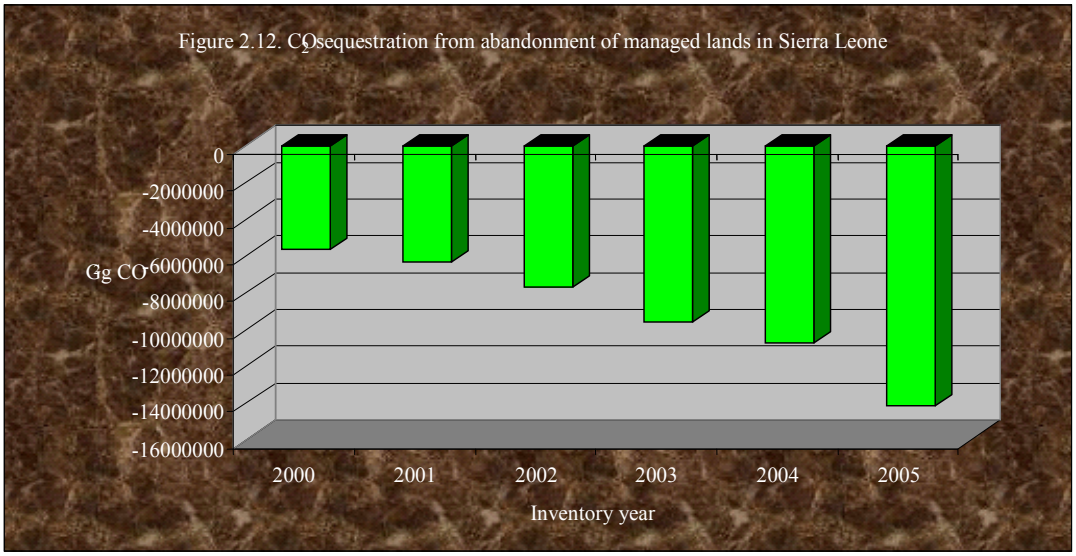


Figure 2.11. $CO_2$ emissions due to changes in forest and other woody biomass stocks (FWBS) and forest and grassland conversions (FGLC) in Sierra Leone

Abandonment of managed lands, on the other hand, is an obvious sink because of $CO_2$ removals from biomass re-growth and soils recovery in abandoned lands. The significant removal of carbon dioxide (Fig. 5) was due only to the land-use practice of abandonment of managed lands.

In Sierra Leone, the decade long brutal civil war saw the abandonment of vast areas of managed plantations and farmlands. As a result, there was significant accumulation of biomass that served as sink for $CO_2$ sequestration. The cumulative biomass growth and the resultant $CO_2$ uptake led to very high $CO_2$ removal in 2005, thereby offsetting the combined $CO_2$ emissions by forest and grassland conversion and changes in forest and other woody biomass stocks, thus producing a net $CO_2$ removal in this year (Fig. 3).




### 2.5.2.4 Emissions and/or removals from Mineral and organic soils

Table 4 and Figure 6 below shows the emissions of trace gases from the conversion of forests and grasslands in to other land-use classes. A total of $2.7 \times 10^6$ Gg non-$CO_2$ trace gases were estimated to have been emitted during the period considered in this inventory. Oxides of nitrogen ($NO_x$) accounted for 73.8 percent of the total non-$CO_2$ trace gas emissions related to forests and grassland conversion, CO emissions represent 21.7 percent, nitrous oxide ($N_2O$) 2.5% and methane ($CH_4$) constitutes 2.0% of the total emissions (Figure 7).

**Table 2.24: Emissions (Gg) of trace gases from Forest and Grasslands Conversion**

| *Year* | CH4 | $N_2O$ | CO | NOx |
|---|---|---|---|---|
| **2000** | 5630.5 | 4645.2 | 49267.2 | 167890.5 |
| **2001** | 8759.5 | 7226.6 | 76645.5 | 261189.0 |
| **2002** | 11611.9 | 9579.8 | 101604.3 | 346242.7 |
| **2003** | 12064.2 | 9952.9 | 105561.4 | 359727.5 |
| **2004** | 14442.0 | 11914.6 | 126367.2 | 430628.4 |
| **2005** | 14480.4 | 11946.3 | 126703.3 | 431773.7 |

INC inventory does not specify the distribution of emissions per sub-sector.

Figure2.13. Non-CO 2 Non C02 trace gases emissions from forest and grassland conversions

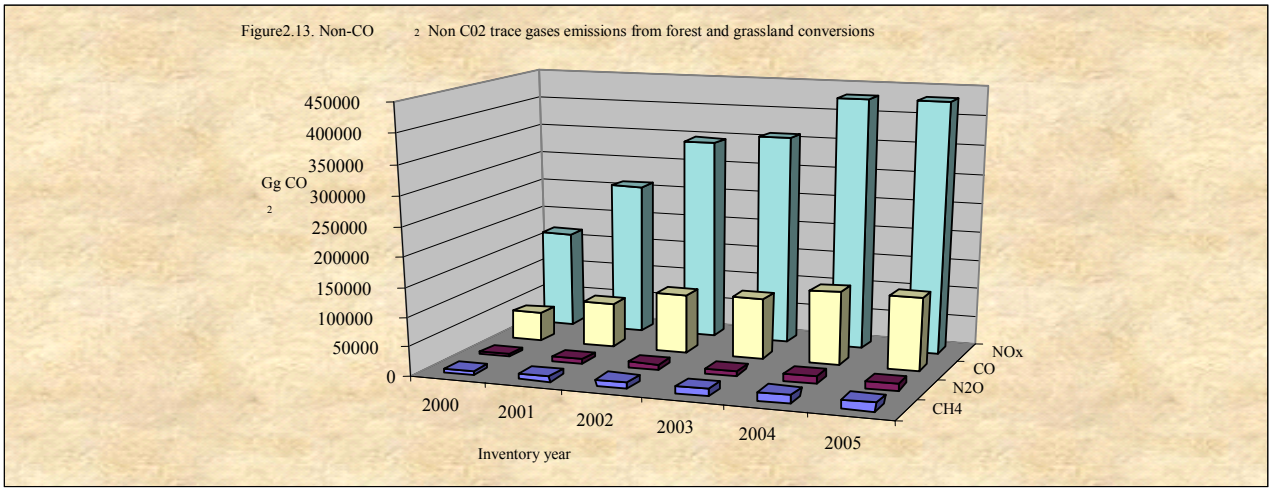
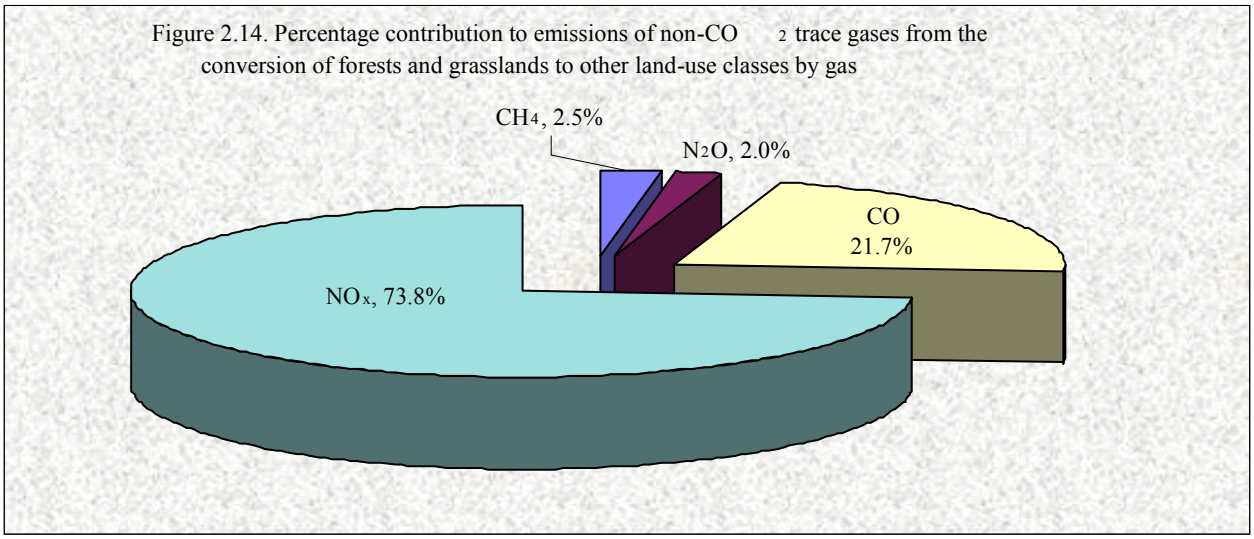



Figure 2.14. Percentage contribution to emissions of non-CO 2 trace gases from the conversion of forests and grasslands to other land-use classes by gas




## Conclusion

The overall assessment indicates that land-use, land-use change and forestry category is a significant source of $CO_2$ emission in Sierra Leone within the period considered in this inventory. Conversions of forests and grasslands and changes in forest and other woody biomass stocks are the most important in this respect. The anthropogenic emission of $CO_2$ due to forest and grassland conversions and changes in forest and other woody biomass stocks was far greater than the amount taken up by land-use activities related to abandonment of managed lands and hence the net $CO_2$ emission.

## Difficulties

- Absence of a national forestry inventory which could generate more up to date data;
- An adequate, obsolete or even shortage of data for almost all the Land Use, Land Use Change and Forestry Sector;

- Unexploitable form of data when they do exist;
- Low concern from holder institutions on data relating to inventory activities;
- Inexistence of an inventory of trees outside forest (towns, villages, grazing areas etc.);
- Obsolete nature of the rate of forest regression.

**Recommendations**

- Realize a national forest inventory with a view to having a better knowledge of the sequestering potential;
- Conduct surveys to fine-tune the estimate of trees outside forests, in particular trees in urban and rural centers.

## 2.6 Emissions of Greenhouse Gases from Waste Management

### 2.6.1 Introduction

Domestic, agricultural and industrial waste is generated in the form of solid and liquid. There is no form of waste management or separation in Sierra Leone. Solid waste is collected from residential properties and commercial services, markets, recreational areas, government offices and institutions (schools and Hospitals), fish and poultry processing plants, industries, hotels, etc. the waste constitutes the following: leftover food, paper, grasses, construction waste and other cutting.

**Table 2.25: Types and composition of wastes generated in the Freetown Municipality**

| Container sites | Sankey Street | Taylor Street | Cape Sierra Hotel area | Lightfoot Boston street | 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 %** |
| **Percentagege 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 %** |
| **Compostable fraction** | 84.5 | 89.6 | 86.1 | 64.4 | **81.15** |

**ource**: Solid wastes management study, 1995, GOPA Consultants in collaboration with AFRIRELIEF

**Table 2.26: Summary table on waste generated and collected 1997 – 2000**

| | 1997 | 1998 | 1999 | 2000 |
|---|---|---|---|---|
| Total Wastes generated (tons/a) | 574123 | 644566 | 715008 | 785451 |
| Vehicle collection by tipper truck | 13670 | 15347 | 17025 | 18702 |
| By 5m$^3$ container to transfer station | 68348 | 76734 | 85121 | 93507 |
| By 5m$^3$ container to transfer station | 39642 | 44506 | 44506 | 49370 |
| 5By 7m$^3$ container direct to land fill | 15036 | 16880 | 18725 | 20570 |
| By hand carts and 20m$^3$ containers | 13670 | 15347 | 17025 | 18702 |
| By hand carts and 7m$^3$ containers | 21871 | 24554 | 27238 | 29921 |
| ***Subtotal/tons/a collected*** | ***746363*** | ***837938*** | ***929514*** | ***1021090*** |
| % of total generated waste | 30 | 30 | 30 | 30 |
| Wastes from transfer station to landfill | 78676 | 95342 | 103008 | 110674 |
| Backyard composting tons/a | 70140 | 76273 | 82405 | 88538 |
| % of total generated waste | | | | |
| Uncollected Waste tons/a | 287061 | 322282 | 357504 | 392725 |
| % of total generated wastes | | | | |
| SEWAGE | | | | |
| Total swag collected in Freetown | 73622 | 7831 | 8300 | 8769 |
| Flush toilet (tons/a | 1030 | 1096 | 1162 | 1227 |
| Pit latrines (tons/a) | 5135 | 5462 | 5789 | 6116 |
| Bucket latrines (tons/a) | 266 | 283 | 300 | 317 |
| River/bush | 2615 | 2622 | 2628 | 2635 |
| **Source: Environmental Health Division of the Ministry of Health and Sanitation** | | | | |

### 2.6.2 Estimates of emissions from waste management

### Methodology

The emission of greenhouse gasses from waste production and management systems in Sierra Leone was assessed by analyzing the types, quantities and composition of wastes generated and the management regimes in place for handling the generated wastes. Wastes generated from Freetown are composed of mainly garbage and non-hazardous solids. The organic materials in the wastes are of biogenic origin e.g. paper, yard trimmings etc. plastics, broken bottles, synthetic rubber, fibres, cans, used clothing and footwear and packaging materials also form a sizable proportion of the wastes IPCC's guidelines for national green house gas inventories i.e. revised version of 1996 describe two methods of estimating CH4 from solid wastes disposal sites, namely, the default method(level 1) and the decomposition method (DPO) (level1)was used. The default method is based on the following equation:

Data obtained from these sources were fitted into the following IPCC equation to obtain the emissions using default factors and some specific factors obtained in specific studies. In cases where different values were recorded by different authors, the average was used.

$$Mthaneemission(Gg/yr) = (MSW_T * MSW_F * MCF * DOC * DOC_F F * {}^{16}\!/_{12} - R) * (1 - OX)$$ Where:

$MSW_T$ = Total Municipal Solid Waste generated in Freetown
$MSW_F$ = Fraction of MSW disposed to solid wastes disposal sites at Kingtom and Granville Brook
$MCF$ = Methane correction factor
$DOC$ = Degradable organic carbon
$DOC_F$ = Fraction of DOC dissimilated
$F$ = Fraction of $CH_4$ in land fill sites
$R$ = recovered $CH_4$ (Gg/yr)
$OX$ = Oxidation factor (fraction- default)

Percent DOC (by weight was calculated from the following equation

$$DOC = 0.4A + o.17B0.15C + 0.30D$$

Where:

$A$ = *percent MSW that is paper and textiles*
$B$ = *Percent MSW that is garden wastes, park wastes or other Non-food organic putrecibles*
$C$ = *Percent MSW that is food waste*
$D$ = *Percent MSW that is wood or straw*

### 2.6.2.1 6A Solid Waste Disposal on Land – CH4

### 2.6.2.2 Methane Emissions from Solid Waste Disposal Sites.

Data in table 2.27 shows results of the analysis of emissions due to total annual solid waste disposed at the disposal sites in Sierra Leone. A total of 785451 tons/a of Municipal Solid Waste (MSW) from table 2.26 was disposed of at solid waste disposal sites (SWDS). This amount could be much higher if the Area Councils were collecting all the waste in the Divisions. Waste is only collected infrequently in market areas, and other growth centres. The result is a gross annual methane generation of 0.6 $CH_4$. None of the CH4 generated is being recovered.

Table 2.27 **Solid Waste Disposal on Land**

| **Solid Waste Disposal on Land** | | | | |
|---|---|---|---|---|
| MANAGED WASTE DISPOSAL ON LAND | 0.6 | 0.6 | 0.6 | 0.6 |
| UNMANAGED WASTE DISPOSAL SITES | 0.28 | 0.28 | 0.28 | 0.28 |

### 2.6.2.3 Methane Emissions from Wastewater produced in the domestic and Commercial Sector

This sub-sector was not estimated

### 2.6.2.4 Methane emissions from Wastewater produced in the Industrial Sector

Domestic and commercial wastewater methane emission was estimated using the default IPCC methodology (IPCC 2000). The Total Population of Freetown, Bo, Kenema and Makeni for each year were multiplied by a per capita wastewater $BOD_5$ production rate to determine total wastewater $BOD_5$ produced. It was assumed that, per capita 0.037 kg kilograms of wastewater $BOD_5$ is produced per day and that 5 % of this are anaerobically digested. This proportion of $Bod_5$ was then multiplied by an emission factor of 0.6 kg $ch_4$ /kg $BOD_5$

### 2.6.2.5 Methane emissions from wastewater produced in the domestic and commercial sectors

The industrial sector of Sierra Leone is under-developed. Most of the industries (metal, fertilizer paper and pulp, petroleum refining and petrochemicals, and rubber) included in the IPCC Guidelines for the development of National Inventory for Industries do not exist. Only the Food and Beverage industry is considered in this study. Table ……shows that a total of ……of wastewater from industrial source was produced. This quantity resulted to the emissions of …….

**Table 2.28 Waste Water Handling**

| **Waste Water Handling** | | | | |
|---|---|---|---|---|
| INDUSTRIAL WASTEWATER | 10.92 | 10.92 | 10.92 | 10.92 |
| DOMESTIC AND COMMERCIAL | 0.01 | 0.01 | 0.01 | 0.01 |

### 2.6.2.6 6B2 Domestic and Commercial Wastewater – N2O

**Methodology**

Nitrous oxide emissions from human sewage were estimated using the IPCC default methodology (IPCC/UNEP/OECD/IAEA 1997) as follows:

$$N_2O_{(s)} = \text{Protein} * Fraction_{NPR} NR_{PEOPLE} * EF_6$$

*Where:*

$N_2O_{(s)}$ =

*$N_2O$ emission from human sewage (Kg $N_2O$-N/yr*

*Protein =annual per capita protein intake Kg/Person/year = 0.044kg/person/day*

*$NR_{PEOPLE}$=number of people in Freetown (Table 3) $EF_6$=emission factor (default is 0.01kg$N_2O$-N/Kg sewage N produced*

*Fraction $_{NPR}$=Fraction of Nitrogen in Protein (default = 0.16kgN/kg Protein*

**Table 2.29: Total Emissions from Waste Sector**

| | 1997 | | | 1998 | | | 1999 | | | 2000 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Greenhouse Gas Source And Sink Categories** | **$CO_2$** | **$CH_4$** | **$N_2O$** | **$CO_2$** | **$CH_4$** | **$N_2O$** | **$CO_2$** | **$CH_4$** | **$N_2O$** | **$CO_2$** | **$CH_4$** | **$N_2O$** |
| **Total Emissions Fron Waste** | 11.81 | 29.31 | | 11.81 | 29.72 | | 11.81 | 30.49 | | 11.81 | 31.29 | |

**Indirect nitrous oxide emissions from Human sewage**

Sewerage system exists only in Sierra Leone. With a per capita protein consumption of ……..per person per year and a population of ……..served by the sewerage system, emissions of $N_20$ are estimated as……per annum.

From table 2.29 above, the gross annual $CH_4$ emitted in Sierra Leone in 2000.was about 31.29.. As shown in table 2.28 and 2.27 of the $CH_4$ emitted came from wastewater handling, particularly from the industrial sector. The bulk .of the emissions came from solid waste disposal.

**2.6.2.6 7C Waste Incineration – CO2, CH4 and N2O**

**Difficulties**

- **Unavailability:**
  - of the total quantity of soda used in the country;
  - of activities data on the consumption of halocarbons (HFC and PFC) and sulphur hexafluoride;

- **Absence of data on:**
  - The home-made production of oil:
  - The baking of bread through the number of bakeries and the total consumption at national level;
  - The production and characteristics of urban wastes of other towns in Sierra Leone (apart from Freetown)

**Conclusions and Recommendations**

From the data collected on the total annual waste produced in Sierra Leone the following observations can be made:

a) Waste produced is not sorted;
b) Lack of adequate resources to collect all the waste in major towns and municipalities makes the results a gross underestimation;
c) All the waste dumped at the disposal sites are not managed;
d) The location of existing disposal sites are inappropriate in terms of environmental sanitation;

e) There is no information on the proportion of the various constitutes that make up household waste, and from waste from institutions;
f) Fire outbreak is common at the disposal sites;
g) Scavengers collect any material that may be useful to them;
h) Animals graze around the disposal sites;
i) There is inadequate data and information on waste management;
j) There is lack of strong legislation to enforce proper waste management, and
k) Administrative and legal frameworks together with institutional and financial commitments are needed to develop an effective management system.

In view of the facts mentioned, the following are recommended;

a) A solid waste strategy needs to be developed for Sierra Leone;
b) Proper landfill sites should be selected;
c) There need to design and operate municipal landfills;
d) Authorities responsible for the collection of solid waste should develop their own solid waste disposal plan and submit it to the NEA for approval;
e) A monitoring strategy for the emissions ($CH_4$, and $SO_2$) and the leachate from the dumpsites should be developed;
f) Tree planting around the dumping sites should be encouraged so that they can serve as wind breaks, to prevent the spread of waste into non-dumping sites, as well as to serve as $CO_2$ sink;
g) Public awareness about waste management should be increased; and
h) The capacity of the personnel on waste management in the municipalities and Area Councils should be increased.

**Waste management sector**

- Conduct a survey to know the composition of urban wastes;
- Conduct surveys to have: (i) the total amount of soda used in the country; (ii) data on activities relating to the consumption of halocarbons (HFC and PFC) and sulphur hexafluoride;
- Conduct surveys to obtain: (i) handicrafts production of oil; (ii) the baking of bread through the number of bakeries and total consumption at national level.

**Difficulties/Recommendation**

Inadequacy or even the absence of statistical data is a general problem in most areas of activity in Sierra Leone. This is partly due to the predominance of the informal sector.

The difficulties are generally similar to those encountered during the drafting of the Initial National Communication. The difficulties encountered in the course of this inventory may be classifies into two categories: (i) difficulties common to all the sectors and (ii) difficulties specific to each inventory sector.

**Difficulties common to all the sectors**

They are difficulties relating to:

- Time management: the time allotted is inadequate to cover all issues of data collection, bibliographical analysis and compilation;
- Dispersal of activity data from many economic actors;
- Inconsistency in the collection of activity data from the sectors professionals and absence archiving of these data. There are very few institutions which correctly hold data sheets or even have the requisite skills within the staff to correctly fill the templates requested. Most often, data, when available, is on paper format and difficult to be retrieved from the achieves of institutions;
- Low concern of sector professionals about emission and conversion factors;
- Absence of data disaggrated per sector;
- Unreliability of most unprocessed data, including at level of organized structure;
- Mismatch of data provided by the National Institute of Statistics and data collected from Technical Directorates.

**Difficulties specific to each sector**

**Energy sector**

- Informal hydrocarbons importation channels are not subjected to the formal channels hence difficulties in even the apparent consumption of the country. Only a regular consumption survey will ensure reliable estimates;
- Increase in the price of hydrocarbons on the international market which increase the previous structure grounds;
- Lack of data on auto-producers due to the low keeping of energy statistics either as a result of lack of interest or for reasons of supply in a parallel market;
- Disregard by many private operators of the energy sector's challenges and the challenges related to climate change particularly the opportunities that the Clean Development Mechanism (CDM) offers;
- Existence of too little official figures on energy data, which tends to prove that this sector is hardly considered at the strategic level by vocational and statistical institutions;
- Confidentiality of energy data for security grounds (army) or taxation (deductible expenses);
- Low prioritization of the sector in the various development policies and strategies in the tools and instruments equal to the related challenges;
- Shortage of energy statistics professionals in institutions due to the lack of motivation from the latter to gain such skills.

**Land Use, Land Use Change and Forestry Sector**

- Absence of a national forestry inventory which could generate more up to date data;
- An adequate, obsolete or even shortage of data for almost all the Land Use, Land Use Change and Forestry Sector;
- Unexploitable form of data when they do exist;
- Low concern from holder institutions on data relating to inventory activities;
- Inexistence of an inventory of trees outside forest (towns, villages, grazing areas etc.);
- Obsolete nature of the rate of forest regression.

**Agriculture and Livestock sector**

- Absence of monitoring of farm clearing;
- Low monitoring capacity of bush fires in the country;
- Total lack of data on some sub sectors such as the use of biomass (notably agricultural residues) as fuels;
- Absence of conversion factors concerning the dry weight of some foodstuff (vegetables for example);
- Inexistence of reliable data on the land areas occupied by organic soils even though they are very few in Sierra Leone.

**Waste Management Sector**

- **Unavailability:**
  - of the total quantity of soda used in the country;
  - of activities data on the consumption of halocarbons (HFC and PFC) and sulphur hexafluoride;
- **Absence of data on:**
- the home-made production of oil:
- the baking of bread through the number of bakeries and the total consumption at national level;
- the production and characteristics of urban wastes of other towns in Sierra Leone (apart from Freetown)

**General recommendations**

Taking into account the foregoing, the following general recommendations are proposed with a view to improving the next inventories:

- integrate the collection of data necessary for the inventory in the routine work of MDAs;
- reinforce information and training of MDAs on issues related to GHG inventories;
- take into account data necessary for the inventory in preparing a progress report of forest services;
- propose a data reporting guide for data holders;
- provide additional support to enable the conduct of studies/surveys so as to generate information necessary for the establishment of better quality inventories;
- set up a databank to be provided regular inputs through an annual transmission system of activity data by holders (the institution most recommended to implement is Statistic Sierra Leone while drawing on data providers);
- define the type of data to be collected concerning formal holders and conduct an awareness campaigns to persuade them to integrate the collection of these data in their activities;
- extend the dissemination of scientific materials by supplying material aid (books, CD, ….) and also the construction of a library to that effect; encourage research on climate change issues; of development cooperation and private funding; sensitize public and private policy-makers on funding mechanisms set up by the international community such as CDM which is of interest to data providers to keep reliable statistics;

- organize specialized training sessions particularly for public and private policy-makers results on the inventory and expanding the range of experts;
- build on the successes of institutions specialized in data collection such as and Statistics Sierra Leone to perpetuate a reliable database; systematically archive available and already processed data after defining a template which is in line with the requirements of the IPCC software.

Consolidate initiative taken in the second national communication. These initiatives are: set up an inventory multidisciplinary team made up of experts from main institutions holding data:

- organize information and sensitization sessions for data holders;
- train experts in charge of the inventory;
- provide all the means and mechanisms likely to serve in complementary surveys during the inventory to check data or to have solid grounds for expert judgments;
- set up a permanent national team in charge of carrying out the inventories;
- organize workshops with the goal of showing to institutions the importance of data used in inventories so as to motivate them to integrate it in their reports.

**Recommendations specific to the sectors**

**Energy sector**

- fine-tune data to make a better assessment of emissions through the sector method; conduct a survey following a relatively less expensive methodology to establish a baseline case with more elaborate collection tools and;
- use this survey to make a better assessment of the technical characteristics of production tools in anticipation of mitigation measures.

**LULUCF sector**

- realize a national forest inventory with a view to having a better knowledge of the sequestering potential;
- conduct surveys to fine-tune the estimate of trees outside forests, in particular trees in urban and rural centers.

**Agricultural sector**

- integrate into the next agricultural and livestock censuses the concerns related to the agricultural sectors inventories;
- set up an efficient monitoring mechanism of the progression of cultivated areas and bush fires.

**Waste management sector**

- conduct a survey to know the composition of urban wastes;
- conduct surveys to have: (i) the total amount of soda used in the country; (ii) data on activities relating to the consumption of halocarbons (HFC and PFC) and sulphur hexafluoride;
- conduct surveys to obtain: (i) handicrafts production of oil; (ii) the baking of bread through the number of bakeries and total consumption at national level.

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# Chapter 3

## Assessment and Prioritization of Mitigation Opportunities to Mitigate the Concentration of Greenhouse Gases

### 3.1 Introduction: Assessing the country situation

In this chapter, an attempt is made to assess and prioritize mitigation opportunities of Sierra Leone in the key sectors for which the Green House gas inventory was done. Reference to other potential sectors to avoid carbon dioxide emission was also made.

A mitigation assessment provides a national-level analysis of the potential impacts of various technologies and practices that have the capacity to reduce greenhouse gas (GHG) emissions. The assessment presented here uses historical data for 2000 (the base year) to 2005 in order to calibrate, where appropriate, the bases for the projections.

#### 3.1.1 Development priorities and national context: Previous and planned initiatives, policies and legislation national and regional

The assessment draws upon the overarching strategic direction that will guide Sierra Leone development to 2025, as articulated in *Vision 2025(see National Circumstances)*

The development priorities have been articulated in chapter one. Beyond the reporting period, Sierra Leone has developed the second PRSP dubbed Agenda for Change for the period 2008 -2012. The PRSP provided the framework within which development partners identified assistance programs, but will also provide an overall framework for private sector international investment. Both will play a key role given domestic resource constraints.

PRSP 2 defined the country strategy for the 2008-2012 period. It focused on growth and human development, and identified three drivers of growth: agriculture, energy, and transport infrastructure. Cross-cutting areas included improved governance, capacity development, private sector growth, and management of natural resources. The 2010 midterm review of the PRSP concluded that there had been impressive progress in a number of areas, including human development, agriculture and infrastructure, and decentralization, but that continued work was needed to build on successes and strengthen capacity in a number of areas, including procurement.

Although the assessment focuses primarily on energy related emissions, non-energy sector activities (agriculture, forestry, waste, and non-energy emissions) are also included.

#### 3.1.2 Outcomes of the GHG inventory

The total carbon dioxide emission (CO2) for the year 2000 is 574.061Gg $CO_2$. The distribution per major sectors is as follows:

The emissions from energy generation are fairly high in the country, amounting to 529.287Gg of $CO_2$ as Sierra Leone energy generation is based on diesel powered generators. Recently, with the

commissioning of the Bumbuna Hydro Electric Power Station, $CO_2$ emission from the energy sector has been fairly reduced at least on a seasonal basis.

The Land Use, Land Use Change and forestry (LULUCF) sector is the least significant source of $CO_2$ emissions up taking 752,748Gg of $CO_2$, followed by the waste sector emitting 11.83. The industrial processes are however marginal amounting to 39.55 Gg of $CO_2$ mostly from cement production.

The total methane $CH_4$ emissions are 32,312.53 Gg. Agriculture is the most important source of $CH_4$ emissions (86.67%), followed by the LULUCF sector (5.631) and finally the waste sector (11.83).

The other sectors are not sources of $CH_4$ emissions.

Nitrogen dioxide $N_2O$ emissions estimated at 13.91 Gg with 8.54Gg coming almost exclusively from the agricultural sector. The waste sector is also a source of emission (31.29Gg).

From the above it can be seen that the LULUC/Forestry sector, agriculture and energy sectors have the most potential for GHG reductions.

Sierra Leone is not a producer of oil and gas and the energy sector is dominated by hydropower. Thus Sierra Leone is mitigating GHG emission which has not yet been quantified for CERs.

Though Sierra Leone emissions are negligible, in a bid to significantly contribute towards the reduction of the sources and potential sources of GHG emissions or enhancing carbon sinks, Sierra Leone proposed to undertake appropriate mitigation actions as listed below in its response to COP 15.

- Establishment of the national secretariat for climate change (NSCC) Setting/developing air, water and soil quality standards, and ensure regular assessments and monitoring through control programs.

- Expanding clean energy utilization (e.g. solar, mini-hydro electric power, LPG, biomass stoves etc).

- Development of energy efficiency programmes through sensitization and awareness raising campaigns. Sustainable production of charcoal a reduce dependence on firewood.

- Development of alternative energy sources such as bio-fuels from sugarcane, corn, rice husk, etc.

- Developing agricultural and urban waste incineration programmes for energy production.
- Improved waste management through composting and recycling of waste.

- Development and enforcement of regulations on regular maintenance of vehicles (vehicle emission testing): formulation of transport plans.

- Improved and promoting use of public transport (e.g. road and water): for passengers and cargo to reduce traffic congestion and GHG's emissions.

### 3.1.3 Gaps and Challenges that the country has faced while elaborating this Chapter

The major gap is a comprehensive economic analysis of mitigation options and identification of viable technological options. The major challenge is in terms of quantitative and qualitative data for the mitigation softwares (LEAP,COMAP ,COPATH etc.), The Project must increase the number of trained personnel skilled in Greenhouse Gases measurements and related technological economic policy analysis, as well as providing an Institutional framework for collaboration among all concerned sectors. Furthermore, the country will benefit by having high quality information on climate change issues that will assist the Government to formulate and implement suitable Greenhouse Gases initiatives and policies relevant to mitigation.

#### 3.1.3.1 Sierra Leone's Second Poverty Reduction Strategy Paper

### 3.1.4 National Institutions and Agencies Related to Implementation of Mitigation Actions.

**Ministry of Lands Country Planning and the Environment**

This Ministry is charged with the responsibility of land country planning also for managing the environment.

**Ministry of Fisheries and Marine Resources** It is responsible for the management of fisheries resources and related habitats in a manner which would maximize benefit in terms of fish catch now and in the future. It is expected to develop fisheries resources and to devise methods of enhancing current production and more effective exploitation. The ministry issues licence for offshore trawling and monitors small-scale inshore and offshore large-scale fishing. It is also responsible for enforcing laws on fishing activities and concerns itself with pollution and other environmental problems which affect water quality and fisheries resources.

**Ministry of Agriculture, Forestry and Food Security**

This ministry if mandated to preserve and conserve, as well as through managed commercial exploitation to provide for sustainable and permanent regenerating forest resources. It is responsible for issuing licences to exploit and maintain all forests types on public lands to monitor their harvesting so that they are sustainable and ecologically stable. It is also now responsible for the management of fisheries resources and related habitats in manner which would maximize benefit in terms of fish catch now and in the future.

**Ministry of Mineral Resources**

This ministry is charged with the responsibility to supervise mining operations in the country. It issues licences for all mining operations, enforces laws and provisions contained in the Mining Act and its amendments. It is responsible for enforcing provisions in the new mining act relating to the rehabilitation of mined out areas.

The main institutional conflicts are (1) the extent to which the Ministry has jurisdiction over marine areas with respect to marine based mineral resource, offshore dredging and its impact on marine resources and (2) the overlap of water quality monitoring with the interest of the Ministry of Marine Resources.

**Ministry of Tourism**

This ministry is responsible to promote and develop the country's tourist industry lies with the ministry of tourism and culture. It is also charged with duty of protecting the country's heritage: monuments, and cultural and historical sites

**Ministry of Transport and Aviation**

This ministry is mandated to deal with issues related to transport on land, air and sea as well as local and international communications. The SLRA maintains the database with registration information for the licensed motor vehicle fleet.

The National Meteorological Office is the focal point for climate change in Sierra Leone.

**Sierra Leone Maritime Administration**

This organisation is responsible for the administration of maritime affairs including shipping activities, safety of marine transportation, pollution and vessel registration

**Ministry of Energy and Water Resources**

This ministry is responsible for the development of the energy sector water supply and generation of electricity are all functions of the above ministry. It is expected to develop the energy resources and enhance current production to meet and satisfy the needs of the community as well as provide adequate water supply to the nation. It enhances the improvement of water supply and delivery facilities and maintenance of existing ones.

The Ministry of Energy and Water Resources (MEWR) has also just formulated the National Energy Policy and the Japanese International Cooperation Agency (JICA) has developed Power Master Plan for the next fifteen years to improve and extend power supply system in the Western Area. One of the main objectives of the Energy Policy is the development of cleaner energy by fast-tracking the development of hydropower nationwide and exploiting other renewable energy resources including solar energy and biomass to reduce dependency on fossil fuels.

**Sierra Leone Environment Protection Agency**

The Government of Sierra Leone has also established the National Environmental Protection Agency (NEPA) in July 2008. This Agency is responsible to coordinate and monitor the implementation of all environmental policies, programmes and projects To ensure the enforcement of the strategic environmental assessment (SEA) and Environmental Impact Assessment (EIA) as well as related legislation to promote sustainable environmental development, human wellbeing and poverty reduction

in the country. EPA- SL is the agency entrusted with managing Sierra Leone's natural and the man-made environment and is the lead government agency responsible for environmental management.

**Local Government Councils**

Are responsible for the administration of local government including and implementation of the devolved

**The Ministry of Finance and Economic Development**:

The MOFED has responsibility for the macro-economy which includes implementing tax related incentives/disincentives for the development of all sectors including the energy sector.

**The Forestry Department**:

The Forestry Department of the Ministry of Agriculture, Forestry and Food Security and is the lead agency responsible for the management and conservation of Sierra Leone's forests. Its functions are mandated by the Forest Act, 1996, and are aimed at managing forests on a sustainable basis to maintain and increase the environmental services and economic benefits that forests provide.

A National Forest Conservation and Management Plan and the Strategic Forest Management Plan 2009-138, among other things, describe the Department's policy and legal framework, forest management constraints, forest values, the current state of Jamaica's forests and establish goals and a wide range of implementation forest management strategies and activities.

**The Sierra Leone Standards Bureau (SLSB)**

SLBS is a statutory body established by the Standards Act of 1988. Its main functions are formulating, promoting and implementing standards for goods, services and processes. The Bureau develops and enforces technical regulations for those commodities and practices which affect health and safety. It is the agency that sets fuels specifications.

The Government of Sierra Leone established the Disaster Management Department in the Office of National Security. As a first step in dealing with the problem of climate change, the Department together with key stakeholders embarked on the development of a national hazard profile, national disaster management policy, national disaster management preparedness and response plan, vulnerability and capacity assessment and contingency plans on health related problems, population movement, floods, water shortage, Avian flu and H1N1 virus

### 3.1.5 Desk review of literature and Stakeholder Consultations

**Key Policies and Legislation Related to Implementation of Mitigation Actions**

Vision 2025: National Development Plan provides the overarching context within which
Sierra Leone's mitigation activities will take place. Two national strategies – NAPA and INC Develop measures to adapt to climate change and Contribute to the effort to reduce the global rate of climate change.

The National Transport Policy drafted in 2009 is guided by the vision to create a "sustainable, competitive, safe, accessible, and environmentally friendly transport network providing world class air, land, rail, and marine facilities contributing to a vibrant import, export and trans-shipment trade for Sierra Leone and the world." The transport policy is designed to encourage energy conservation measures (e.g., efficient traffic management; car pooling; park and ride; use of clean fuels to minimize pollution;
The possibility of enhanced coastal and rail transport will be kept under constant review

The overarching objective is to position Sierra Leone to capitalize further on opportunities for partnerships with other developed countries, private organizations, as well as relevant regional or international institutions. This will generate social, economic and environmental benefits for the country through investment in initiatives that will also foster sustainable development goals.

The Government of Sierra Leone established the Disaster Management Department in the Office of National Security. As a first step in dealing with the problem of climate change, the Department together with key stakeholders embarked on the development of a national hazard profile, national disaster management policy, national disaster management preparedness and response plan, vulnerability and capacity assessment and contingency plans on health related problems, population movement, floods, water shortage, Avian flu and H1N1 virus

### 3.1.6 Reduction Potential

It has been difficult to calculate the emission reduction options for each sector. It has also been difficult to calculate the emission potential of each sector or for each one of the identified mitigation measures however we would try to provide this kind of information since this it is one of the most important elements of the mitigation analysis in the next NC Report.

There were a number of challenges for the conduct of the mitigation studies these include but not limited to:

a) Lack of comprehensive and software (LEAP,COMAP ,COPATH etc.), compatible data;
b) Shortage of qualified professionals;
c) The Project has not been able to benefit from UNFCCC/UNDP Workshops, Seminars and Conferences as recommended in the Project Document;

### 3.1.7 Contribution of mitigation efforts to national development

For instance, renewable energy- solar and biomass policies in the context of National Development can contribute to poverty reduction and pollution control.

### 3.1.8 Approach in the Mitigation Assessment

#### 3.1.8.1 Desk review of literature and Stakeholder consultations

The first approach to mitigation assessment was to conduct a scoping workshop, (LEAP, COMAP} which involved collecting data and information through stakeholder consultations and desk review of

literature on mitigation options of GHGs. The outcome was the development of a comprehensive list of mitigation options, which were then screened for further analysis:

An International Consultant from ENDA, Senegal, Mr. Libasse Ba carried out training on the use of LEAP and COMAP. Hands-on-desk simulation exercises were carried out with available data. However particularly for LEAP Software compatible data was in very short supply. Hence the mitigation analysis team had to resort to the conventional approach of identifying and the screening the mitigation options.

### 3.1.8.2 Residential sector

In the residential sector, in both rural and to a lesser extent urban areas, household energy consumption in Sierra Leone is dominated by biomass fuel essentially for cooking and kerosene for lighting. The mitigation options here are: popularization of metallic improved stoves with a better output (between 12 and 30%) and substitution with a fuel more appropriate to current uses.

### 1. (a) Rural Areas

Food preparation in rural areas is done almost exclusively from biofuels (fuel wood and various residues). As reported in the INC, the current dominant technology makes use of "three stones stoves" with very low energy yield (about 4 to 5%). As rural populations make up about 83% of the total population of the country, the economic potential of fuel is very high there. This economy could be obtained by combining two technologies namely the popularization of metallic improved stoves with a better output (between 12 and 30%) and substitution with a fuel more appropriate to current uses.

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.

The LPG and other petroleum by-products technology is less appropriate in this environment for issues of cost and security. Lighting is dominated by kerosene, oils and gas as well as torches and agricultural residues.

### 1.(b) Urban Areas

However, in urban areas, NPA plans to electrify over 60% of households through a electrical grid extension policy. Cooking stoves notably coal stoves and the LPG are being promoted in order to cover the needs of the populace. The major obstacles here are the cost of new equipment (both solar and fuel), maintenance and especially the high level of the task

### Possible Technological Resources

The Economically Profitable Technologies (EPT) potential, as envisaged in this case, is the extension of the rural electrical and electrification.

Another EPT consists of using portable PV solar lamps. It is a unit made up of a fluorescent tube, 6 to 12 V battery and an amorphous panel of 10 Wc. The major obstacles are high cost, unavailability of spare parts and inexistence of skilled staff for the maintenance of this equipment.

**(2)Transport Sector:**

Designing and improvement of provincial and feeder roads, Lead-free petrol, Mass transportation (road and water) for passengers and cargo, Quality control for spare parts for all types of vehicles, enforcement of regular maintenance regulations for vehicles, regulations / policies on fuel use and consumptions.

**(3)Energy / Industrial Sector**

Hydro Electric Power (HEP), switching and promotion for 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).

**(4)Agricultural sector**

Water management in rice cultivation and maintenance of soils, use of rice-straw, compost, and biogas residues, mineral fertilizers, fallow incorporation and mulching.

**(5)Forestry sector**

Forest protection, conservation and increased efficiency in forest management.
Reforestation, afforestation and agroforestry, urban and community forestry

**(6)Waste management sector**

Waste incineration, composting, recycling, landfills and open-dumps

### 3.1.8.3 Screening

In screening this long list of mitigation measures the following criteria were applied:
National and project screening criteria and indicators. The criteria included the availability and ease of collecting the data needed for project development and implementation, the benefits and costs of the projects, the economic and social importance of the project in the country, and, reduction of the concentrations of GHGs in the atmosphere. The additional national indicators used include:

- National development benefits and policy priority;
- How well the projects span the range of GHG mitigation opportunities in the country;
- How representative these projects are of GHG mitigation opportunities in the country sub-region as a whole; and
- The availability of information to assess these projects;

### 3.1.8.4 Outcome of the screening

The outcome of the screening was the reduction of the options in the various sectors above to manageable options that were then subjected to some general analysis using benefit-cost and cost effectiveness.

Transport
- ✓ Improvement of the water transport system
- ✓ Designing and improvement of provincial and feeder roads
- ✓ Quality control for spare parts for all types of vehicles

Energy

- ✓ Rural electrification using solar Home Systems to compliment the Hydro Power Plant;
- ✓ Greenhouse gas reduction through the use of Improved Cooking stoves;
- ✓ Large scale introduction of Liquefied Petroleum Gas to displace fuel wood;

Forestry
- ✓ Carbon sequestration through reforestation and protection of existing forests;
- ✓ Managing a multi-product forest for cashew nuts, honey-bee-keeping, etc;

Agriculture
- ✓ Integrated crop and livestock farming – utilizing rice straw (treated with urea) as cattle feed;

Waste
- ✓ Waste Utilizing waste to generate landfill gas for bottling
- ✓ Waste management using composting;

#### 3.1.8.5 Analysis of options and project ideas by sectors

A comprehensive economic analysis of mitigation options and identification of viable technological options and a calculation of the emission reduction options for each sector was not carried out. However from the sectors above, from expert judgement it is thought that the options proposed above would to a large extent reduce the huge dependence on fossil and bio (wood) fuels. This general analysis was based on the methodology below.

#### 3.1.8.6 Methodology Utilized for the Analysis

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.

### 3.2 Assessing and Prioritizing Mitigation Opportunities

### 3.2.1 Assessing and Prioritizing Mitigation Opportunities in the Transport Sector

### 3.2.2 Analysis of the sector

Since 2000, there has been a steady increase in the number of vehicles plying the roads. No data exists on the consumption rates of motor vehicular transport in the country.

In 2000, the transport sector had some 16,763 constituent units for about $^{2}/_{3}$ of the passenger vehicles including motorcycles and remaining 1/3 for transportation of goods. Its growth rate is quite high

especially since the advent of low cost second-hand car, which increases $CO_2$ emission potential in the sector.

The ERT potential envisaged in the NTS is the promoting of alternative means of transportation, the modernization of number of motor vehicles and especially the construction of 2000 km of railway lines.

| Table 3. 1 **Vehicle Population By Region** | |
|---|---|
| East | 9826 |
| North | 6770 |
| South | 7452 |
| West | 38560 |
| Total | 62608 |

As presented in the table above, the vehicle population of the country, found by the census is 62.608. The Western region takes 38,560 of this total, followed far behind by the Eastern region with 9,826, then the South with 7,452 and the North in the fourth position with 6,770.

This shows that on the basis of percentage, the Western region takes 61%, Eastern region 16%, Southern region 12% and Northern region 11% as seen in pie chart below.

**Figure 3.2**

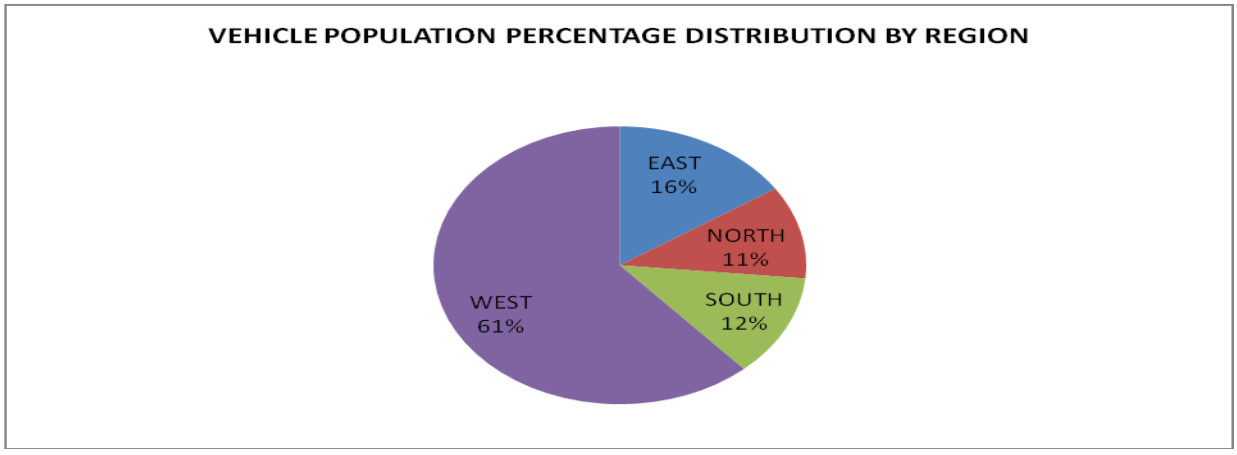


**Figure 3.1: vehicle population percentage distribution by region**

### 3.2.3 Results of Screening

The list of mitigation options, for the transport sector outlined above which as a result of the screening exercise are summarised and prioritized below:

**Table 3.2 Summary of Analysis of Mitigation Options for GHG Emission in Transport**

| Mitigation Options | Priority |
|---|---|
| Designing and improvement of provincial and feeder roads | High |
| Mass transportation (road and water) for passengers and cargo | High |
| Improvement of the water transport system | Moderate |
| Quality control for spare parts for all types of vehicles | High |

### 3.2.4 Analysis of options and project ideas

#### 3.2.4.1 Description of the potential of mitigation options

That most mitigation efforts from private vehicles would need to be carried out in the Western region given that they concentrate more than 61% of the emissions. Improvement of feeder roads in the city for instance would significantly reduce congestion and engine idling. Improvement of conditions in the provinces will encourage vehicle owners to use their vehicle in those areas rather than the Western area where there is a high vehicle population concentration.

Other strategies can be envisaged which basically make use of energy conservation through the users capacity building. The promotion of urban transport and the technical control of means of transportation. Costs are also major constraint here both for the renewal of the car fleet and for the promotion of transit in urban centers. The promotion of less pollutant alternative fuels, such as LPG, biofuels or battery-powered vehicles, is other Energy Profitable Technology alternatives, though some obstacles remain.

### 3.2.5 Potential mitigation measures for the relevant sector

### 3.2.6 Possible Technological Resources to implement the measures

In the urban areas of Sierra Leone particularly, more roads can be designed and constructed at strategic places to ease congestion and idling of vehicle engine. In the case of new vehicle imports, vehicles used for more than ten years should not be allowed for import. The importation of Lead-free petrol should be encouraged.

Another Economically Profitable Technologies (EPT) potential, as envisaged in this case, is the extension of the railway.

## 3.3 Assessing and Prioritizing Mitigation Opportunities in the Energy Sector

### 3.3.1 Analysis of the sector

Regarding the energy sector, poor access to electricity is recognized as a binding constraint to long-term economic growth in Sierra Leone. Energy was a major focus of the PRSP 2's Agenda for Change, which included a goal of "cheap, affordable energy for all". Overall, access to modern energy has increased

from 3% of the population in 2000 to 9% in 2011, but biomass from fuel wood and charcoal still accounts for more than 85% of total energy use. There ist scope for efficiency gains from all sources of energy, and transmission losses remain high at over 40%. The target is to increase billing and collection rates to 90%. Fuel prices (USD 0.94 per liter for both gasoline and diesel in 2010)[9]. Sierra Leone currently has only 90 MW of installed capacity, of which 86% is for Freetown; electricity generated from the hydro-electric facility at Bumbuna, completed in 2009, accounts for 62% of power generated and oil-powered facilities the remainder. [10]

There is potential for more sustainable fuel wood production, charcoal processing, and marketing. Improving charcoal conversion rates and energy efficiency of cook-stoves (currently, only 30% of the cook-stoves are energy efficient) is a priority. This sector is important economically; a recent study in Rwanda estimated the value added from fuel wood and charcoal at 5% of GDP, and a study of Tanzania estimated that the sector created 2 million jobs.[11] The National Energy Profile also makes the case for increased solar and hydro power generation and a range of biomass sources. It also highlights knowledge and capacity constraints. With private sector support, Sierra Leone has invested in hydroelectric power generation, building the Bumbuna hydro-electric plant.

The Ministry of Energy and Water Resources has prepared an ambitious new Energy Strategy has been outlined in chapter one. [12]

Its vision builds on the three pillars of access, efficiency and renewable energy[13], with specific, time bound targets for each pillar.

Sierra Leone, a water-abundant country, has potential in bio-energy production, especially from sugar-cane, so long as environmental and social safeguards are respected.

The use of palm nut shells as fuel for thermal generators of electricity was also viewed as a viable mitigation option. These shells are being produced in huge quantities during the harvesting period of palm oil in the provinces. They can be used as a 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 to use electric stoves. This will result in fuel wood savings, less time spent collecting wood, forest preservation and income generation through the selling of the nuts since these nuts are annually produced in large quantities in the provinces.

Sierra Leone has over 20 hydro potential sites of which the Bumbuna Dam is the only one that has been tapped. This dam, which has been completed, 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 almost zero emission from the electricity sector.

[9] World Development Indicators, 2012.
[10] MEWR Energy Strategy 2012
[11] Biomass Energy Strategy for Rwanda, 2009: "Environmental Crisis or Sustainable Development Opportunity" Transforming the Charcoal sector in Tanzania" WB policy note, 2009.
[12] "Sustainable Energy for all": MEWR Government of Sierra Leone June 2012.
[13] The pillars are consistent with the UN 2012 Energy for All goals, which aim to double energy access, double the rate of improvements in energy efficiency and double the proportion of renewable energy in the energy mix by …?

Projections 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 not functioning most of the time.

**Production of petroleum products**

All the petroleum products consumed in Sierra Leone are imported basically from international market. Recently the country has proved to have oil reserved. At present this is at an exploratory stage. A development of this resource is envisaged in the future; therefore emission from this sector will consequently be enhanced.

### 3.3.2 Result of Screening

**Mitigation options, for the energy sector**

The list of mitigation options, for the energy sector outlined above which as a result of the screening exercise are summarised and prioritized below:

**Table 3.3 Proposed mitigation options in the Energy and Water Sector**

| Energy and Water Sector | |
|---|---|
| **Possible Mitigation Options to be Considered** | **Priority** |
| Hydro Electric Power (HEP), | High |
| switching and promotion for renewable energy (Solar Energy & LPG) | High |
| development of alternative energy sources such as Bio-fuels (from corn, sugarcane, rice husk etc) | Moderate |

### 3.3.3 Potential of the mitigation options

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 3.4).

**Table 3.4: 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 |

## 3.4 Mitigation Capacity in the Waste Sector

### 3.4.1 Analysis of the sector

Domestic, agricultural and industrial waste is generated in the form of solid and liquid. There is no form of waste management or separation in Sierra Leone. Solid waste is collected from residential properties and commercial services, markets, recreational areas, government offices and institutions (schools and Hospitals), fish and poultry processing plants, industries, hotels, etc. the waste constitutes the following: leftover food, paper, grasses, construction waste and other cutting.

In Sierra Leone, waste management analysis is only conducted in the Freetown municipality, which is located in the Western area. As such, much of the data used 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 seat 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 most food stuffs produced in the country.

#### 3.4.1.1 Estimates of Emissions from Waste Management Sector

Five main sources were considered: solid waste disposal on land – CH4, industrial wastewater – CH4 , domestic and commercial wastewater – CH4, domestic and commercial wastewater – N2O, waste incineration – CO2, CH4 and N2O

### 3.4.2 Mitigation options, for the waste sector

The list of mitigation options, for the waste energy sector outlined above which as a result of the screening exercise are summarised and prioritized below:

**Table 3.5 Proposed mitigation options in the Waste Sector**

| Waste Sector | |
|---|---|
| **Waste Management Practices** | **Possible Mitigation Options to be Considered** |
| Solid Waste Disposal On Land | Composting |
| Industrial Wastewater | Recycling |
| Domestic And Commercial Wastewater | Recycling |
| Waste Incineration | Conversion to biogas |

#### 3.4.2.1 Results of screening
**Mitigation options in the waste management sector**

The method used to arrive at the mitigation options proposed by the stakeholders was the "Mitigation Option Weighting" method. The following options listed in table 3.21 were identified and weighted:

**Table 3.6: Weighted Mitigation Options**

| Mitigation options | Weighting 30/priority |
|---|---|
| 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 should be encouraged.

### 3.4.3 Potential of the mitigation options

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.

Operations such as thinning 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 off-cuts produced during the processing of cut timber make very good fuel. The sawdust and off-cuts can be collected countrywide from furniture industries and processed to produce fuel.

Over 90% of domestic waste in Sierra Leone is currently land-filled and most of the remainder is 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.

Again, large scale plans for waste separation, recycling and composting remains elusive 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 are constraints.

### 3.4.4 Possible Technological Resources to implement the measures

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 (LPG), 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

The potential technology options for the different mitigation options are identified below:

| **Table 3.7 :Potential technology options** |
|---|
| Waste incineration |
| Landfills and open-dumps |
| Composting |
| Recycling |

## 3.5 Mitigation Capacity in the Agriculture Sector
## Assessing and Prioritizing Mitigation Opportunities in the Agricultural Sector

### 3.5.1 Analysis of the 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 2010). The period of inventory was ten years, 1995-2005, with 2000 as the base year.

The agricultural sector, contributed in 2006 to approximately 46% of gross domestic product (GDP) and employing over 65% of the labour force. Increase in food production and security is another government's top priority on its national agenda. Mechanisms have now been put in place to ensure that higher crop yields are obtained in order to reduce on food imports to save more foreign exchange earnings that could be used for other development programmes and projects.
Government is also making strides to give a face lift of meteorological Department into an Agency to provide agro-meteorological information to avoid crop failure in the country

Crop production in the country is very sensitive to climate and climate variation. Agriculture is the largest economic sector in Sierra Leone, contributing (in 2006) to approximately 46% of GDP[1] and employing over 65% of the labor force. Rice is the main agricultural production and it is mainly cultivated for subsistence purposes. The fluctuation in yearly crop yields is mostly due to weather effects and climate variability. The impact of climate change is already tangible in the country. Indeed, Sierra Leone is experiencing climatic hazards such as seasonal drought, strong winds, thunderstorms, landslides, heat waves, floods and changed rainfall patterns. As reported in the Sierra Leone's National Adaptation Programmme of Action (NAPA), poor communities have suffered the most from climate change impacts, as floods destroyed their crops and increased droughts caused water shortages in some areas of the country. In particular crop production, being highly vulnerable to climatic change, has been affected by prolonged period of dry days even during the rainy season (July/September) and heavy rains in March that prevented farmers to burn their fields resulting in weeds expansion. As an example of predicted climate change impact on crop production, for temperature above 25° C rice production is expected to retard and yields to decrease[2]. Other production such as maize, millet and cocoa are projected to be negatively affected by climate change. Considering that food production depends entirely on subsistence farming, a decline in agricultural productivity – coupled with the increasing trend of food prices – is expected to ultimately worsen current food insecurity problems.

The rainfall in the country is increasingly becoming sporadic and in the last two years more rain has fallen in March which is the driest month of the year than the last three decades. Furthermore, 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 yield of crops.

### 3.5.2 Mitigation options in the agricultural sector

The list of mitigation options, for the agricultural sector outlined above which as a result of the screening exercise are summarised and prioritized below:

**Table 3.8 Potential Agricultural Mitigation Options in the Agriculture Sector**

| Agriculture Sector | |
|---|---|
| **Agriculture Management Practices** | **Possible Mitigation Options to be Considered** |
| Deep Water Rice Cultivation | Fallow incorporation and Mulching |
| Flooded Rice | Water Regime Management/ Modification |
| | Organic Amendment |
| | Mineral amendment |
| | Straw Management |
| | Composting |
| | Crop Establishment |
| Low Land Flooded Rice | Prevention of Denitrification- Avoiding Nitrogen Fertilizer |
| Enteric Fermentation | Feed and fodder modification |
| | Manure Management |
| Burning of Savannahs | Formulate legislation 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 |
| 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 |

#### 3.5.2.1 Results of screening
#### Mitigation Options for GHG Emission in Agriculture

The method used to arrive at the mitigation options proposed by the stakeholders was the "Mitigation Option Weighting" method. The following options listed in table 3.21 were identified and weighted

.

**Table 3.9 Summary of Analysis of Mitigation Options for GHG Emission in Agriculture**

| Mitigations options for irrigated rain fed and deepwater rice cultivation. | | |
|---|---|---|
| **No.** | **Mitigation option** | **Weight /30/priority** |
| 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 |

### 3.5.2.2 Potential of the mitigation options

### 3.5.2.3 Possible Technological Resources to implement the measures

The potential technology options for the different mitigation options are identified below:

| **Table 3.10 Potential technology options** |
|---|
| Water regime modification |
| Organic residue management |
| Use of mineral fertilizer |
| Straw management |
| Crop establishment |
| **LIVESTOCK: ENTERIC FERMENTATION AND MANURE MANAGEMENT** |
| Improved intensive/semi-intensive ducks and chicken management |
| Animal manure management – use of manure in lowland and upland rice fertilization |

## 3.6 Mitigation Capacity in the Forestry Sector

### 3.6.1 Analysis of the sector

**Forestry and land-use situation:**

As reported in the INC, Sierra Leone is essentially a forestry country, but the forest types have been 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).

**Ecosystems Conservation and Management**

One major forest policy objective is to lessen the impact on the environment of necessary deforestation, and to prevent, as much as possible, unnecessary deforestation. A number of strategies will be developed to help achieve the policy objectives in this area, including:

The development of integrated watershed management in the major catchments areas, where watershed degradation is beginning to be evident, as well as in those watersheds which are critical for meeting national energy and water supply needs;

Collaboration in all matters pertaining to the forest environment and climate change with the Sierra Leone Environmental Protection Agency now responsible for oversight on environmental matters;

The preservation and protection of natural fauna and flora where their retention is essential for climatic stability and for the conservation of soil and water resources and; Liaison with adoption of, association with, and pursuit of the plans of UN agencies in matters regarding the forest environment.

**Public Awareness**

The mounting of a public-awareness campaign using the various public media, and the provision of incentives to aid awareness of the importance of sustainable management of forest resources and the value of forests. The major thrust in this regard will be the development of education packages for schools, media, and communities to increase awareness about issues in the forest sector.

**Forestry Education, Training and Research**

The main objectives here are the development of a forest sense. The vital element in the achievement of this policy objective is a well-planned and well-coordinated educational and training policy. Very high priority will be given to educating a cross-section of the community in the value of forests in national development.

Government's main strategy will involve grassroots-education by promoting the formation of nature clubs and forestry cooperatives, so that the benefits of forestry can be discerned easily, and by gradually introducing forest conservation into school curricula. Another important strategy will involve intensifying national Tree Planting Day activities so that there is more widespread involvement, and encouraging youth participation in nursing and planting tree seedlings, for example, schools and clubs will be encouraged to establish their own nurseries.

### 3.6.2 Potential forest Mitigation Options

**The following** Comprehensive **list of mitigation options**, which were then screened for further analysis:

i. Reducing the demand for fuel wood (reducing deforestation)
ii. Preserving forested lands as national Parks, Sanctuaries, Aboreta etc
iii. Afforestation /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 bio fuel for fossil fuels
xii. Integrating trees into existing land use patterns-shelter belts
xiii. Residential shade trees/roadside vegetation

### 3.6.2.1 Mitigation options for the forestry sector

The list of mitigation options, for the transport sector outlined above which as a result of the screening exercise are summarised and prioritized below:

All these thirteen options have been grouped into;

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

### 3.6.2.2 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 policies 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 policies that emphasize more intensive farming and conversion of fewer marginal woodlands

### 3.6.2.3 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 50 years.

### 3.6.2.4 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.

### 3.6.2.5 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 scenarios' 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.

### 3.6.2.6 Result of Carbon Pool and Sequestration

| | **Baseline Scenario** | **Mitigation Scenario** |
|---|---|---|
| Biomass density tons per area (t/ha) | 107 | 238 |
| Biomass Carbon density tons per carbon (tc/ha) | 54 | 119 |
| Soil Carbon density (tc/ha) | 100 | 149 |
| Total Carbon density (tc/ha) | 154 | 268 |

### 3.6.2.7 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 and 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 alternative 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.

### 3.6.2.8 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 for a 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.

### 3.6.2.9 Potential of the mitigation options

Identify possible technology resources to implement the measures
If possible. Prepare a national mitigation strategy to reduce GHG emissions or a prioritization of mitigation options, at a minimum, for this you can use a table prioritizing measures.

**Table 3.11: Summary of Analysis of Mitigation Options for GHG Emission from Forestry**

| Mitigation Options | Prioritizing Measures |
|---|---|
| Reducing the demand for fuel wood (reducing deforestation) | High |
| Preserving forested lands as national Parks, Sanctuaries, Aboreta etc | High |
| Afforestation /plantation establishment | Moderate |
| Community Forestry | Moderate |
| Forest Conservation | High |
| Forest Protection | High |
| Agro-forestry cropping system | High |
| Reforestation/Rehabilitation of degraded lands | High |
| Increasing efficiency of wood recovery/use | Moderate |

| | |
|---|---|
| Substitution of timber for high energy construction material | moderate |
| Substitution of wood and other bio fuel for fossil fuels | moderate |
| Integrating trees into existing land use patterns-shelter belts | High |
| Residential shade trees/roadside vegetation | Moderate |

### 3.6.3 Possible Technological Resources to implement the measures

## 3.7 Other Potential Sectors to Avoid Carbon Dioxide Emission

**Analysis of these sectors**

Other potential sectors to avoid carbon dioxide emission related to the energy sector are: (i) manufacturing and construction industries, (ii) agriculture, fishery and fishing activities, (ii) Mines (gold washing and exploitation of rutile, bauxite, iron ore and diamonds). Emissions from these sectors are presently not quantified but may develop further considering the targeted ambitions in the various strategic frameworks by the year 2017. ERT possibilities in these sectors may be summarized as follows:

### 3.7.1 Manufacturing and construction industries

There are plans to increase agro-industries particularly slaughterhouses, hides and skins and agricultural by-products. The viability of such industries depends, to a large extent, on the source of energy and its cost.

Consequently, industrial units out of the electrical grid are hardly sustainable. It is thus possible to expect few risks in their development out of the electrical grid in the various electrical energy supply scenarios in the country.

### 3.7.2 Agriculture and Fishing Activities

The energy consumption of this sector has experienced a substantial lift with the Modernization program of this sector in recent years.

Emissions result from two sources: (i) mobile through the extension of agricultural tractors and (ii) fixed through the promotion of irrigated farming.
The mechanization of ploughing is limited in Sierra Leone and its development will not be quite promising in view of the projection of the country's various strategies. However, irrigated farming is highly envisaged with targets of about 270 000 ha by 2015 compared with less than 50 000 ha today. At least 50% of this land area is envisaged in the form of smallholder size private farms.

The major constraints are the costs and maintenance operations. With the building of the Bumbuna Dam, the navigability of the river will be certain, which will increase emissions caused by fishing and possibly fish farming. Measures should also be envisaged here on the most appropriate means of navigation. Sierra Leone has very little experience in this area.

To conclude this chapter; one may say that the ultimate aim is the economic and social development while protecting the environment.

The achievement of these objectives is a national priority for a country with a low human development index which led to a high mobilization of the international community.

The country's huge natural resources offer great potentials and therefore make the issue of technology transfer crucial in all sectors and the energy, mining, agricultural and fisheries sectors in particular. Fortunately for all the possible technology alternatives, the country is endowed with the resources necessary. The major challenge is their correct assessment and a consequent capacity building program to tackle the situation.

### 3.7.3 Assessment of the institutional capacity-building requirements to sustain mitigation work and the related legal and institutional frameworks

Sierra Leone has very low institutional and technological capacity to sustain or to undertake the mitigation work. This is because the country has very high level of poverty, low level of trained and qualified personnel at all levels in the sectors were mitigation can occur.

However, the various sector policies particularly those dealing with natural resource management, mining, agriculture, fishing and others have components with the potential of enhancing mitigation activities.

**Barriers and opportunities for mitigation**

A lot of barriers and opportunities for implementation of the different identified measures exist. These include both institutional and those related to capacity and inter –agency coordination.

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# Chapter 4

## 4.0. Vulnerability of the Major Economic and Other Crosscutting Sectors of Sierra Leone to Projected Climate Change

### 4.1 Introduction

Vulnerability generally refers to as the incapacity of a system to address the negative effect of climate change. It is usually a function of climatic variations, the system's degree of sensitivity to these variations and its adaptation capacity. The information relating to the vulnerability of Sierra Leone to Climate Change is limited due to the amount of available data and the incompleteness of the areas and topics being looked at.

The main purpose of this chapter is to present the results of sector based and other cross-cutting studies on the impact and vulnerability of key economic sectors to Climate change. A study to develop current climate and future climate change scenarios was undertaken by the Meteorological Department of Sierra Leone. The scope of this study is to characterize the climate of Sierra Leone for the period 1961-2010 with projections up to 2050 and consider it as the continuation of current climate of the country.

The results were made available to the sect oral teams for their use in their inter-disciplinary vulnerability assessments.

The methodology used for the assessments were sector specific**.** The country has identified the most vulnerable sectors based on the following set of criteria: Contribution of the sector to the National Gross National Product (GNP), Contribution of the sector to food security and vulnerability of the sector to physical alterations due to Climate Change and extreme weather events.

### 4.2 Current Climate variability

### 4.2.1 Baseline Climate Scenarios

Forty nine years (1961-2010) of current climate data were used to develop the baseline climate scenarios for Sierra Leone. Selection of this period is expected to minimize bias towards dry or wet periods that span more than 20 years.

**The Dry and Wet Seasons - Precipitation**

As a typical tropical country within latitudes 7º and 10º N and being on the Atlantic on the West at Longitude 13º W extending eastward to longitude 10º W, the country has two main seasons of wet and dry. The wet season is associated with the southwesterly tropical maritime monsoon with pressure and drift originating from the St. Helene High Pressure belt gradually encompassing northwest.

As a tropical country, all the months give appreciable amount of sunshine hours as seen in Figure 1

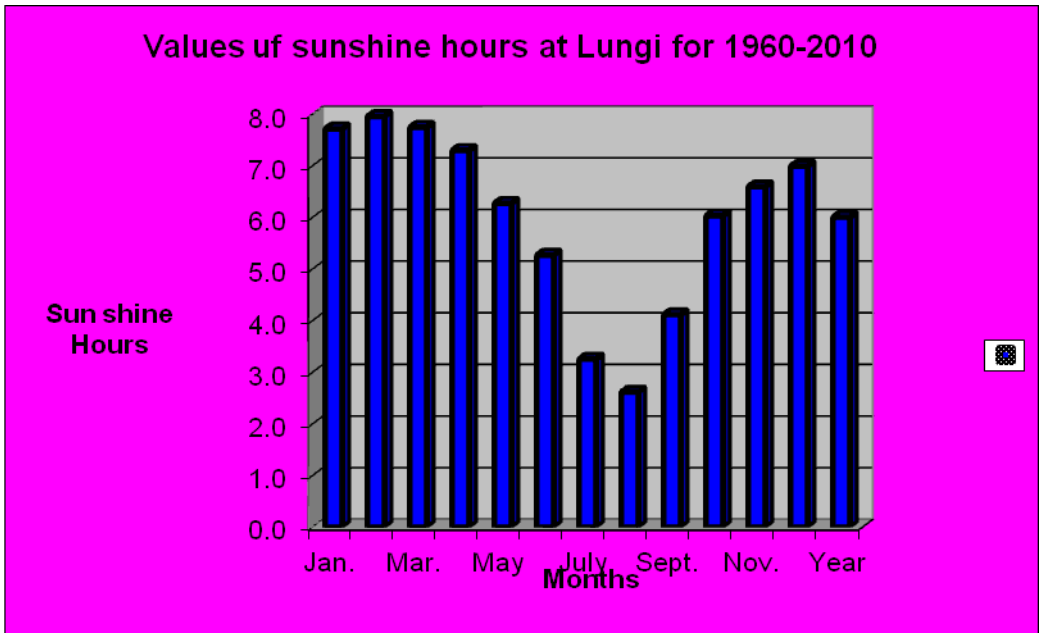



**Figure 4. 1: Means monthly temperature (0C) of Sierra Leone for period 1960 - 2010**

The pre-monsoon period runs for two months from April to June when the predominant wind direction is South-westerly.

As the convective activity gathers strength and due to the embedded high energy, thunderstorms are frequent. The most important weather phenomenon is Squall Lines which a line of thunderstorms and strong winds resulting from the local as well as regional frontogenisis inter-play and brought about by the sudden depression of the Inter-Tropical Convergence Zone (ITCZ). Surface winds of 60 or more nautical miles per hour (Kts) are common with Squall Lines and are sometimes accompanied by rain storms. They bring with them periodic disastrous consequences to some weakly constructed village houses and vegetation. There are instances of tree fall causing the loss of lives as in the last Kenema Airfield area tree fall that reported the death of three people in 2001. Within the period under review, some five recorded squall caused tree falls and the destruction of homes and property in several parts of the country. This situation has changed in the last years with more frequent and violent storms.

**The Wet or Monsoon Season**

The monsoon season runs for the period July to September when the direction of wind continues to be south-westerly and the ITCZ makes its highest northward ascend. The intensification of south-westerly moisture laden wind is at its peak. Thus the coastal areas of the country experience the heaviest deposit of this moisture in the form of torrential rains.

These rainfall amounts decrease progressively as one moves eastwards and northwards. For the period 1961 to 2010 the country average rainfall is about 2650 millimeters (mm) and varies from 3614 mm at Bonthe in the south, 2865 mm at Lungi in the west (Freetown), 2358 mm at Kabala and 2585mm at Bo in the north and central parts of the country respectively.

Figure 4.2 below shows the monthly variation of rainfall at the major stations whose data has been used in this study to construct the present climate of Sierra Leone and also the climate change scenarios for the impacts studies. The precipitation regime has become more erratic in the last 50 years.

The mean annual rainfall over the country is about 3000mm and 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.

The temperatures are consistently high throughout the country, roughly averaging about 28 degree centigrade. The humidity, like the temperature is usually high as a result of the heavy rains coupled with high temperature and 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.

**Figure 4.2**: ***The Average Monthly Rainfall (mm) of Sierra Leone at selected Stations for the Period 1961-2010***

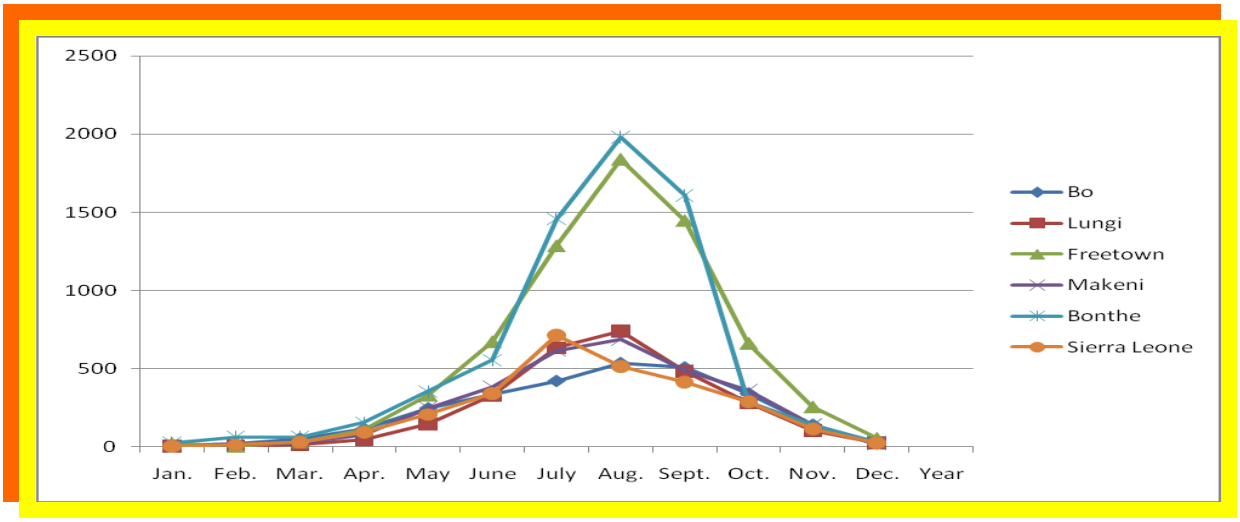
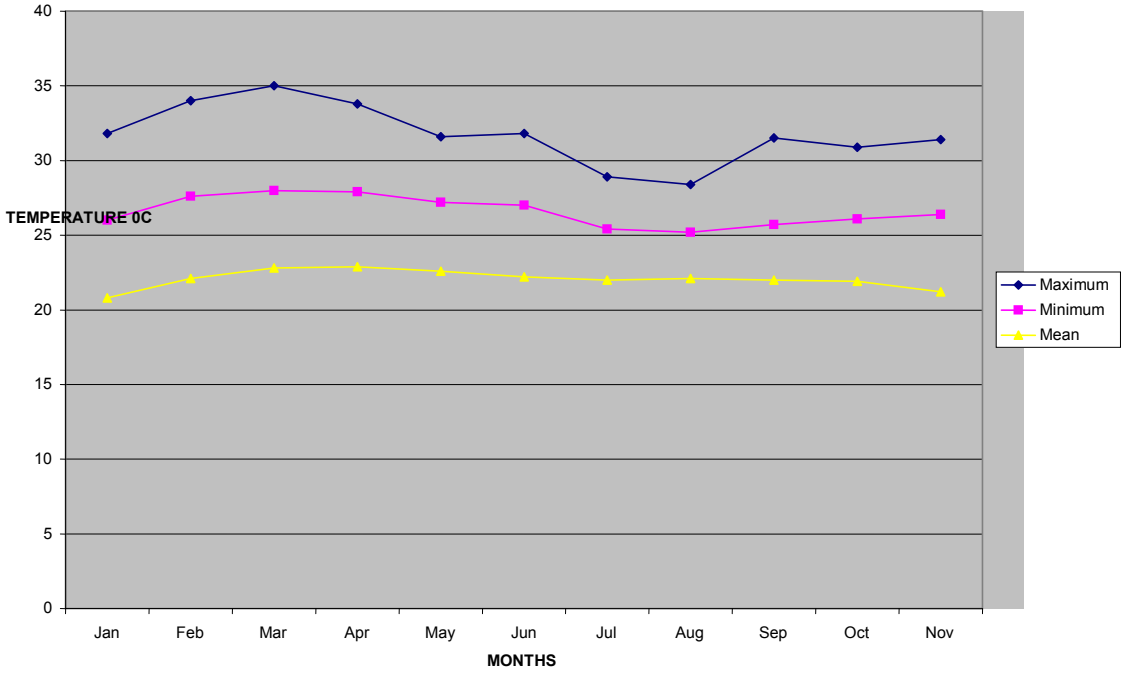


**Figure 4.3: Average Monthly Temperature (0C) of Sierra Leone for the period 1961-2010**




## Other Meteorological Elements of Sierra Leone

The post monsoon period of October to November has predominant wind direction of south-westerly but with lesser strength 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 due the similar high-energy surrounding air mass is weaker. 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 3 below the amplitude of the average annual mean temperature (middle curve) of Sierra Leone is about $3^{O}$C. Maximum temperature shows larger amplitude (about $5^{O}$C) while minimum temperature has an amplitude of about $2^{O}$C; (Figures 3a and 3b) Highest temperatures are recorded in March and resonate between February and April while lowest temperatures are recorded in July and August. The low temperatures in July and August are mainly due to almost continuous cloudiness and rain during these months of the south western Monsoon Season described in preceding sections of this report.

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 as about 40% while it is mostly above 60% throughout the year.

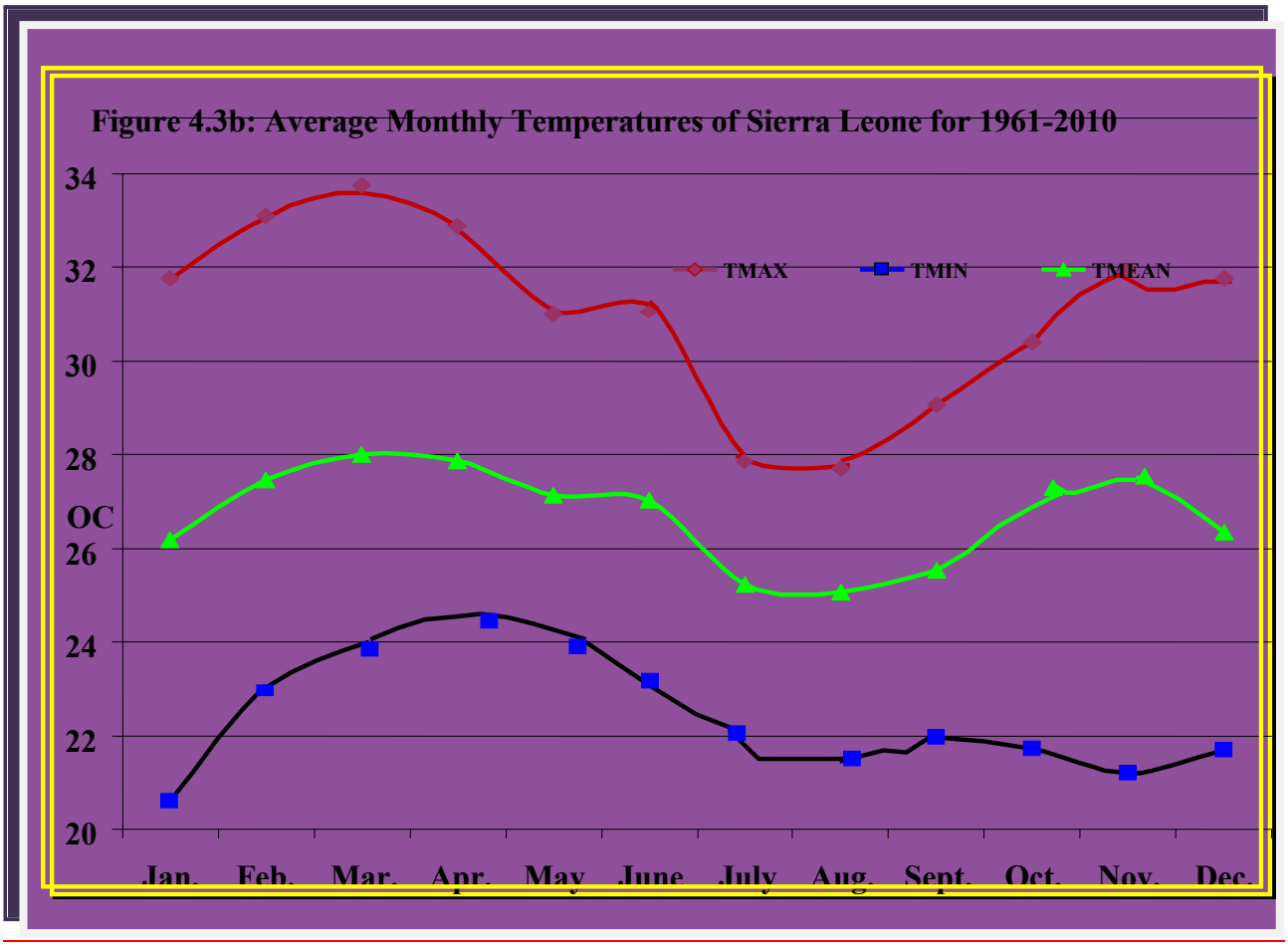



Figure 7 shows that since 1961 evaporation has a decreasing trend and was low in the late 1970s. It, however, picked up an increasing trend in the early 1980s. The top graph of Figure 2(see the country mean curve) is the plot of rainfall for the same period. The figure illustrates that annual rainfall is about twice annual evaporations but decrease in rainfall is more rapid.

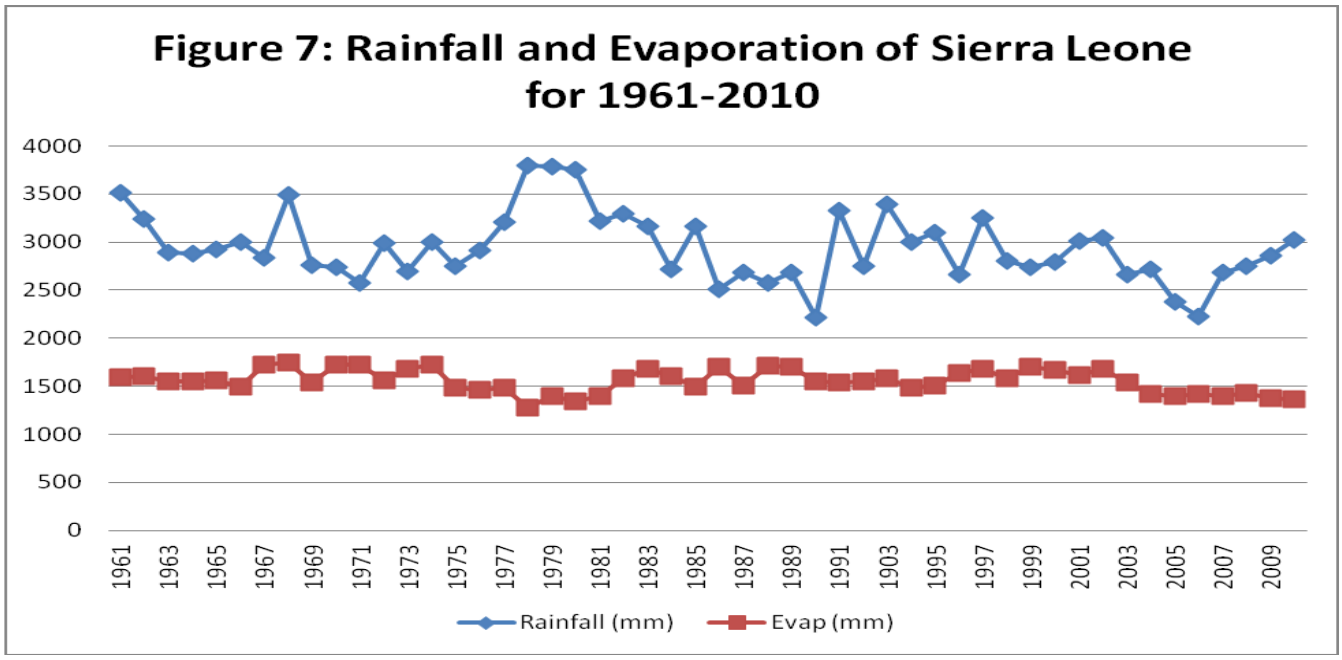



**Figure 4.4 Rainfall and Evaporation of Sierra Leone for 1961-2010**

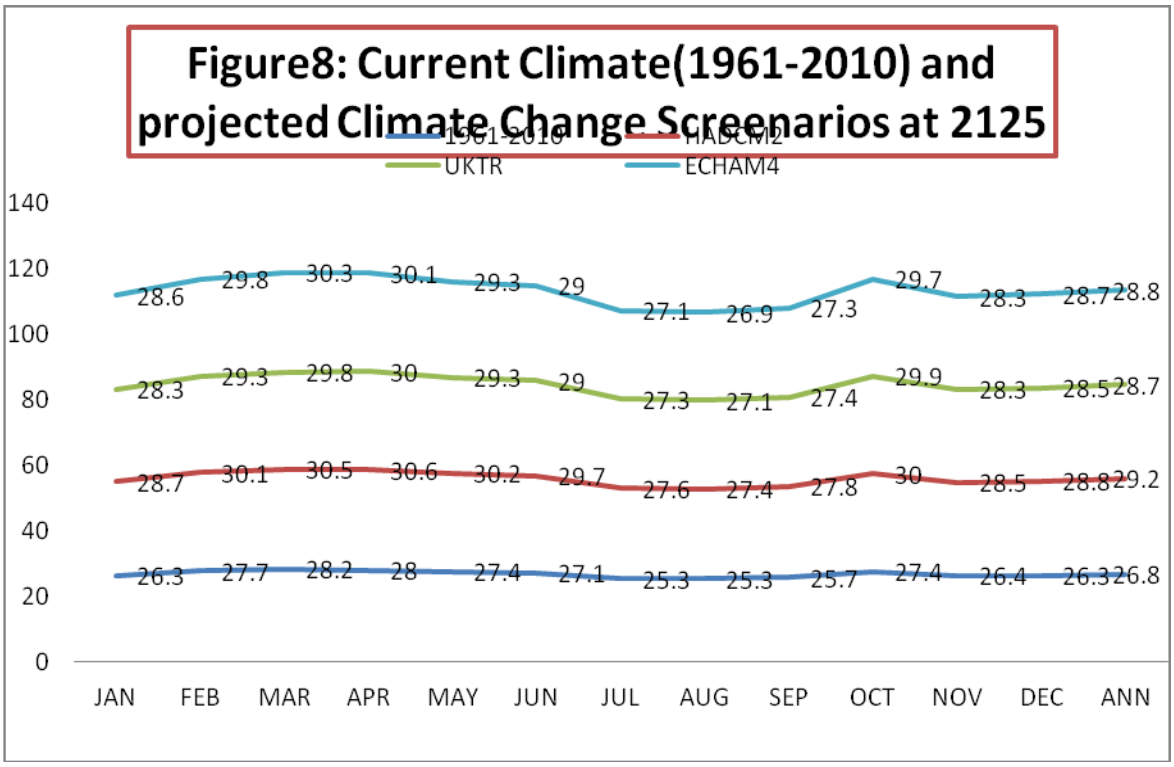
**Climate Change Scenarios**

In this report the current climate change scenarios for Sierra Leone was accomplished through the use of MAGICC version 5.3 (Model for the Assessment of Greenhouse-gas Induced Climate Change). The models used by MAGICC have been developed in the Climatic Research Unit and the climate model is a standard upwelling-diffusion, energy- balance model of the form originally developed by Hoffert et al. (1980) and described by Wigley and Raper (1987, 1992, 1993) and by Raper et al. (1996). The GCM output from the HADCM2, UKTR, CSIRO-TR and ECHAM4 models were used to construct the climate change scenarios.

All of the climate scenarios show an increase for the future in the normal annual maximum temperature for the whole country, ranging for e.g. from 1.25 °C (32.13° to 33.38 °C for MIROC3.2) to 1.87 °C (29.56° to 31.42 °C for CSIRO-MK3).

**4.2.2.1 Temperature Scenarios**

The average annual temperature of Sierra Leone for the period 1961 to 2010 and based on observed data from the meteorological stations discussed in preceding sections is about $26.9^{O}$C. Combining this average annual temperature with the 2*CO2 output from the GCMs, the average annual temperature for Sierra Leone for the period 1961-2010 is projected to increase by about 7 to 9.5 per cent above this average temperature at 2125. Figures 8a, Figure 8b and Table 2 below show the variation of this projected increase in the annual average temperatures at 2125.




The current Climate Scenarios projected for 2025 are given in the Chart below for HADCM, UKTR and ECHAM4 model runs.

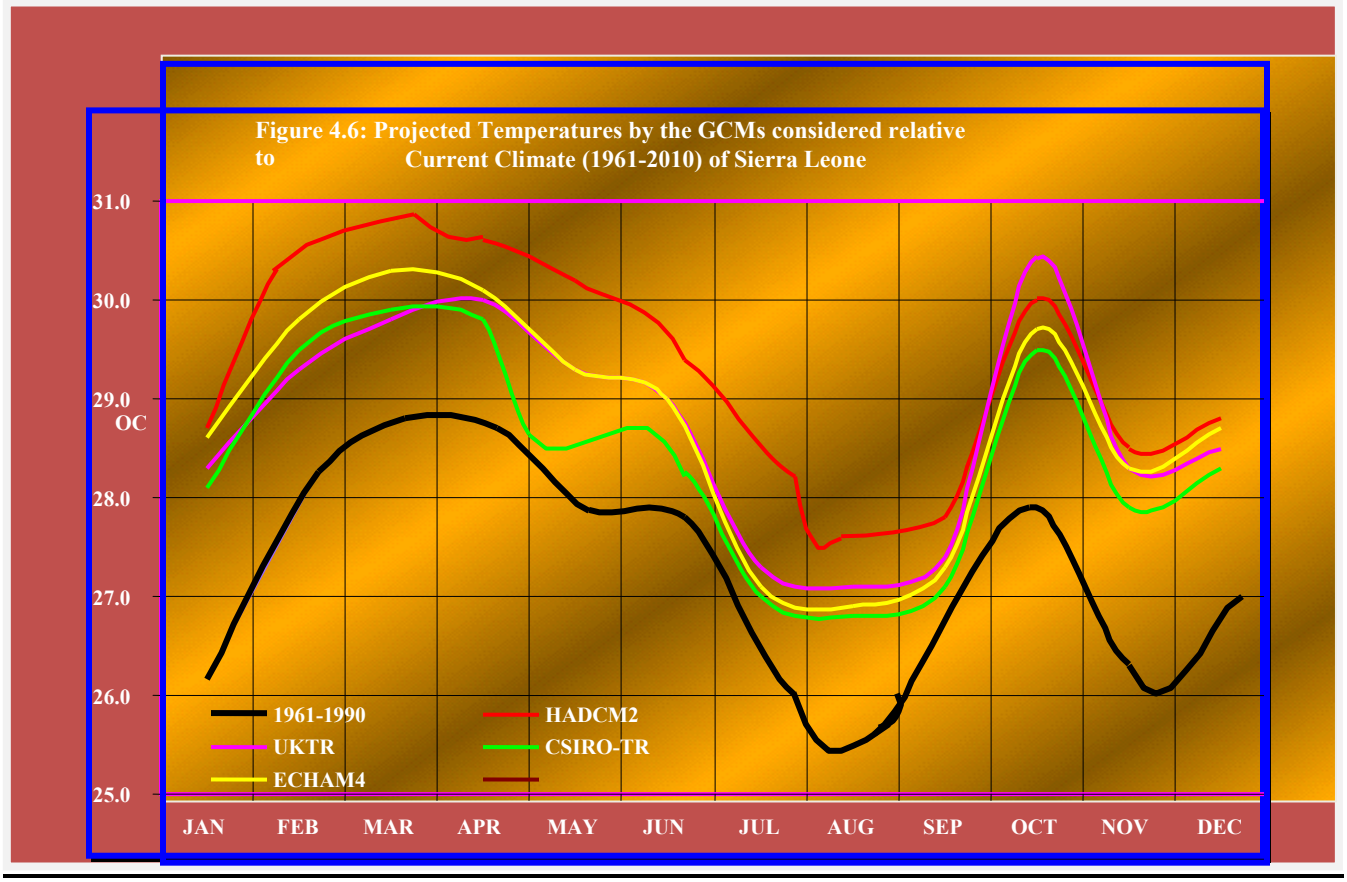
**Figure 4.5: Current Climate (1961-2010) and three projected Climate Scenarios at 2025**

Similar work with the CCSIRO-TR model only gave the projection for 2010 using the same country data of 1961-2010.

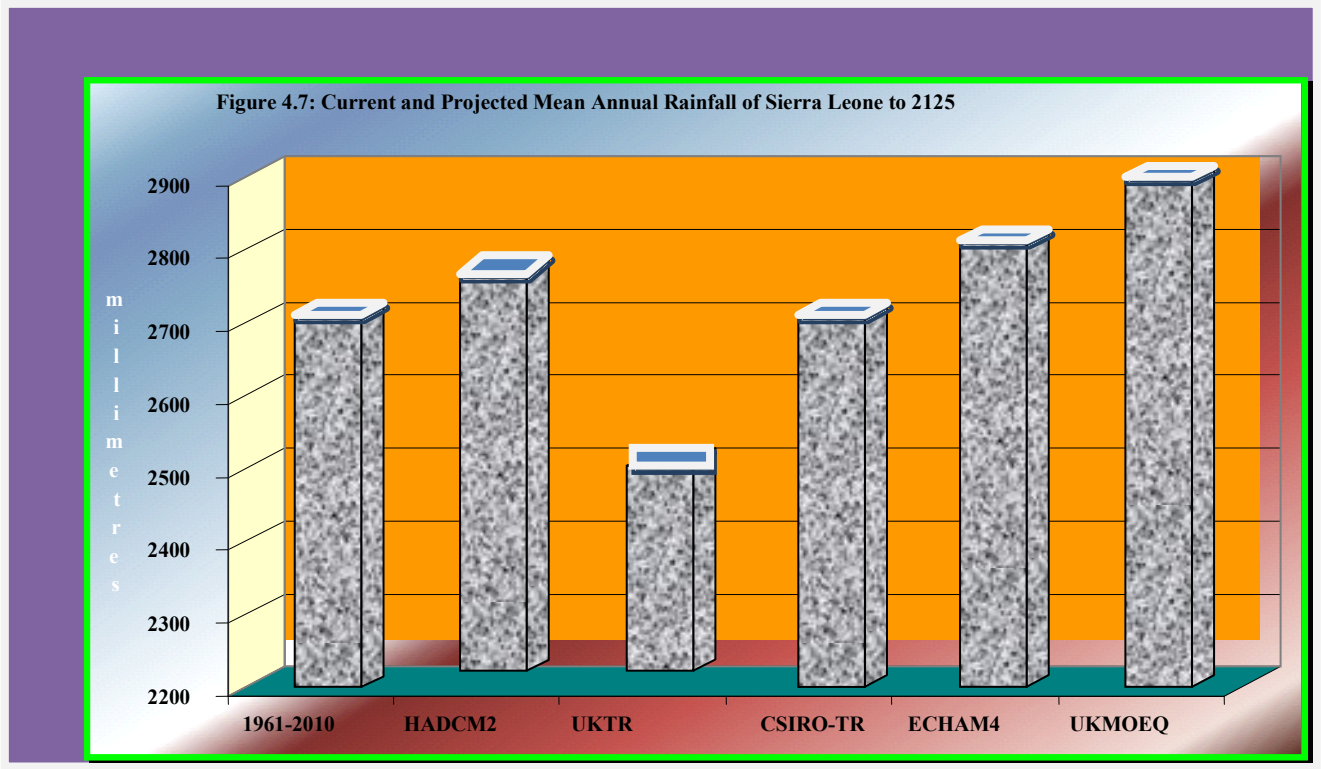
**Table 4.1: Current climate (1961-2010) and projected climate change temperature scenarios at 2120**

| Scenario | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC | ANN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 |

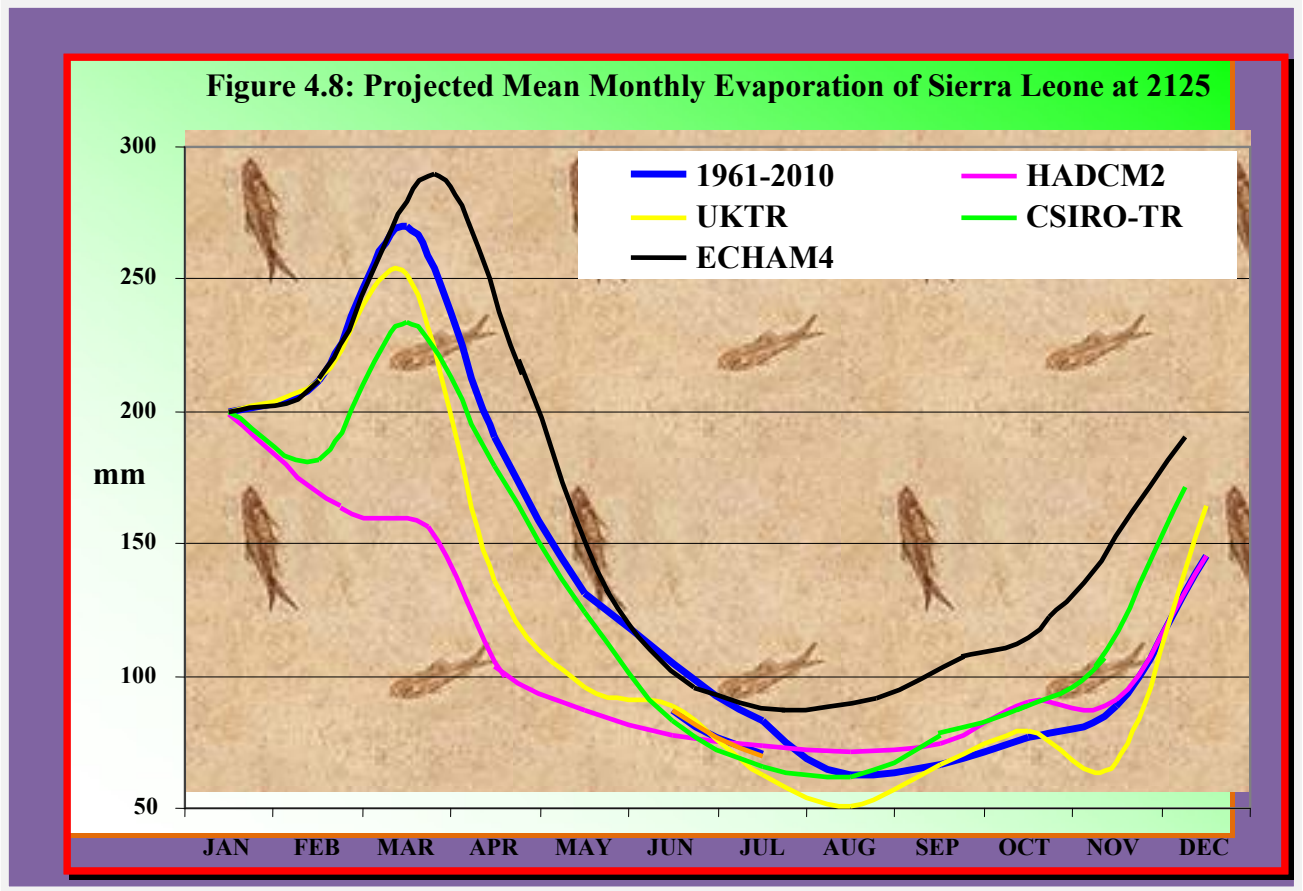
However the GCMs were considered where the later was extrapolated to give Figure 8b




### 4.2.2.2 Precipitation Scenarios

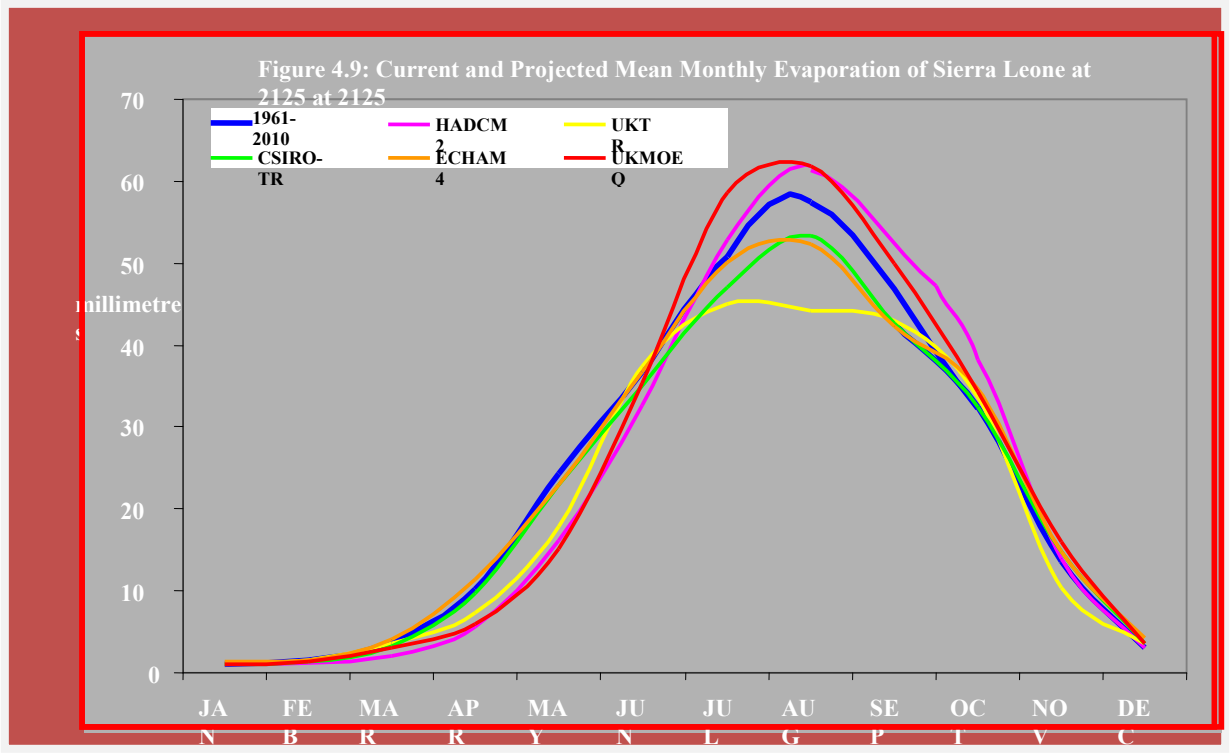



Figures 9 and 10 show current (1961 -2010) and projected rainfall to 2125. Both figures show that monthly (Figure 9) and annual (Figure 10) rainfall values at 2125 under the ECHAM4 and HADCM2 models are similar to current climate rainfall values



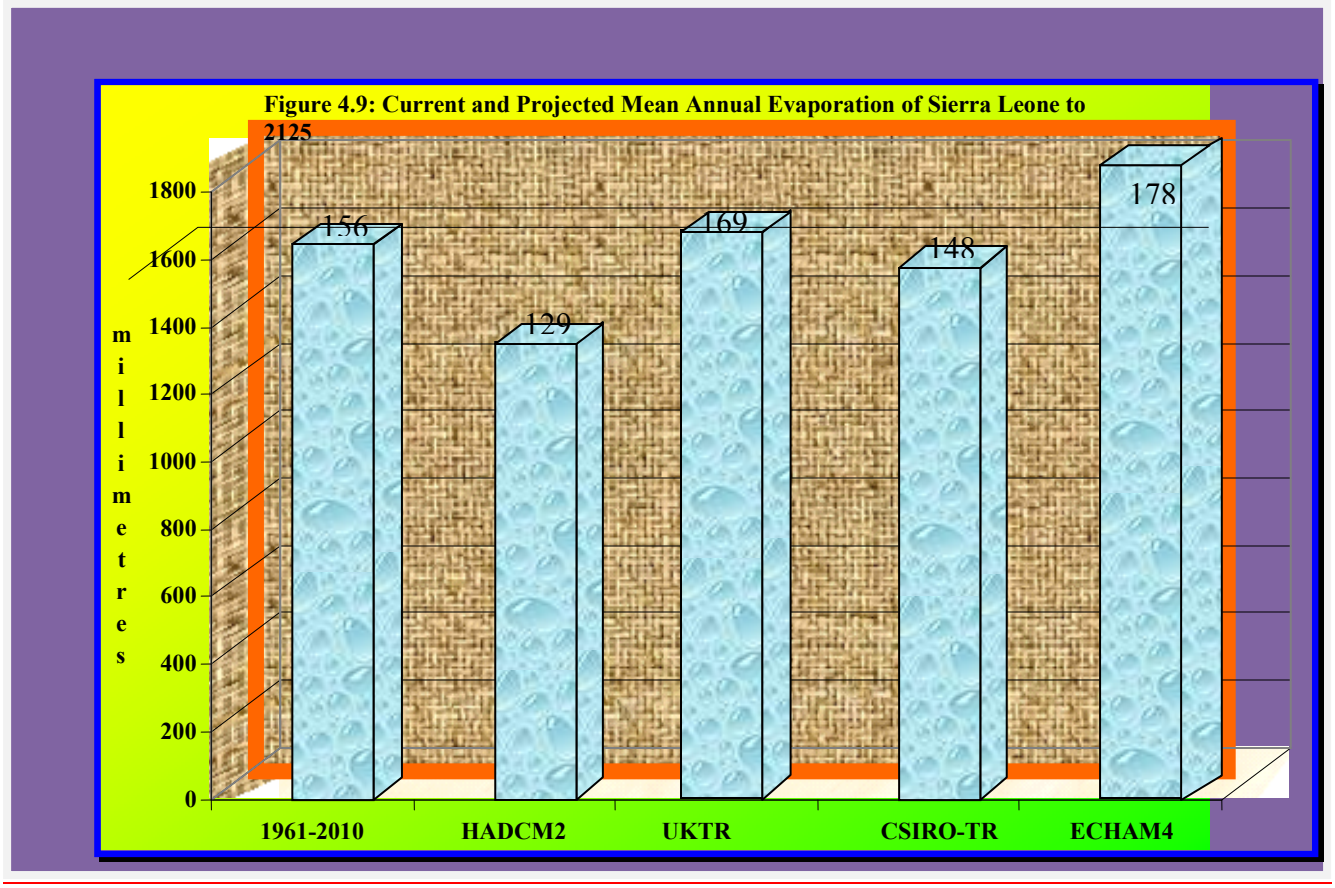

Mean monthly evaporation for current climate (1961-2010) and projected values at 2125 by GCMs are illustrated in Figure 11. During the period from January to May monthly evaporation values under current climate are higher than all projects to 2125 by the GCMs except for the ECHAM4 model whose projection is higher than current climate values and projects by all other GCMs used in this study.

#### 4.2.2.3 Evaporation




However, the CSIRO-TR and UKTR models show a decrease in rainfall by about 3.5% and 9% respectively below current monthly and annual rainfall values.

The monthly variations in evaporation shown in Figure 11 above are markedly reflected in the mean annual evaporation values illustrated in Figure 12 below. Variations about the mean annual evaporation of 1690 mm under current climate (1961-2010) show an increase of about 6.5% under the ECHAM4 model but a decrease of about 20% under the HADCM2, 8.5% under the UKTR and 5% under the CSIRO-TR models.




#### 4.2.2.4 Solar Radiation

From Table 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 4.2: Current (1961-2010) and Projected (to 2125) Solar Radiation (MJ/m$^2$/month) for Sierra Leone**

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1961-2010** | 530 | 412 | 601 | 567 | 552 | 486 | 446 | 422 | 465 | 530 | 498 | 512 |
| **HADCM2** | 530 | 292 | 319 | 306 | 364 | 433 | 464 | 481 | 521 | 626 | 513 | 512 |
| **UKTR** | 530 | 412 | 559 | 403 | 403 | 496 | 397 | 341 | 470 | 546 | 378 | 578 |
| **CSIRO-TR** | 530 | 354 | 523 | 533 | 519 | 462 | 415 | 413 | 465 | 530 | 543 | 578 |
| **ECHAM** | 530 | 412 | 641 | 632 | 521 | 486 | 440 | 406 | 462 | 565 | 542 | 703 |

**$CO_2$ 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 and to about 950 ppm by 2025. 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 and by 3.5 m (IPCC, 1990).

**Table 4.3: Atmospheric $CO_2$ concentrations and sea level rise scenarios**

| Year | $CO_2$ Concentrations (ppm) | Sea level rise | |
|---|---|---|---|
| **1990** | 350 | | |
| **2000** | 370 | | |
| **2025** | 425 | **Baseline** | 0.2 m by 2100 |
| **2050** | 510 | **ASLR1** | 0.5 m by 2100 |
| **2075** | 580 | **ASLR2** | 1.0 m by 2100 |
| **2100** | 700 | **ASLR3** | 2.0 m by 2100 |
| **2125** | 950 | **ASLR4** | 3.5m by 2025 |
| **ASLR is Accelerated Sea Level Rise** | | | |

## 4.3 Vulnerability of the Major Economic and Other Crosscutting Sectors

**Introduction**

Vulnerability assessments were carried out using standard software packages for the sectors below. However, the unavailability of data during the war years of 1991 to 2002 when the war was declared officially over made it difficult to improve on the GCM scenarios, and socio-economic data to run the simulation of impacts to climate change on the forestry and fisheries sectors in the country. The simulations using the models below could therefore not be run including these years. Nonetheless, expert judgment from consultations with in-country forestry and fisheries specialists was used to suggest likely effects of climatic changes to the forestry and fisheries sectors in the country based on modelling results of the INC.

### 4.3.1 Agriculture

The primary objective of the study is to provide a preliminary assessment of the vulnerability of agricultural sector to climate change.

The study further assesses the potential impacts on key agricultural crops in Sierra Leone to likely climate change in some detail.

#### 4.3.1.1 Current Conditions

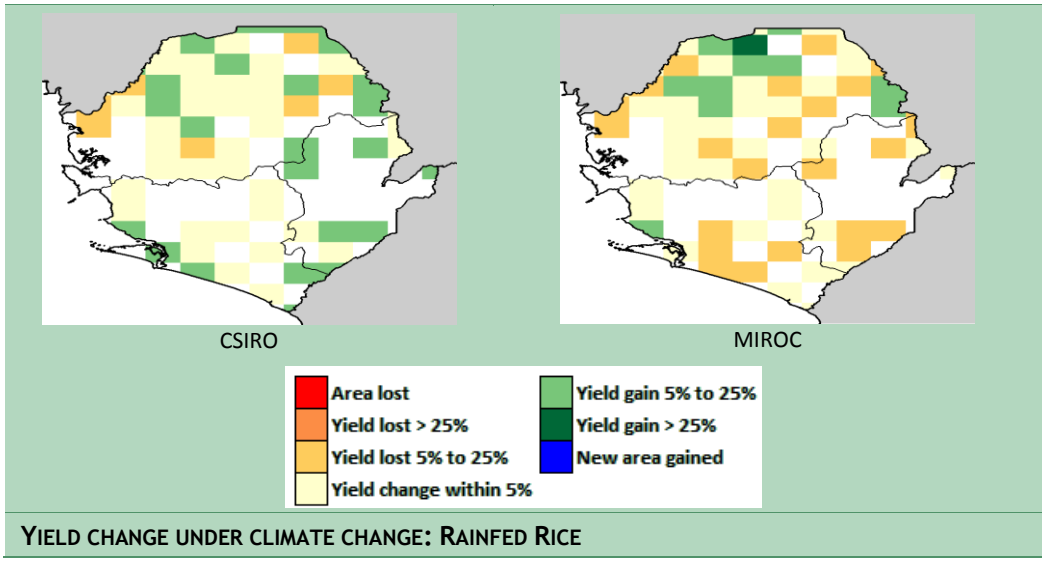
Agriculture is the largest sector in the economy of Sierra Leone providing employment for over 65 percent of the labour force, and contributing about 35 to 47 percent of the Gross Domestic Product. Rice is the staple food crop in Sierra Leone, grown mainly by small-scale farmers under rain-fed conditions. The impact of climate change is already felt in the country, in changed rainfall patterns, strong winds, thunderstorms, landslides, heat waves, floods, and seasonal drought. Transporting agricultural produce continues to be a challenge in the country; most of the roads in remote areas are impassable during the rainy season.

**Data Requirement**

The crop specific data required for the assessment of the impacts of climate change on agriculture was obtained from the Sierra Leone Agricultural Research Institute (SLARI).

#### 4.3.1.2 Climate Change Scenarios & Their Potential Future Effects on Yields

All the climate scenarios show an increase in the normal annual maximum temperature for the whole country, ranging from 1.25 °C (32.13° to 33.38 °C for MIROC3.2) to 1.87 °C (29.56° to 31.42 °C for CSIRO-MK3). For rice, the productivity effects of climate change, would result in yield declines of 3.7 to 4 percent. Climate change would result in yield declines of 3 to 4 percent and 2 to 2.5 percent for cassava and groundnuts respectively.




YIELD CHANGE UNDER CLIMATE CHANGE: RAINFED RICE

#### 4.3.1.3 Impacts of Climate Change on Crop Production

In assessing the impacts of climate on the crop production sub-sector of agriculture climate change, socio-economic and crop production data and scenarios were input into the DSSAT3 biophysical model to run the simulation of impacts of climate change.

#### 4.3.1.4 Crop physiological response to climate change

The effect of climate change on key crops is mapped. Crop yields for 2050 with climate change are compared to the projected 2050 yields with unchanged (2000) climate. Both CNRM-CM3 and CSIRO-MK3 show rice doing well under climate change, particularly in the northern regions of the country. These scenarios show yield gains greater than 25 percent of baseline in areas throughout the country. ECHAM5 and MIROC3.2 show similar results for rice, particularly in the northern region. Under these scenarios, the rest of the country shows yield losses of 5 percent to 25 percent of baseline, as well as areas with yield change (positive or negative) within 5 percent of baseline.

Under climate change scenarios, groundnuts show a yield loss of 5 to 25 percent of baseline in many areas of the country. MIROC3.2 medium resolution shows relatively less area being affected. CSIRO-MK3 and MIROC3.2, however, show a yield increase of 5 to 25 percent along the coast.

#### 4.3.1.5 Agricultural Vulnerability Scenarios (crop-specific)

All of the scenarios show increasingly negative trends for net rice exports—though much less so in the case of the pessimistic scenario. All three scenarios show a general increasing trend in the world price for rice. Rice productivity needs to improve to meet domestic consumption demand; increasing production will also benefit farmers, through high world prices.

The scenarios for production and yield of cassava and other roots and tubers show an increase toward 2050, with only a slight increase in the area under cultivation. Net export of cassava and other roots and tubers is shown increasing up to 2030, followed by a decline up to 2050 for all the scenarios.

Groundnut production is shown to increase as a result of expansion in area under production; productivity is shown to decrease, probably due to climate change. Depending on the scenarios, net exports are shown to increase through 2020 and decline thereafter. With decreasing productivity, more area has to be brought under cultivation to meet the demand for groundnut as population increases, while increased land degradation forces farmers to use expensive inputs.

#### 4.3.1.6 Potential Adaptation Measures

#### 4.3.1.7 Conclusions and policy recommendations

Crop production in the country is very sensitive to climate and climate variation, as seen in recent experience as well as in the modelled outcomes. Rainfall is becoming increasingly sporadic; in the last two years, more rain has fallen in March (the driest month of the year) than in the last three decades. The model outputs, based on climate scenarios, show specific climate change impacts: for temperature above 25°C, for example, rice production is expected to show decreasing yields. Other crops, such as maize, millet, and cocoa, are also shown negatively affected by climate change.

The various models show different results, while differing significantly from the baseline scenarios. The most significant results are those relating to possible declines in production of basic food crops: the vulnerability of crops to climate change also poses a direct threat to farmers' livelihoods and to overall

food security. These disturbing scenarios would undermine government plans to expand agricultural production, to alleviate poverty, and to secure affordable food for all.

Potential adaptation measures include improving water-use efficiency of crop through management of soil fertility, improved irrigation systems, developing early warning system, and promoting and encouraging improved post harvest technologies and switching to drought and salinity tolerant, and high yielding crop varieties.

The following specific adaptation measures regarding agricultural policy measures are strongly urged to implement in order to mitigate the impact of current and future climate challenges:

- Support the establishment of adequate weather stations around the country in order to provide reliable and adequate weather data that will be useful to properly inform farmers.
- Provide adequate support to the Sierra Leone Agricultural Research Institute as well as Njala University to develop appropriate crop varieties and production practices that will enhance resilience to adverse weather conditions
- Develop and maintain seed banks to provide a variety of seed types that preserve biological diversity and enable farmers to make informed choices.
- Promote innovative and adaptive approaches such as irrigation and water harvesting, to protect farmers from variability in rainfall.
- Make provision for the construction of appropriate roads particularly feeder roads in the rural areas to be able to withstand increasing rainfall.
- Take appropriate measures to control rapid increase in population as well as providing appropriate infrastructure, social services and mechanization of agriculture in the rural areas to slow down massive movements of youths into urban areas.

#### 4.3.1.8 Future Vulnerability of the Agriculture Sector

The models are showing normal annual maximum temperature increases. The most worrying temperature increases will be the range of – 2.50-3.50C. With such increases, the country should be bracing itself for sea level rises along the coasts, serious drought and extreme heat, which might adversely affect all forms of agricultural activity (crops, livestock, fisheries).
Under the influence of population pressure, the gap could in the long term have an exponential trend (resulting in a demand/probable production balance sheet) which will always be negative in spite of the sensitive growth of rice, cassava and groundnut production.

The major impact of rainfall decline will be soil degradation, decline in agricultural production and chronic distribution of food supply. There is also an expected continuous large scale movement of populations, and increase in diseases and an important loss in terms of biodiversity.

#### 4.3.1.9 Livestock production

The various results of the study on the vulnerability and adaptation of the livestock sector to climate change illustrated the influence of climatic factors particularly rainfall and temperature on livestock.

There is a correlation between the total number of cattle, as for example in 1990,the total number of livestock increased by about 10**%** as compared with their 1990 value notably as a result of rainfall fluctuations which have an impact on forage crop production. The socioeconomic impact of climate factors on the livestock sector can be characterized by:

- A decline in the incomes of rural dwellers;
- Important modifications of the composition of herds through a progressive replacement by small ruminants;
- Malnutrition of the population;

**The impact of future condition on the livestock**

The models are showing normal annual maximum temperature increases. The most worrying temperature increases will be the range of – 2.50-3.50C. With such increases, the country should be bracing itself for sea level rises along the coasts, serious drought and extreme heat, which might adversely affect all forms of agricultural activity (livestock, fisheries, etc). This could limit the amount of fodder available for grazing and could lead to conflict between communities in the country as is already occurring between cattle herders and farmers in the north of the country.

The major impact of rainfall decline will be soil degradation, decline in agricultural production and chronic distribution of food supply. There is also an expected continuous large scale movement of populations, and increase in diseases and an important loss in terms of biodiversity.

### 4.3.2 Water

#### 4.3.2.1 Current Conditions

Adequate amount of water exists in Sierra Leone from rainfall, surface and underground. The mean annual rainfall ranges between 4000 mm along the coast and 2000m in the northeast. The duration of the wet season varies from 9 months, stating in March in the East to 7 months, starting in May in the north and west and ending in November.

Sierra Leone possesses enormous water resources which are contained in over twenty major rivers. These include Rokel, Moa, Sewa, Little Scarcies, Pampana, Great Scarcies and Mono, with lengths ranging from 40 kms to 290 kms. Four of these rivers namely, Moa, Lillte Scarcies, Mano, and Great Scarcies have their sources in the neighbouring countries of Guinea and Liberia.

Most of the flow in the rivers during the dry season comes from ground water storage that recharges the channels. According to occurrence, most of the ground water comes from sedimentary and igneous rocks. In the soft sedimentary rock, good ground water potential and depth to water have been found to be shallow, about 6 meters below ground level. Ground water potential in the hard rocks depends on the weathering depth and the amount of rainfall in that area. Ground water has been found to occur around 8

– 10m below ground level on average with a seasonal fluctuation of 3 – 5m**.** However the recharges rates were not measured.

Water resources management in Sierra Leone is very limited and carried out on a sectoral basis, under which each institution involved in water related issues has its own separate legislation for management of the resources.

The social and economic circumstances prevailing today in Sierra Leone have made exacting demands upon the country's water resource base and the environment and its un-sustainability is threatened by various human and climate induced activities. Over the last decade these demands have intensified with increase in population in urban areas, and the development of economic activities such as industries and mining which require water as an input.

Despite the abundant water resources, access to safe drinking water is very limited as a result of unavailable or limited functional infrastructure for water supply. Today only about 32% of the rural population has access to a reliable water supply. Due to poor operational and maintenance arrangements, most of the urban water supply schemes are not functioning properly. The water supply coverage for urban areas, in particular Freetown, the capital city is about 50%. The poor state of the water services in Freetown do not meet the needs of its population which increased during the period civil war.

The sewerage and sanitation situation in the country is also highly unsatisfactory. Sewerage infrastructure is confined to Freetown where it is limited, old and inadequate to meet the ever increasing demand. The institutions responsible for provision of sewerage services have insufficient human resources as well as financial ability to carry out their responsibilities.

The sanitation situation in Freetown not served by the sewerage system and in the rest of the country is not satisfactory. An estimated 3.43 million Sierra Leoneans do not have access to adequate sanitation facilities. The estimated number of people who do not have adequate sanitation in urban areas is about half a million. Diseases associated with lack of safe water, poor hygiene and sanitation are major causes of sickness and death in the country. In addition to the adverse impact on the health of the population, sanitation has a serious economic impact on household economies, keeping families in the cycle of poverty, illness, illiteracy and lost income.

Access to improved water supplies in the country is in the form of pipe-borne water, boreholes or wells. These are distributed unequally between rural and urban areas. In rural communities, the main water sources are from shallow wells, rivers, lakes and swamps. Until recently, much of the effort has come from NGOs who provide rural areas with hand-dug wells some of which are fitted with pumps.

The average minimum per capita consumption of improved water for the rural population measured in litres per day is as low as 2 in the dry season and 20 in the wet season. During the dry season, most of the rivers, streams and swamps dry up and women and children have to travel long distances in search of water.

Due to rural-urban migration as a consequence of the civil conflict, water demand in the city of Freetown now far exceeds the supply. This aggravated by climate change is responsible for the perennial water shortage that now affects many parts of the city.

In the water sector, the National Water and Sanitation Policy has been prepared and approved by Cabinet in 2008. The Policy sets out the government's vision for the management and sustainable use of water resources, and the draft Strategy and Action Plans have been proposed. The key objectives of the Strategy include (i) ensuring efficient water utilization and (ii) sustainable development and use of water resources which include plans to protect catchment areas.

The overarching objective of the study is to assess the vulnerability of the water resources sector in Sierra Leone to climate change with a view to formulating strategies to adapt to the adverse impacts.

The specific objectives include: To carry out an assessment of the performance of the WatBal model on a selected exposure unit of water in the country.
To use simulation technique(s) to predict changes in the hydrological regime with and without climate change.

To proffer measures aimed at reducing the likely impacts of changes in the availability and timing of water resources.

The choice of water unit subjected to climatic stimuli is based on:

- ✓ The availability of long data series;
- ✓ The sensitivity of the water resource system to climate stimuli;
- ✓ The socio-economic importance of the system;

#### 4.3.2.2 Impacts of Climate Change on Water

Against the backdrop of these principles, the agreed exposure unit is:

Surface water; Water resources have been identified as one of the sectors that will be affected by climate change if and when it happens. Water scarcity is already occurring in the country as some of the scenarios predict. Our socio-economic development will suffer serious setbacks if the available water becomes insufficient to meet the domestic, agricultural, industrial, and energy needs of the rapidly growing population.

In a similar vein, excessive rainfall could lead to high incidences of flooding. Consequently, a national strategy must be put in place to identify the sub-sectors that are likely to be affected by climate change and to proffer adaptation measures for coping with the irreversible changes in the hydrological regime.

Climate change will affect the water balance, more so the amount of runoff and recharge, which in turn determines the water resources available for human and ecosystem uses. In this study, a conceptual hydrological model is employed to simulate runoff of the Rokel Basin in Sierra Leone, without and with climate change. The result of model calibration will be to predict the changes that are expected by increases in temperature caused by an increase in greenhouse forcing.

#### 4.3.2.3 The specific objectives of the study included:

- To carry out an assessment of the performance of the WatBal model on a selected exposure unit of water in the country.
- To use simulation technique(s) to predict changes in the hydrological regime with and without climate change.

- To proffer measures aimed at reducing the likely impacts of changes in the availability and timing of water resources.

#### 4.3.2.4 Scope of Assessment

The scope of the assessment was on a river basin scale – the Rokel River which has a fairly long record required for the analysis of the water balance for the catchment. The temporal scale is monthly for some analyses and annual for others. The monthly time step is suitable for assessing climate change as it models fairly accurately the seasonal distribution. The analyses of water demand and supply were done using a water supply scheme that had operated for over 30 years now.

#### 4.3.2.5 Climate Change Scenarios & Their Potential Effects on Water

#### 4.3.2.6 Assessment (Simulation) Methodology

The procedure for assessing the impacts of climate change on water resources and possible adaptation measures can be divided into four steps:

1. Assessment of the impacts of changes in temperature on river runoff.
2. Assessment of the effect of the impacted river runoff on the management of water resources for sustainable development.
3. Assessment of the vulnerability of the river basin to changes in the supply and demand balance.
4. Assessment of adaptation measures for coping with the adverse impacts of climate change on water resources.

The framework for assessing the impacts of climate change on national water resources and analyzing possible adaptation assessments is made up of four distinct components: supply, demand, vulnerability, and adaptations. Supply is analyzed in two stages. In the first stage river runoff impacts are assessed by means of one of the methods recommended below. The second stage involves the assessment of the effect of the impacted river runoff on the management of the water resource system and the resulting water supply. National vulnerability is accessed via a gross national supply-and-demand balance and by a restrictive basin method.

The model used (WATBAL) is a monthly spatially lumped, one-dimensional water balance model that is used to model the hydro-climatic cycle. To apply the model, the Rokel watershed was selected that has one or more stream flow measuring stations with ‘’sufficiently’’ long records. In the evaluation of the impact of global warming the runoff model is executed to generate 100 monthly flow sequences assuming (i) no rise in global temperature, $dT/dt = 0$, and (ii) a warming trend $dT/dt$ that depends on the GCM output used.

$$Q(t) = P(t) - E(z, PET, t) - S_{\max} \frac{dz}{dt}$$

where $\mathbf{S_{max}}$ is defined as:

$$\mathbf{S_{max}}\,{}^{dz}/_{dt} = \mathbf{Pe}(t) - \mathbf{Rs}\,(z,Pe,t) - \mathbf{Rg}\,(z,t) - \mathbf{Ev}\,(z,PET,t)$$

in which $S_{max}$ is the maximum water holding capacity (mm) of the catchment; Pe is the effective precipitation (mm/day); Rs is surface runoff (mm/day); Rg is subsurface flow (mm/day); Ev- is actual evapotranspiration (mm/day) which is a function of potential evapotranspiration (PET), relative catchment storage (z), and time in days.

In the model, PET can be estimated by using a variety of methodologies based solely on average monthly temperature and daily sunlight duration. Precipitation is divided into interception, direct surface runoff, and infiltration. The impact to climate change is analyzed by inputting to the model baseline and climate change scenarios of mean monthly temperature and precipitation values. The climate change scenario values are obtained by using GCM-generated monthly differences in temperature and precipitation between $2*CO_2$ and $1*CO_2$. The model is run holding all parameters constant, and runoff estimates are generated. These new runoff values represent the estimate of the impact of the associated GCM scenario on water supply, both in terms of total annual supply and seasonal distribution.

The application of the model involved two stages, that is, calibration and validation. During the calibration stage the model parameters are adjusted by trial and error until the model closely reproduces the observed runoff. Six years of monthly flow records was used during the calibration (Jan. 1972 – Dec. 1975).

Validation of the model was performed using monthly stream flow records for the period Jan. 1976 to Dec. 1979. Precipitation and potential evapotranspiration also covered that period. The model was also calibrated for high, low and normal flow years.

#### 4.3.3.7 Data Requirement

The data required for the assessment of the impacts of climate change on water resources can be divided into (a) hydrological i.e. stre4.am discharge record for a period of about 30 years (b) meteorological i.e. air temperature, precipitation, and potential evapotranspiration. Potential evapotranspiration is determined by the hydrological model given the number of sunshine hours and air temperatures.

The stages of the Rokel have been recorded since 1970 when the first gauge was installed under a UNDP program. Previous to this, no stream discharge data were available for the Rokel. Stream discharge data were recorded for a 7 - year period (1972 – 1979). Since relatively long records were needed for the hydroelectric project, the measured stream discharge data were modeled to produce a 59 – year record extending from 1921 to 1979. Both the measured and simulated data have been used in the current study.

Water supply and demand data are necessary to assess the impacts on water resources supply and demand caused by changes in the hydrological regime due to climate change. Population estimates are also required to assess future changes in supply and demand due to rural-urban migration.

#### 4.3.2.8 Baseline and Climate Change Scenarios

Sierra Leone is drained by 12 major river basins with 9 of these having their sources within the country. Table 1 shows the largest basins.

| Table 4.4: The location and catchment area of some of the major river basins in Sierra Leone | | |
|---|---|---|
| **River Basin** | **Catchment Area ($km^2$)** | **Location of Station** |
| **Little Scarcies** | 12,870 | Mange |
| **Sewa** | 14,140 | Jaiama |
| **Rokel** | 10,620 | Bumbuna |
| **Moa** | 9,220 | Kenema |
| **Pampana/Jong** | 7,511 | Magburaka |

The Rokel Basin has been selected for the assessment of the impacts of climate change on water resources. The Rokel watershed is the third largest in Sierra Leone, and supports the biggest hydroelectric scheme (The Bumbuna Falls Hydroelectric Project) in the country. It is also the source of an irrigation scheme where water is diverted to support a sugar cane plantation at Magbas. The River is 380 km long and drains an area of 10620 $km^2$.

#### 4.3.2.9 Impacts on Rokel River Runoff/Flow

Figure 1 below shows the monthly flow characteristics of the Rokel River under current climate. 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 when it is one standard deviation higher than the average flow.

The Model was executed with the values for LF, NF and HF combined with the climate change scenarios developed from the GCM outputs serving as input. Table 2 shows the percent change compared to the current climate values of 1921 to 1978 monthly and annual averages.

The results indicate that with the projected climate change, flow of the Rokel River Basin will increase by about 1% to 7% by 2100. A decrease of about 5%-6% is projected by the UK Meteorological Office Transient Model (UKTR). These variations are also depicted by Figures 2 to 4 below.

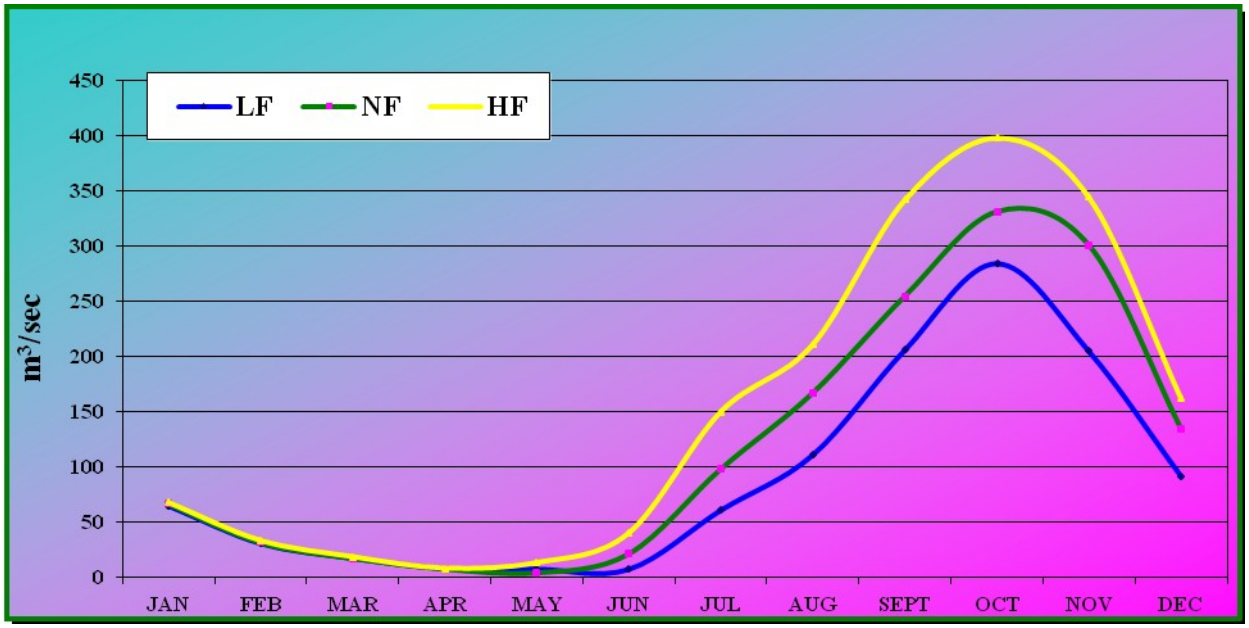



**Figure 4.10: Low (LF), Normal (NF) and High (HF) Low characteristics of the Rokel River**

**Table 4. 5: Percent Variation of Flow of the Rokel River Basin compared to 1921 to 1978 flow**

| LOW FLOW | HADLEY2 | UKMOTR | CSIRA | ECHAM4 |
|---|---|---|---|---|
| **2025** | *2* | *1* | *1* | *2* |
| **2050** | *4* | *1* | *1* | *4* |
| **2075** | *5* | *1* | *1* | *6* |
| **2100** | *7* | *-5* | *1* | *6* |
| | | | | |
| **NORMAL FLOW** | **HADLEY2** | **UKMOTR** | **CSIRA** | **ECHAM4** |
| **2025** | *2* | *1* | *1* | *2* |
| **2050** | *4* | *1* | *1* | *4* |
| **2075** | *5* | *1* | *1* | *6* |
| **2100** | *7* | *-6* | *1* | *6* |
| | | | | |
| **HIGH FLOW** | **HADLEY2** | **UKMOTR** | **CSIRA** | **ECHAM4** |
| **2025** | *2* | *1* | *1* | *2* |
| **2050** | *4* | *1* | *1* | *4* |
| **2075** | *5* | *1* | *1* | *6* |
| **2100** | *7* | *-6* | *1* | *6* |

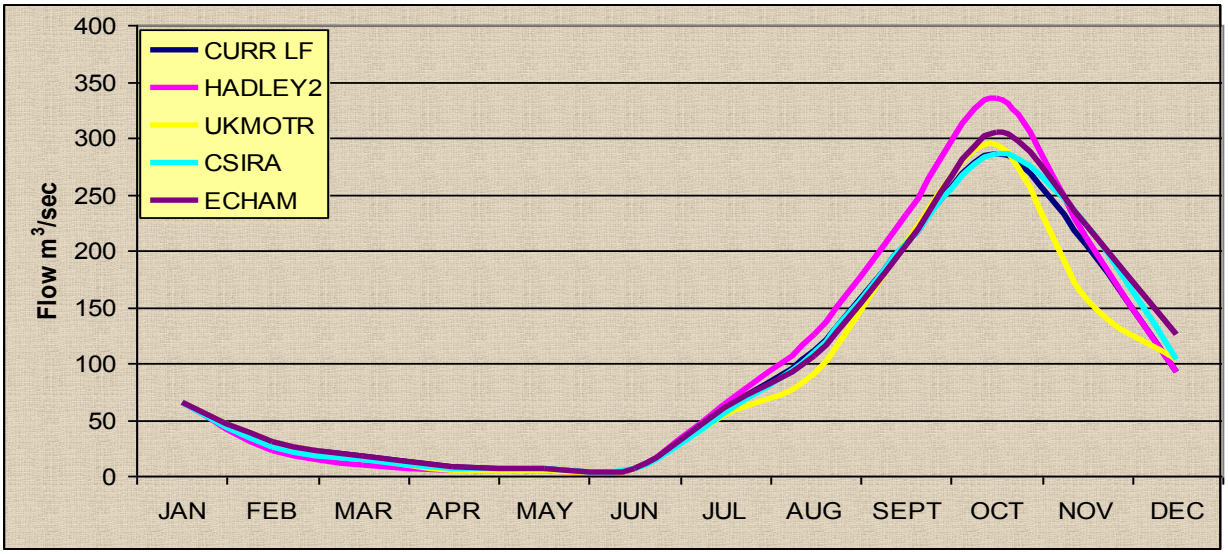



**Figure 4.11: Simulated Flow of the Rokel River at 2100 compared to the 1921-1978 Normal Flow Average**

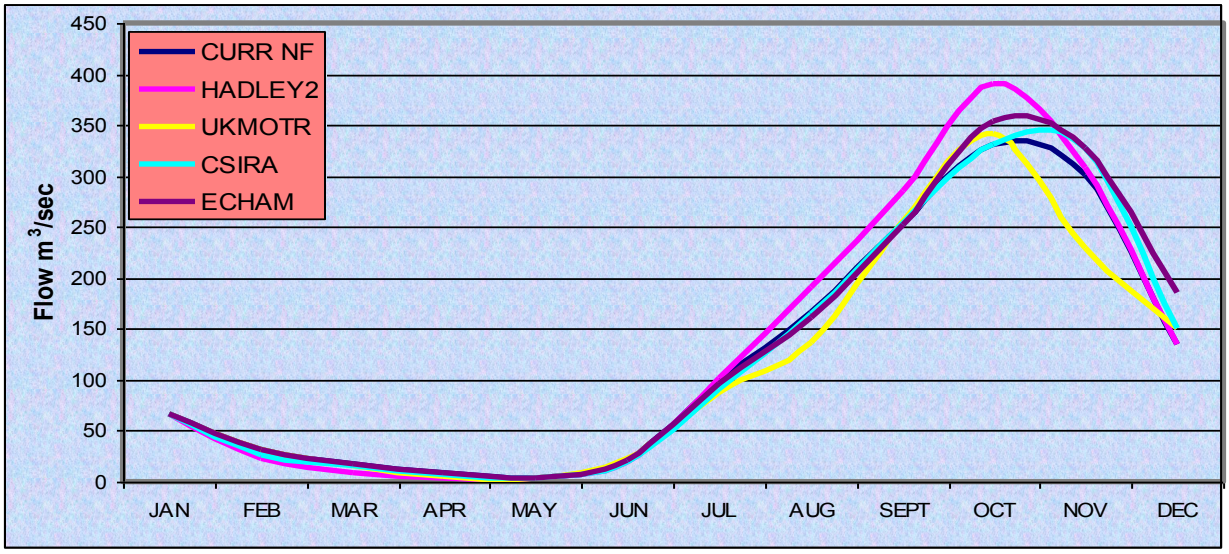



**Figure 4.12: Simulated Flow of the Rokel River at 1921-1978 Low Flow Average compared to the 1921-1978 normal flow average**

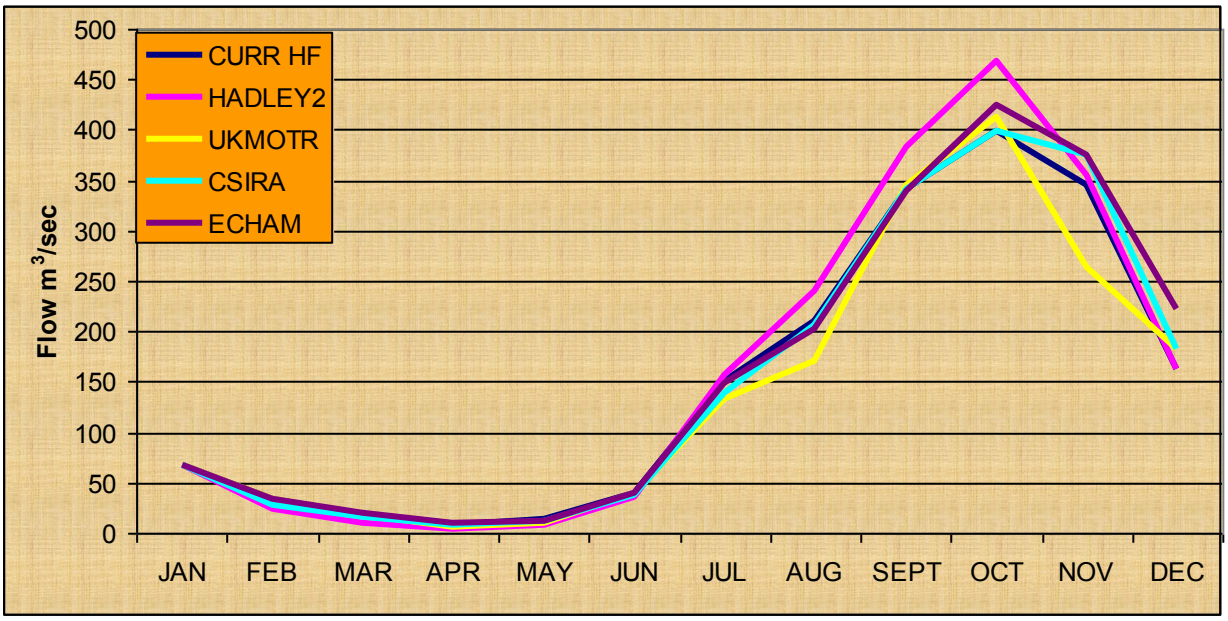



**Figure 4.13: Simulated Flow of the Rokel River at 2100 compared to the 1921-1978 High Flow Average**

#### 4.3.2.10 Assessment of Adaptation to Impacts on the Rokel Basin

Inadequate resources (human, financial and time) were a big constraint in the identification, evaluation and development of adaptation options for Sierra Leone, particularly for the water sector. The water resources assessment team resorted to desk review of potential climate change adaptation measures adoptable for Sierra Leone.

Three broad adaptation measures are possible in the water resources sector: Management of supply and demand, improved planning and coordination of activities in the river basin and effective monitoring and management of the watershed.

#### 4.3.2.11 Management of Supply and Demand:

Efficient management is expected to reduce demand and increase the supply base. Water demand can be reduced through the following options.

- Identification and adoption of positive behaviors to use less water reuse water and recycle water. This will also include decrease in the activities that require water and also modification of crops and cropping patterns that have low water use efficiency.
- Encouragement of efficient water use through education, voluntary compliance, pricing policies, legal restrictions on water use, rationing of water, or the imposition of water conservation standards on technologies.

Increase in water supply can be achieved through:

- Improvement of catchment vegetation cover aimed at improving the soils' water holding capacity, and thus reduce surface and sub-surface runoff.
- Construction of reservoirs and dams,
- Development of groundwater resources and
- Utilization of inter-basin transfers.

#### 4.3.2.12 Improved Planning and Coordination of River-Basin Use

Comprehensive planning across a river basin may allow coordinated solutions to problems of water quality and water supply. Planning can also help to address the effects of population, economic growth, and changes in the supply of and demand for water. It is prudent to devise and adopt contingency planning for drought. Plans for short-term measures to adapt to water shortages could help mitigate droughts. The cost of developing contingency plans is relatively small compared with the potential benefits.

In planned construction, consider marginal increases in the size of dams or marginal changes in the construction of canals, pipelines, pumping plants, and storm drainages. This change may be much less expensive than building capacity in the future.

#### 4.3.2.13 Effective Monitoring and Management of Watershed

Climate change is likely to affect the frequency of floods and droughts. Monitoring systems will help in coping with these changes and will be beneficial even without climate change.

#### 4.3.2.14 Future Vulnerability of the water sector

The analysis of rainfall anomalies in the available stations distributed over parts of the country shows variable rainfall since the last three (3) decades. The corresponding rainfall deficit is in average of 10% but may reach higher values at 20% in some regions.

Recent studies conducted in the entire West African region (Servat et al. 1998) show that the decline in rainfall is basically as a result the reduction of the number of rainy events. In addition, the analysis of rainfall time-series shows a definite trend of isohyets slide southwards.

Furthermore, in spite of the country's rich water resources potential, there are constraints on water availability including difficult-to-access water sources, poor quality surface sources, limited capacity for ground water abstraction, inaccessible water table during certain periods of the year, inadequate funding to meet the challenges in abstraction and delivery, poor community attitude towards development interventions, poor technology design and low community involvement in planning, other problems relate to fragmented institutional structures and diffused responsibilities;

#### 4.3.2.15 Surface water

Hydrometeorological observations show that consequence on water flows and the decline in rainfall

observed over three (3) decades are: (i) a significant variation of annual average flows, concomitant with that of rainfall from 1961 for the major part of rivers and notably the Rokel River, (ii) a widespread decline in flows from rivers.
The decline in the Sierra Leone River flows for instance is more significant than that of rainfall of 40% to 60% since the early 1970s compared with 20 to 30% for rainfall at the Sierra Leone station. This decline is however less obvious in tributary basins of the river's right bank.

The vulnerability of ground water resources to climate change and variability lies on the qualitative levels. Concerning the qualitative level, the variation of ground water quality is linked to the modification of mineral properties of water.

### 4.3.3 Health

#### 4.3.3.1 Current Conditions

The health sector of Sierra Leone is a government institution set up by an act of parliament to deliver health service to the people of Sierra Leone.

#### 4.3.3.2 State of health in Sierra Leone

The profiles of health and disease vary greatly between regions in Sierra Leone. In Sierra Leone infections disease (especially in childhood) are very important. However an emerging trend shows that non-communicable disease such as cardiovascular diseases, cancer and depression are becoming more common. This can be attributed to an increase in urban populations with changing lifestyles, trauma from the decade old war and environmental exposures.

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.

#### 4.3.3.3 Environmental Conditions

In general, there is poor environmental sanitation throughout the country. Due to inadequate water supply, poor land use planning resulting in slum development, poor sanitation facilities and poor drainage systems.

**Climate Risks**

Flooding of the city are common occurrences during the rains.

There have been serious ecological disturbances thus interfering with agricultural activities leading to inadequate food supply and the consequence of malnutrition particularly in women and children. Deforestation is a serious factor which leads to soil erosion and this too has affected food production.

#### 4.3.3.4 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.

#### 4.3.3.5 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.

Choice of criteria of exposure units concerns the characteristics of the disease itself and the geographical area.

As far as the disease is concerned, it should be a public health problem, climate sensitive and ravaging over a given area and quite a considerable period. Finally, we should have data on a relatively long series.

In this study, geographical areas of regions were chosen which have data on diseases which ravage in an endo-endemic manner and have a considerable socio-economic impact. These areas that met this

conditions are the provincial areas of the country, northern, eastern and southern provinces and the western area, for the following three diseases; malaria, cholera, and typhoid.

Time scale
The study considered the following time horizons;

- The baseline reference period: 1961 – 2010
- The period under study; 1961 – 2005
- Climate change projection period: 2020 to 2049

Assessing the potential health effects of climate change involves many uncertainties. Researchers considered not only future scenarios of climate change but many non-climate factors as well. For example, trends in socio-economic conditions can have a major affect on a population's vulnerability. Clearly, poorer communities will be more vulnerable to the health impacts of climate change than rich ones.

#### 4.3.3.7 Health models

Methods of assessing the potential health impacts of climate change included Analogue Studies.

This involves analogue of a warming trend (e. g. increase malaria in highland region correlated with a local trend in warning analogue of extreme events e.g. assessment of the mortality impact of a heat wave and a description of curve or recurrent climate/health relationships (e.g. inter annual variation in malaria correlated with minimum seasonal temperature using time series data.

Predictive Models empirical – statistical models which incorporated extrapolation of simple climate / disease relationship using univariate, e.g. daily temperature and mortality and extrapolation of climate / vector / disease relationship using mapping and statistical methods for use with spatially correlated data e.g. mapping tick abundance with climate and other variables.

#### 4.3.3.8 Potential impacts of climate change on Health

Climate change is expected to have wide-ranging consequences for human health.
Public health depends on sufficient food, safe drinking water, secure shelter, good social conditions, and a suitable environmental and social setting for controlling infectious diseases. All of these factors can be affected by climate.

The results obtained by the study on the vulnerability and adaptation of the health sector relative to the occurrence of diseases such as malaria, cholera, and typhoid reveal sound correlations between meteorological and health parameters.

In fact, in the northern region studied, it was established that extreme temperatures influence the seasonal or quarterly distribution of cases or rates of occurrence of these diseases, and in particular cholera which occurred in February to March and which is now being reported in three districts and the western area of the country. Rainfall is also a climatic parameter which influences the incidence of the rate of malaria attack. Indeed, the same study shows that the highest rates of malaria attack were recorded during the transition period to the rainy season. For the case of malaria, the five months

characterized by higher temperatures and the second half of the year corresponding to the lowest, experience the lowest rates of attack of the year. The influence of extreme temperatures on the rate of malaria attack is translated by low rates during the first two quarters (January, February, March, April) during which temperatures are highest. During the rainy season months of May, June, July and August water borne diseases such as cholera and diarrhea and typhoid predominates

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. A greater frequency of warm or hot weather, thermal inversions (a meteorological phenomenon that can delay the dispersal of pollutants), and wildfires may also worsen air quality in many cities.

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. It could also lower the efficiency of local sever systems, leading to higher concentrations of bacteria and other micro-organisms in raw water supplies. Water scarcity may force people to use poorer quality sources of fresh water, such as rivers, which are often contaminated. All of these factors could result in an 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.

Food security may be undermined in vulnerable regions. Local declines in food production would lead to more malnutrition and hunger, with long-term health consequences, particularly for children.

**4.3.3.8 Adaptation measures to minimize these enhanced health risks.**

The most important, urgent, and cost-effective adaptation measure is to rebuild the public health infrastructure in the country given that the conditions have deteriorated in recent years. Many diseases and public health problems that may be exacerbated by climate change can be effectively prevented with surveillance, sanitation programmes, disaster preparedness, improved water and pollution control, public education directed at personal behaviour, training of researchers and health professionals, and the introduction of protective technologies such as housing improvements, air conditioning, water purification, and vaccination.

The strategies to achieve the above goals are as follows:

- Rehabilitation of the network of health facilities at primary, secondary and tertiary level.
- Promotion of environmental health, especially the supply of safe and adequate drinking water and improved sanitation.
- Control of communicable diseases through improved Maternal and Child Health and Immunizations.
- Promotion of community participation and involvement and also intersectoral cooperation in health care delivery.
- Strengthening of cooperation with international agencies and NGOs in the drive towards better health care in the service.

- Decentralization of the health services.
- Partial privatization of certain services within the health care system
- Increasing allocation of GNP to the health sector

Major impacts on human health may occur via changes in the magnitude and frequency of extreme events. 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).

#### 4.3.3.9 Future Vulnerability of the health sector

In Sierra Leone institutional and cultural barriers inhibiting the use of seasonal forecast information remain. Decision makers should be educated or encouraged to used scientific information that may lead to reductions in losses from natural disasters.

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.

### 4.3.2 Forests

#### 4.3.2.1 Current conditions

Sierra Leone is essentially a forest country but with the forest types considerably modified by the activities of man. Relic stands of high forest indicate that much of the country was at one time covered with forests. The present extent of forest re-growth attests to this and that the forest was removed in the process of shifting cultivation. Rotational bush fallow is by far the most widely practiced farming system in the country and it is estimated that the current area occupied by this system is about 3.7 million ha (Allen 1990). Only about 185,000 ha (5%) is closed high forest located largely in the eastern part of the country.

#### 4.3.2.2 Forest Ownership

The system of forest ownership is very simple. Outside the Western Area, forests are owned by the communities. Thus, although 296,000 ha forming the national estates are under tenure of Government, only 17,688 ha (in the Western Area) are directly owned by Government. All the remaining forests are privately and communally owned.

### 4.3.2.3 Forest Resources and their Management

The extent of Sierra Leone's Forest is limited to 87% of the land area or 6,305,500 ha. Timber resources occupy an even smaller area restricted to closed forest formation of about 365,000 ha. 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 (Kamau 1988). Forestland lost to infrastructural development, encroachment etc amounts to 300,450 ha.

**Table 4.6: 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 Re-growth (Bush Fallow) | 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** |

*Source; Forestry Division 2000*

### 4.3.4 Forest Policy

When the Forestry Department was established in 1911 to provide merchantable timber, fuel-wood and to protect catchment areas, subsequent policies were formulated and implemented as interventions to control the effects of factors which impacted negatively on development and growth of the sector i.e. the proliferation of forest industries, expansion of urban settlements, mining in forest reserves, increasing demand for fuel-wood and charcoal etc.

The goal of the Forestry Policy is to support the development and exploitation of the forest and wildlife resources of Sierra Leone in a sustainable manner for the material, cultural, environmental and aesthetic benefit of the people of Sierra Leone in particular and mankind in general.

The Forestry Act (1988) and Regulations (1989) recognized and classified the forests into three categories i.e. National Forest, Community Forest and Private Forest.

### 4.3.4.1 National Forest Policy:

The main general forestry objectives are to develop, conserve and maintain forest land resources covering at least 45% of the total land area of the country.

### 4.3.4.2. Methodology for Vulnerability and Adaptation Assessment:

Two techniques are normally used in the programme to assess the Vulnerability and Adaptation of Forests to Climate Change; these are (1) Preliminary screening technique and (2) Simulation technique.

### 4.3.4.3 Preliminary Screening Technique

This technique can be used to identify areas and/or species of greatest vulnerability or as a substitute for more quantitative analysis where insufficient data are available for model development and application. The process identifies;

- Factors within the scenarios (e.g., Climate Change) that may influence forest ecosystems
- Areas critical to forest resources, i.e., Forest conservation areas and Forest production areas
- Critical species and/or groups of species within these areas so identified

By examining the climatic changes and other environmental features predicted by the global change scenarios, it is possible to evaluate the susceptibility of the identified areas or species to the predicted changes in environmental conditions.

The following have been identified as Areas Critical to forest conservation in Sierra Leone;

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

The following are Critical to Forest Production:

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

Critical species or groups of species within the identified Areas: A list of thirty species within these areas has been compiled with relevant basic parameters to define species attributes, i.e.

- Maximum height (m)
- Maximum diameter (m)
- Maximum age in years
- 1Shade tolerance
- Number of seedlings produced per year

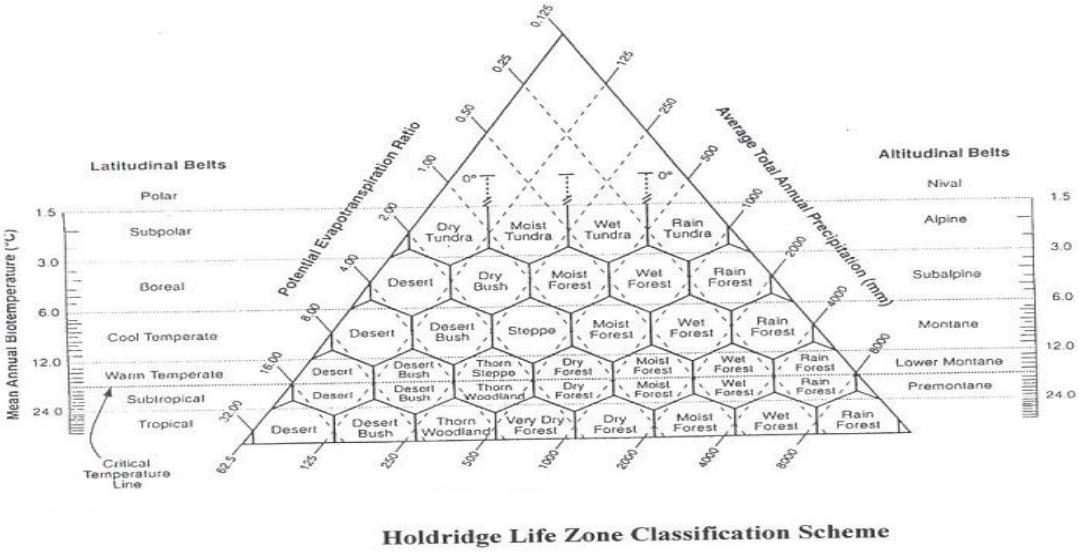
### 4.3.4.4 The Simulation Techniques

This technique employs two biophysical models for evaluating the potential impacts of climate change on forest ecosystems. I.e. (i) the Holdridge Life Zone Classification and (ii) the Forest Gap models.

### 4.3.4.5 The Holdridge Life Zone Classification Model:

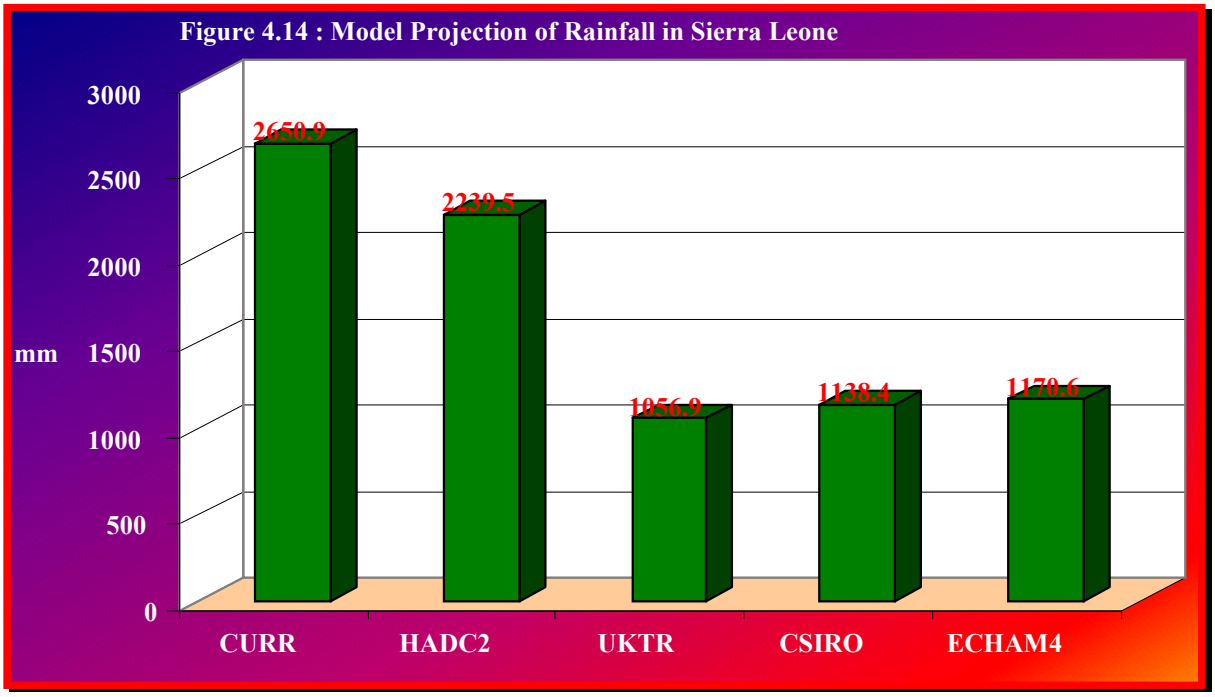
This is a climate classification model that relates the distribution of major ecosystem complexes to the climate variables of bio-temperature and associated mean annual precipitation. It is suitable for examining the broad-scale pattern of vegetation as they relate to climate and the influence of climate changes on the suitability of a region to support different vegetation/forest types.

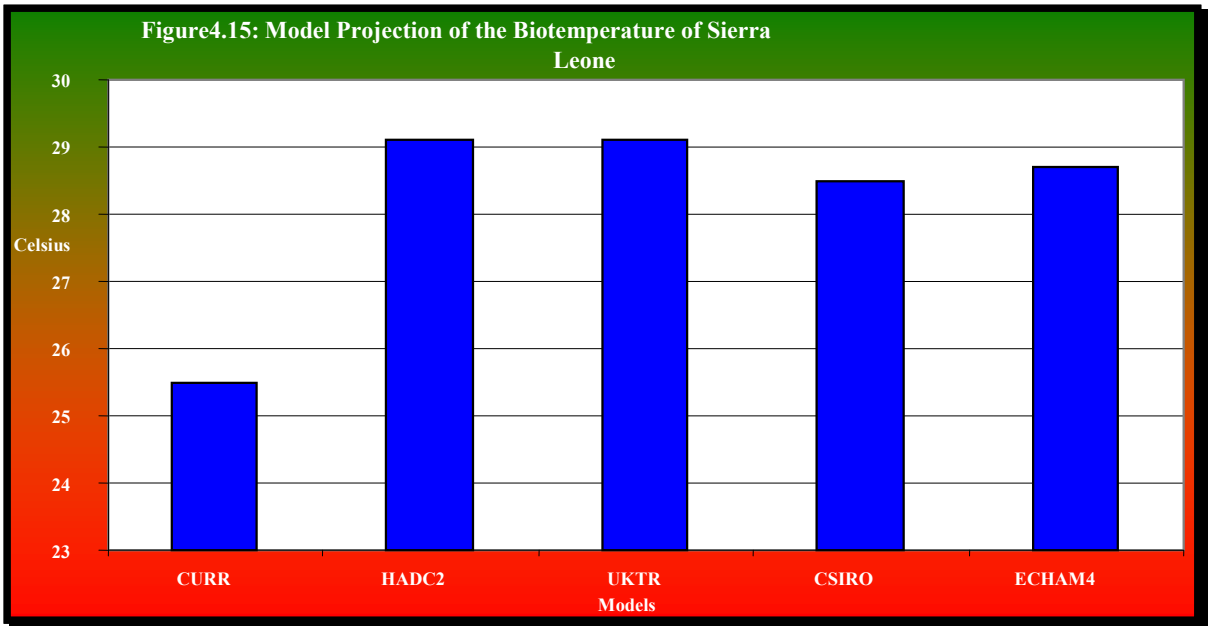
The Figure 1.1 below illustrates the Holdridge Life Zone classification scheme. The life zones are depicted by a series of hexagons in triangular coordinate systems. Identical logarithmic axes for average annual precipitation form two sides of an equilateral triangle. The PET ratio forms the third side, and an axis for mean annual bio-temperature is oriented perpendicular to its base. The two variable 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). Fig…




**Holdridge Life Zone Classification Scheme**

Implementation of the Holdridge model for a region requires only data on annual rainfall and 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 (Figure 2) and bio-temperature (Figure 3) 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.




### 4.3.4.6 Simulation Results from the Holdridge Model

Under current climate the land in Sierra Leone has the potential land cover 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 analysis are that under an equilibrium climate the potential land cover of Sierra Leone as projected by the GCM outputs used in this study will tend to the 66% (HADC2), 55% (UKTR), 66% (CSIRO) and 81% (ECHAM4) ***tropical dry forest*** and 30% (HADC2), 40% (UKTR),

26% (CSIRO) and 13% (ECHAM4) ***tropical very dry forest*** categories as a result of the projected decrease in precipitation ( Figure 2) associated with the increase in bio-temperature (Figure 3) by 2100.

### 4.3.4.7 Simulations using the Forest Gap Model

The Forest Gap 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 Gap model can simulate species composition and structure on an annual basis. It also simulates the temporal dynamics of forests in response to environmental conditions.

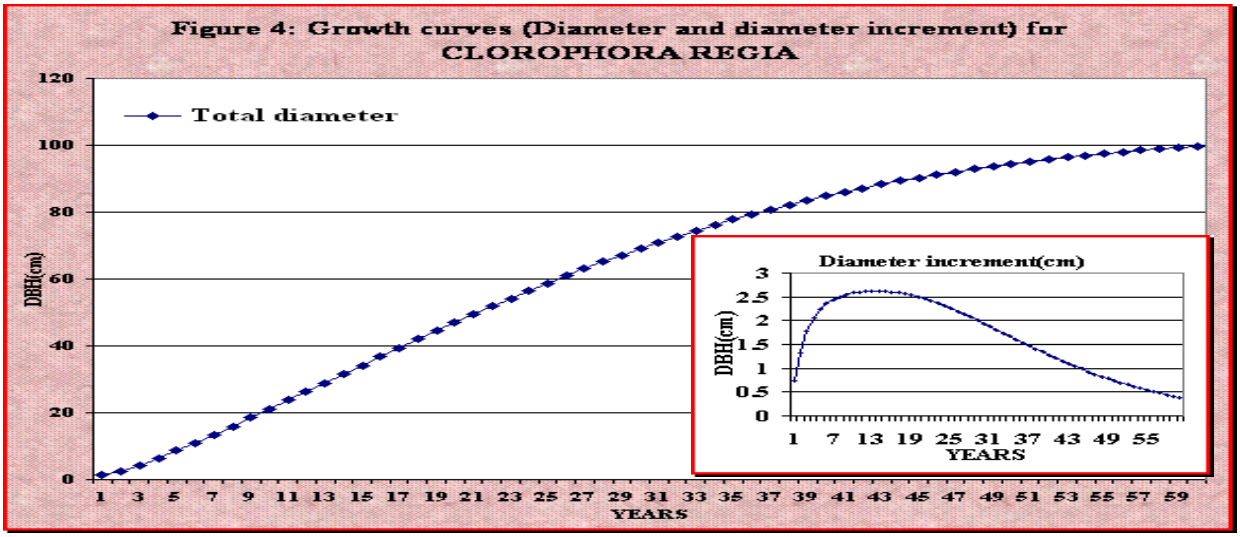
The model is run on data from individual species as discussed in section 2.2.1 below. The potential growth of each tree is estimated from species-specific optimal growth curves. This growth curves are derived from simple silvicultural data on maximum tree size and longevity.

The following twelve (12) species were used in the simulation and are discussed in greater detail below: **Chloraphora Regia, Cordia platythyrsa, Cordia, Hannoa Klaineana, Nauclea didderrichii, Terminalia ivorensis, Tieghemelia heckelii, Daniella thurifera (Ogea) Khaya anthotheca** (African Mahogany), **Parkia bicolor, Gmelina anborea (Yemane) Ceiba Pentandra:**

### 4.3.4.8 Species Specific Growth Data (Diameter and diameter increment):

Data on diameter size and diameter increment were imputed into D-CURVE component of the GAP Model to determine the growth characteristics of the twelve individual tree species. Figures 4 and 5 show the species-specific optimal growth curves for Chlorophora regia and Terminalia, the most valuable, widespread and multipurpose species simulated. 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.

**Figure 4.16: growth curves (diameter and diameter increment) for CLOROPHORA REGIA**



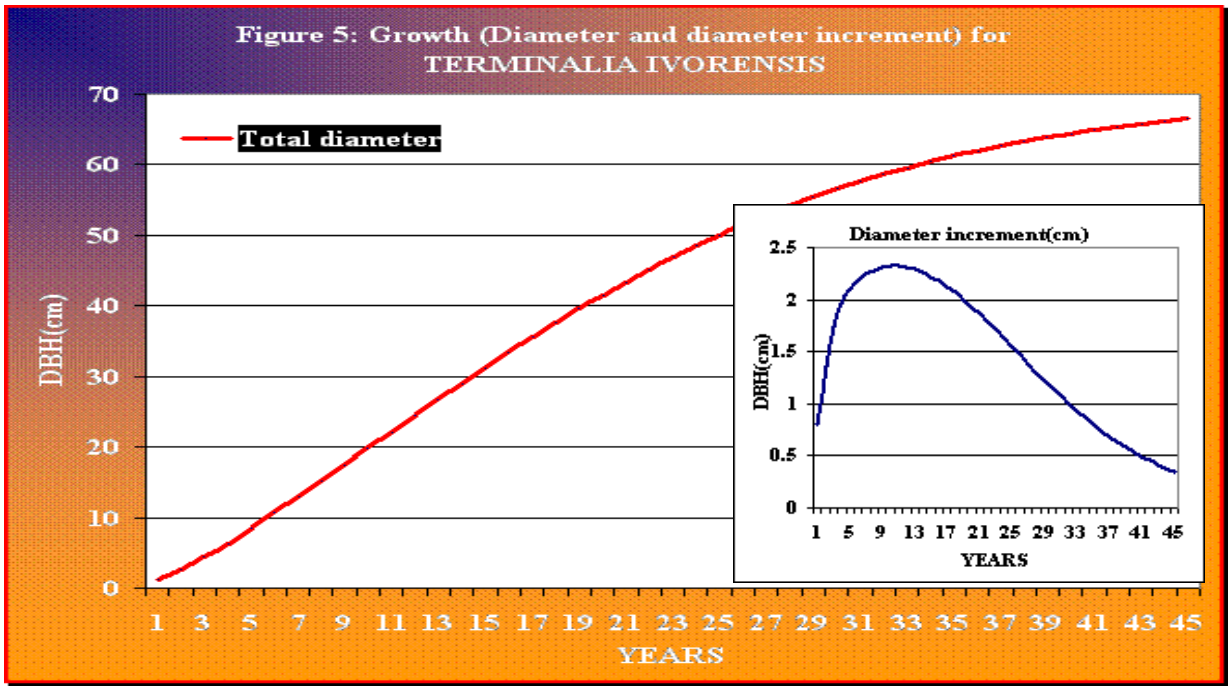


Figure 4.16: growth (diameter and diameter increment) for TERMINALLA IVORENSIS

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 below:

**Table 4.7 Simulation results from the Forest Gap Model**

| 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 |

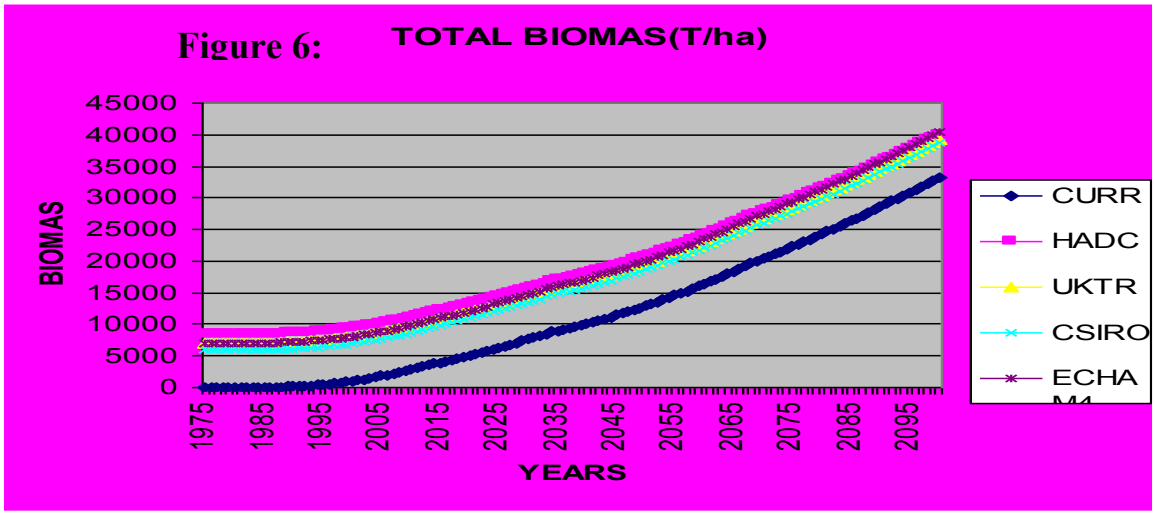



**Figure 4.17: Total Biomass (T/ha)**

**Figure 4.18: Total Biomass (T/Ha)**

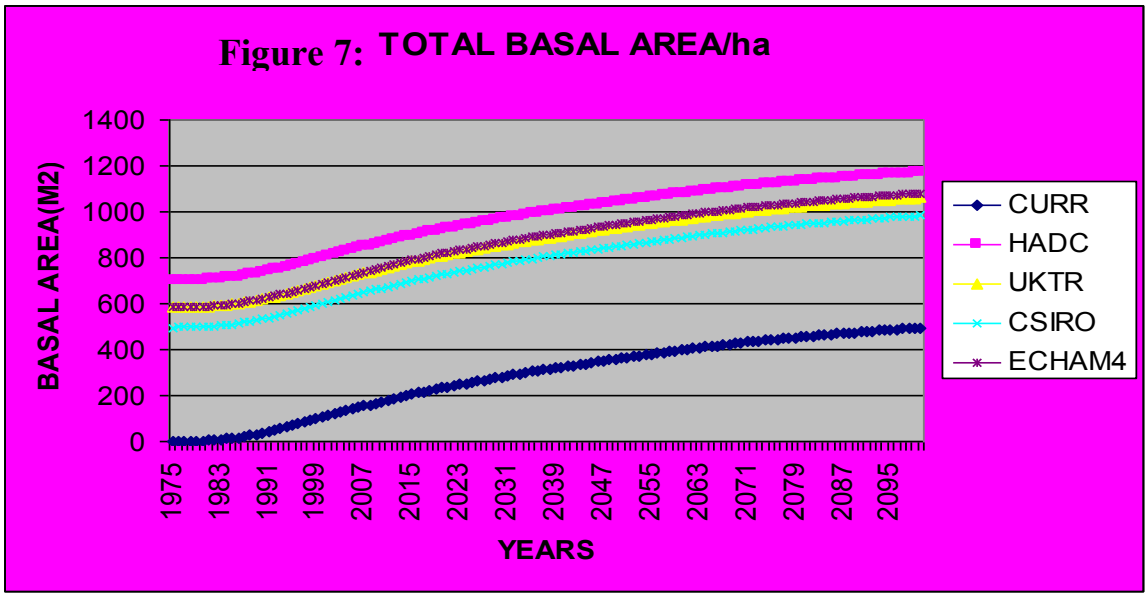



Figure 6 shows the total Biomass produced under the various climatic scenarios and indicates that there is an overall gradual increase In total biomass production in the following ascending order of magnitude: CURR, CSIRO, UKTR, ECHAM, and HADC.

Figure 7 similarly predicts the same trend for the total Based Area production but with a wider difference of 450m2/ha between CURR and CSIRO. HADC continues to dominate the total basal area production.

Species distribution by per class size for each specific year is shown in table 3. Hannoa klieneana is by far the fastest growing species attaining the 6th diameters class (over 60 cm diameter) in 25 years. The slowest growth was exhibited by seven species (Chlorophora, Cordia, Daniella, Gmelina, Khaya, Nauclea and Parkia)

### 4.3.4.9 Adaptation measures/Strategies/Options

Tropical trees and other woody plants have remarkable recuperative capacities and rapidly reoccupy disturbed forests and open spaces. However, the number of economically and socially desirable species present following disturbance is seldom adequate. Regenerating and adequate number of desired species that are used locally and/or have a marketable value will therefore usually require additional silvicultural interventions. Prominent among these are:

Stimulating natural regeneration from seed trees

- Afforestation
- Reforestation
- enrichment planting
- introduction of new species/provenances
- additional silvicultural interventions and appropriate management and adaptation measures including adjusting planting and harvesting dates and switching to more drought-resistant species.

Other important silvicultural treatments applied in the adaptation of forests are refining and liberation thinning. 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 defined as 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 becomes available. Therefore silvicultural interventions need also to be considered as an important policy tool in the management and adaptation of forests to climate change.

### 4.3.4.10. Policies for Adaptation responses

Despite their large extent, rapid growth and increasing importance at the local, national and regional levels for the products and services they provide, forests are not afforded adequate prominence in forest policy, planning and research. There is a general lack of policies regulating and encouraging their management, use and conversion. Ecological, silvicultural, and socio-economic knowledge regarding forests exists to a certain extent, and there is an increasing volume of research regarding restoration, rehabilitation and management.

Currently the National Forestry Policy formulated by government and strategies to achieve policy objectives are those outlined 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.

A fundamental problem in trying to achieve this balance is the question of change over time. When communities evolve, markets change and fluctuate in response to changing human values and demands. However, the adaptation of forest ecosystems is a long-term enterprise. The social and economic conditions that exist when a forest crop is destroyed (or harvested) are seldom the same as those prevailing when a tree seedling first takes root, nor do the priorities of individual remain the same. Strategies for the management and adaptation of forests must adopt a long-term perspective, anticipating, as far as possible, future trends. But they must be flexible and capable of adaptation to changing circumstance.

The primary objective of this study is to provide a preliminary assessment of the vulnerability of the forestry sector to the projected rise in temperature and variation of other climatic factors.

The study further assesses the potential impacts of key tropical forest tree species in Sierra Leone to likely climate change using accepted IPCC models.

### 4.3.5. Coastal Zone and Resources

#### 4.3.5.1 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 mudflats. 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. They also 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 a significant role in stabilizing shorelines, by serving as barriers for coastal erosion. They also serve as recreational sites in the tourism industry and as landing sites in the fishing communities. Other resources include hard rock, gravel in sea beds, clay materials, salt etc.

The coastal zone of Sierra Leone is one of the most densely populated areas of the country and is already vulnerable to a number of natural and man-made hazards including, inundations from the major rivers flowing through Sierra Leone to the coast of Sierra Leone, flash floods which come down from a

number of rivers during the monsoon period and also saline intrusions due to decreased low water flows in the dry season. Because of all these characteristics the coastal zone of the country will be particularly vulnerable to any climate change and sea level rise that may occur if they were to increase the intensity or frequency of these natural hazards.

The need for a vulnerability assessment of all coastal zones to climate change and sea level rise has been identified by the Inter Governmental Panel on Climate Change (IPCC) and endorsed by the UN Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil in June 1992 as part of a strategy for coastal zone development globally.

The present vulnerability assessment for Sierra Leone to climate change and sea level rise is part of a study on Sierra Leone prepared for the Second National Communications, under the Climate Change Project on behalf of the Ministry of Transport and Aviation, Government of Sierra Leone with support from the UNDP.

The primary objective of this study is to provide a preliminary assessment of the vulnerability of the coastal zone of Sierra Leone to the projected rise in sea levels as an input to national studies on vulnerability and adaptation strategies for climate change.

The study further assesses the potential impacts of sea-level rise on the coastal zone of Sierra Leone with emphasis on loss of land due to erosion and inundation. The most likely scenario of a rise of one metre (1m) by the year 2100 was examined in some detail.

**4.3.5.2. Methodology for Vulnerability and Adaptation Assessment:**

Two techniques are normally used in the programme to assess the Vulnerability and Adaptation of Forests to Climate Change; these are (1) Preliminary screening technique and (2) Simulation technique.

**4.3.5.3. Preliminary Screening Technique**

This technique can be used to identify areas of greatest vulnerability or as a substitute for more quantitative analysis where insufficient data are available for model development and application.

For the screening process of this study, the coastline was divided into a series of geomorphic units and for each of those units the relevant development factors were identified and an assessment of physical changes and natural system responses were assessed.

Unit 1: From the Guinea border to the southern bank of the Great Scarcies River

Unit 2: From the southern bank of the Great Scarcies River to the Southern (back) of Sierra Leone River estuary

Unit 3: From the southern bank of the Sierra Leone River estuary to the southern tip of the Freetown peninsular of the Western Area.

Unit 4: Yawri bay

Unit 5: From Yawri bay (Northern bank of the Sherbro river) to Sherbro Island to Southern tip of Sherbro Island

Unit 6: Turner's peninsula to the Mano River

In this study, on the vulnerability of coastal areas and resources of Sierra Leone to climate change, the study has been conducted as a local area study with respect to the Freetown Peninsula coastline.
This sample area was chosen as a result of the following considerations:

- Off the 510km coastline, only about 150km is significantly developed and this includes Freetown the capital city.
- Elsewhere the coastline is largely underdeveloped except for some fish landing sites and jetties strewn along the coastline.

- The rest of the coastline is dominated by sheltered embayment and mangrove systems with mud flats and a long stretch of sandy coast (beyond Bonthe Island).

The Sierra Leone coastal zone is defined as the area below the 30-m contour and covers about 10% of the total land area. At present it is already vulnerable to a number of natural and man-made hazards including coastal erosion, deforestation of coastal vegetation and on adjacent hill slopes, sand mining, and flash floods due to heavy rainfall and salt water intrusions due to decreased water flows in the dry season (Johnson & Johnson 1998). Because of these characteristics, the coastal zone of Sierra Leone will be particularly vulnerable to any climate change and sea level fluctuations that may occur. Several consequences could be expected for a rise in the level of the adjacent sea in Sierra Leone. Low lying sandy coastal areas all along the Freetown peninsular, bays and estuaries will be most affected. The expected impacts of sea-level rise includes but not limited to:

- Submergence of low-lying areas (bays beaches mangrove swamps)
- Erosion of beaches and soft shores leading to increased loss of sediment (offshore)
- Salinity increases in estuaries and aquifers
- Raised coastal water tables
- Aggravation of coastal flooding and storm damage.

### 4.3.5.4. Study Area site specific

The study area comprises the western area coastal zone of Sierra Leone in line with the requirements of the common methodology, for the assessment of climate change impacts of sea level rise. It is defined as all the land that has annual flood probability of 1/1000 (or 0.1%) in 2100. The area generally covers much of the sandy and beach areas of the Sierra Leone coastline below the 3m contour. The fringes of mangrove swamps and other wetlands along the coastal are included in the study area.

### 4.3.5.5. Objectives

The primary objective of this study is to provide a preliminary assessment of the vulnerability of the coastal zone of Sierra Leone to the projected rise in sea levels as an input to global studies on vulnerability and adaptation strategies for climate change.

The study further assesses the potential impacts of sea-level rise on the coastal zone of Sierra Leone with emphasis on loss of land due to erosion and inundation. The most likely scenario of a rise of one metre (1m) by the year 2100 is examined in some detail. The other sea level rise scenario although relevant could not be evaluated on account of limited data on topography of the coastal zone. Assuming that sea level rise is the only driving force (IPCC, 1990), various response strategies are developed. Probable cost of protection of critical areas is assessed and the consequences of doing nothing are evaluated as well as controlled abandonment.

### 4.3.5.6. Procedure and Methodology

The procedure used in this study involves the collection of data on infrastructure, land, buildings and population along the coastline that would potentially be vulnerable to sea level rise. An analysis of the cost involved in adopting a measure to adapt to the risk is carried out. The analysis assumes protection for all critical areas (i.e. areas with a population density of 10 persons per square kilometre).

When no adaptation measure is prescribed (i.e. the do-nothing option) the area threatened by inundation or erosion is considered at risk. The vulnerability of that segment is eliminated by full protection. Land and infrastructure that is at risk is considered lost and the population at risk is assumed displaced. Wetlands subject to inundation are considered lost.

The bulk of this study is focused on the loss of land and property as a consequence of shoreline recession, flooding and inundation. A qualitative assessment of other impacts such as loss of wetlands, salinisation of coastal zone is also carried out. The IPCC procedure was followed as much as possible utilizing existing data. Various simplifying assumptions being that out of the many elements that might influence shoreline evolution, sea level rise is the main driving force of coastal change. This assumption is considered appropriate as an initial analysis towards a more detailed coastal zone management strategy.

The procedure considers:
1) One socio-economic scenario (the case as at 2000)
2) A future sea-level rise of one metre, and
3) A defined response scenario and estimates of the associated cost.

### 4.3.5.7. Data Requirements

The major constraints for the quality of available data for this assessment have been the data on coastal topography to the scale required and the accuracy of such data.

### 4.3.5.8. Impact on Climate Change Induced Sea Level Rise

It is expected that for the year 2020 the SLR will be one meter**.**
With this expectation, it is projected that about 45% of the coastal zone of Sierra Leone will be inundated, and about 25% of the land lost to inundation will come from the sheltered coast. The low lying beaches along of the capital city of Freetown will be lost due to the fact that the greater part of the city is on raised beaches. The mangrove systems on sheltered embayments are likely to be lost.

### 4.3.5.9. Potential Impacts of Climate Change on Coastal Zone

The main limiting factor for making an 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 Freetown and coastal towns of Kambia, Bonthe Sherbro Island do not have these data. As much data as possible 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.

### 4.3.5.10. Shoreline Recession

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

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

### 4.3.5.11. Coastal Structures

The coastal structures that could be affected by a 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 structural integrity in the light of new evidence of water level increases.

### 4.3.5.12. Flooding and Inundation.

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

### 4.3.5.13. Saltwater Intrusion

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

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

### 4.3.5.14. 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.

### 4.3.5.15. Land at risk

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

### 4.3.5.16. 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 is an emerging industry within Sierra Leone's coastal area.

Sea-level rise on the coastal zone is largely concentrated on the Freetown peninsular, where about 70% of the vulnerable areas are located. 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.

Incomes within the coastal zone are generally low except for the urban centres 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 slum area along the coast is also increasing putting further pressures on the resources of the coastal zone.

Sea-level rise is expected to inundate many of the areas covered by mangroves along the Sierra Leone coast. 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.

### 4.3.5.17. Autonomous adaptation strategies/Options

The following are adaptation strategies recommended to combat coastal erosion:

**Set Back** – allowing space between the shoreline and associated coastal hazard and property to act as buffer.

**Controlled abandonment** – abandoning the 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 nourishment.

**Do nothing** – the option that involves abandoning the existing line of defence without any future monitoring or intervention of any kind.

The various options 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 in order to come up with a rational response.

### 4.3.5.18 Barriers and Appropriate Policies. It could be very important to have a similar section for all the sectoral assessments Legal Framework

In Sierra Leone a legislative framework for coastal zone management is absent. However, there is a large number of scattered legislations and regulations, which are designed to protect the coastal zone directly or indirectly. Again the implementation of these sectoral legislations that border on the coastal zone has generally been very poor. This has resulted in a large number of illegal settlements and activities, which have been allowed to continue, mainly as a result of overlapping mandates.

The Environment Protection Agency-(EPA-SL) raised the profile of the management and conservation status of the coastal zone. However, it is necessary to draft a law to acquire 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 rocks, 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 and swamps, together with the intervening interfluves areas within 30 metre contour adjacent to the ocean space; and the continental shelf of Sierra Leone as defined by statute for the time being in force.

### 4.3.5.19. Vulnerability and adaptation projects

The most important issues to be addressed in the management of the coastal zone in Sierra Leone are:

- establishment of sea level observation system and studies on coastal erosion in Sierra Leone
- mapping of disaster prone and hazard areas,
- 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 EPA-SL.

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.

### 4.3.6 Fisheries

#### 4.3.6.1 Current conditions

The Fisheries Sector is comprised of the industrial and artisanal fisheries sub-sectors and contributes about 12% to GDP. The sector produces food-fish (which is the major source of animal protein for the majority of Sierra Leoneans) for local consumption and for export to earn foreign exchange. The average annual per capita fish consumption is estimated at 23kg. Fish consumption is higher than other sources of protein (livestock & poultry). As the population continues to expand in Sierra Leone, fish demand is going to increase.

The artisanal fisheries sub-sector is the major employer and supplier of almost all the supplement animal protein needed in the diets of Sierra Leone. The fishing and fisheries related activities provide direct and indirect employment for over 36,000 people. It provides employment for about 6,000 people in the harvesting side and about 30,000 on boat building, fish handling, processing, transportation and marketing activities. If fishermen and people working on the ancillary activities as well as their dependants are added, it is estimated that not less than 140,000 people in Sierra Leone depend on the fisheries sector for their livelihood.

About 80% of artisanal catches are bonga (Ethmalosa fimbriata). The riverine artisanal fishery is considered non-industrial operation, employs traditional methods, and is under-exploited due to low levels of fisheries technologies. Some of the marine fish species caught in the Sierra Leone River include shade (Ethmalosa fimbriata), threadfins (Polynemidae sp.), marine catfish (Arius sp.) and solefish (Cynoglossidae sp.). The lower reach of the river has a brackish water regime and attracts certain marine species, which use the river for feeding and spawning purposes (e.g. threadfins, solefish, catfish and shrimps). These fish migrate up the river during the dry season. The upper reach of the river has freshwater regime where Tilapia nilotica and Clarias luzerra are important fish species. The most important crustaceans in the river fishery are shrimps caught by artisanal fishermen in the estuary. These species are caught and sold to industrial companies which usually provide nets, engines and ice to these fishermen as an agreement for them to sell their products to these companies.

The industrial fisheries sub-sector comprises of local fishing companies and licensed local and foreign industrial fishing vessels of various capacities and fishing techniques. The fishing methods employed are trawling, purse seining and long lining. The sub-sector also targets species in all four stock categories (pelagic, demersal, cephalopods and crustaceans). It is this aspect of multi-species fisheries that creates problems in the management of fishery resources due to the fact that both artisanal and industrial fisheries target the same species especially the most valuable categories of fish stocks namely, demersal, cephalopods and crustaceans. Over 95% of industrial fisheries production is processed and exported. In

view of the reported resource potential and the current rate of exploitation of marine resources, demersal fish resources are believed to be fully exploited, whilst the pelagic resources are under exploited.

The major aquatic habitats present in Sierra Leone are the main rivers, it's tributaries and floodplain systems, coastal habitats such as estuaries and mangrove swamps.

In addition to this diversity of habitats, an even greater variety of ecologically and economically important species occupy these habitats and will have to be considered with regard to the impacts of potential climate change.

The fishery resources of the coastal area and marine areas of Sierra Leone comprises pelagic and demersal species found in various ecologies along the coastal zone, as well as the inland fishery found in inland ecologies. These ecologies consists of estuaries, bays, lakes, mangrove swamps inland valley swamps etc.

The fishery is very diverse and contains different species of fish belonging to various genera. At present the fishery is vulnerable to a number of natural and man-made hazards including; over-fishing, deforestation of fish spawning grounds, increased turbidity of coastal waters (due to coastal erosion), flash floods, land and sea pollution, saline water intrusion etc.

Because of its diversity, the fishery of Sierra Leone will particularly be vulnerable to any climate change and sea-level fluctuations that may occur. Several consequences could be expected for a rise of sea temperature or sea level fluctuations. The pelagic fishery of Sierra Leone, which by expert experience has proved to be very sensitive to environmental variations, will be most affected.

#### 4.3.6.2. Impacts of Climate Change on Fisheries

This study assesses the potential impacts of climate change on the fishery of Sierra Leone, or the vulnerability of the fisheries sector of Sierra Leone to climate change.

The methods for evaluating climate change impacts on riverine-based fisheries are focused on the assessment of the impacts of temperature, dissolved oxygen, and precipitation on fish growth, life history and habitat suitability and yield.

#### 4.3.6.3. Methodologies Used and Results of Impacts of Climate Change

The assessment for evaluating potential climate change impacts on fisheries resources follows a weight of evidence approach. This is as a result of the diversity of fisheries resources and aquatic habitats that are to be addressed, and the inability of any single approach to evaluate potential impacts on all the fisheries resources and habitats. The weight of evidence approach uses multiple lines of evidence to identify potential impacts and evaluate the significance of any projected impacts.

In general the methods involve:

- Use of General Circulation Model Predictions of air temperature, precipitation, solar radiation and wind;

- Identification of coastal marine and fresh water conditions vulnerable to climatic changes such as increased water temperatures reduced dissolved oxygen levels, altered lake and sea levels, changed river hydrographs.

- Development of habitat and catch/yield models including empirical models relating fish yield or catch with habitats or climatic factors relationships between population abundance and thermal habitat and temperature – process relationships and predict process responses.

The procedure used in this analysis involves a collection of data on the fishery of Sierra Leone and other allied data to feed into the specific methods outlined later, that may be applicable to Sierra Leone for assessing the vulnerability of the fisheries sector of Sierra Leone to climate change. Two approaches are involved in the general vulnerability assessment:

**Preliminary screening technique:**

The purpose of the preliminary screening is to identify and prioritize those fisheries within a country for which detailed vulnerability and adaptation analyses might be needed. The screening technique used is heavily based on expert judgment. Having identified and prioritised the fishery within Sierra Leone their vulnerability to potential changes in precipitation, temperature or sea level rise will be ranked as low, moderate or high. All fisheries that have high economic or ecological importance and are ranked as highly vulnerable are then considered for detailed analyses. Table 4.8 illustrates the form used in the preliminary screening process.

**Table 4.8: A Typical Preliminary Screening form**

| Fishery (ranked) | Low | Moderate | High | Remarks |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

**Detailed Simulation technique**

Fisheries that are ranked as moderately vulnerable are also considered for detailed analyses. In the detailed analysis various formulae are utilized based on available data and information.

### 4.3.6.4. Description of the Methods considered in the detailed analysis and potential impacts of Climate change

### 4.3.6.5. Assessing the Effects of Temperature on Productivity

This method evaluates the annual productivity, K, of a river on the basis of average stream, average annual temperature, $K_1$, the acidity or alkalinity, $K_2$ of the water and the type of fish. The productivity is calculated using the formula:

Productivity $K = B * W * (k_1 * k_2 * k_3)$

Where K = annual productivity (kg/km of river)
W = average width of the river (m)

B = the Biogenic capacity (B = 1 – 3 for waters with little food for fish; B = 4 – 6 waters with average levels of fish food; and B = 7 – 10 for waters that are rich in fish food).
$k_1$ = annual average water temperature of selected sites across the country
$k_2$ = salinity of the water
$k_3$ = type of fish population present in river.

The value for $k_3$ can be approximated on the basis of the percentage of fish found in rheophilic (fast flowing waters, such as rivers) and limnophilic (slow moving waters, e.g. streams) using the equation $k_3 = (2L + R)/100$, where L = the percentage of the fish comprised of limnophilic species and R = the percentage of fish comprised of rehophilic species. Values of L = 5% and R = 95% as assumed by Jallow (1997) are used in this study. Most rivers are fast flowing waters hence it is reasonable to assume R to be 95%.

The data required for the assessment include estimate of food resources available for the river segment of concern, alkalinity data/salinity, historic and predicted mean annual water temperatures, average stream width data, topographic/bathymetric maps and current annual productivity estimates.

For 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 metres for the Rokel River, the biogenic capacity of the stream, the average 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 current (1961-1990) climate is 228 tons per kilometre (tons/km) reach of the river.

All the climate change model scenarios project an increase in the productivity of the river. The highest increase in productivity is projected by the HADLEY2 model scenario and it ranges from 3% (~ 236 tons per km) increase by 2025 to about 8% (~249 tons/km) increase in 2100. The projection based on the CSIRA model is lowest of all the models considered for this assessment. The projected productivity under the CSIRA varies from about 2% (~ 234 tons/km) increase in 2025 to about 6% (~ 243 tons/km) increase in 2100.

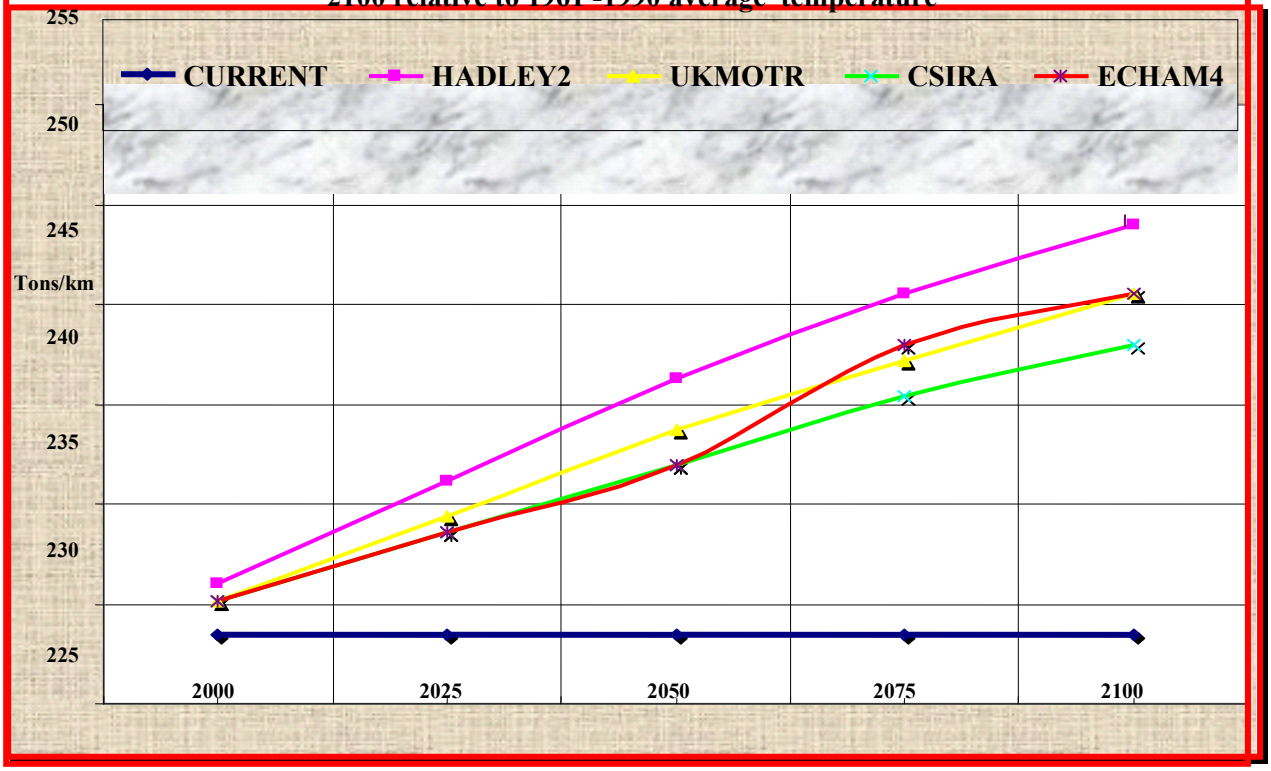
Table 4.9 and Figure 1 show the results of the assessment under the various climate change model scenarios.

**Table 4.8 : Estimates of Fish Biomass Productivity (Tons/Km) for the Rokel River as Climate Changes**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | **2000** | | | | |
| **Scenario** | B | W | L | R | k1 | k2 | k3 = (2L+R)/100 | K=B*W*(k1*k2*k3) | Percent |
| | | (metres) | (%) | (%) | $^{(0}$C) | ph | | (Kg/km of River) | Variation |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CURRENT** | 6 | 250 | 95 | 5 | 24.0 | 3.25 | 1.95 | 228,435.2 | 0 |
| **HADLEY2** | 6 | 250 | 95 | 5 | 24.3 | 3.25 | 1.95 | 231,001.9 | 1 |
| **UKMOTR** | 6 | 250 | 95 | 5 | 24.2 | 3.25 | 1.95 | 230,146.3 | 1 |
| **CSIRA** | 6 | 250 | 95 | 5 | 24.2 | 3.25 | 1.95 | 230,146.3 | 1 |
| **ECHAM4** | 6 | 250 | 95 | 5 | 24.2 | 3.25 | 1.95 | 230,146.3 | 1 |
| | | | | | **2025** | | | | |
| **Scenario** | B | W | L | R | k1 | k2 | k3 = (2L+R)/100 | K=B*W*(k1*k2*k3) | Percent |
| | | (metres) | (%) | (%) | ($^0$C) | ph | | (Kg/km of River) | Variation |
| **CURRENT** | 6 | 250 | 95 | 5 | 24.0 | 3.25 | 1.95 | 228,435.2 | 0 |
| **HADLEY2** | 6 | 250 | 95 | 5 | 24.8 | 3.25 | 1.95 | 236,135.3 | 3 |
| **UKMOTR** | 6 | 250 | 95 | 5 | 24.7 | 3.25 | 1.95 | 234,424.1 | 3 |
| **CSIRA** | 6 | 250 | 95 | 5 | 24.6 | 3.25 | 1.95 | 233,568.6 | 2 |
| **ECHAM4** | 6 | 250 | 95 | 5 | 24.6 | 3.25 | 1.95 | 233,568.6 | 2 |
| | | | | | **2050** | | | | |
| **Scenario** | B | W | L | R | k1 | k2 | k3 = (2L+R)/100 | K=B*W*(k1*k2*k3) | Percent |
| | | (metres) | (%) | (%) | ($^0$C) | ph | | (Kg/km of River) | Variation |
| **CURRENT** | 6 | 250 | 95 | 5 | 24.0 | 3.25 | 1.95 | 228,435.2 | 0 |
| **HADLEY2** | 6 | 250 | 95 | 5 | 25.4 | 3.25 | 1.95 | 241,268.6 | 5 |
| **UKMOTR** | 6 | 250 | 95 | 5 | 25.1 | 3.25 | 1.95 | 238,701.9 | 4 |
| **CSIRA** | 6 | 250 | 95 | 5 | 24.9 | 3.25 | 1.95 | 236,990.8 | 4 |
| **ECHAM4** | 6 | 250 | 95 | 5 | 24.9 | 3.25 | 1.95 | 236,990.8 | 4 |
| | | | | | **2075** | | | | |
| **Scenario** | B | W | L | R | k1 | k2 | k3 = (2L+R)/100 | K=B*W*(k1*k2*k3) | Percent |
| | | (metres) | (%) | (%) | ($^0$C) | ph | | (Kg/km of River) | Variation |
| **CURRENT** | 6 | 250 | 95 | 5 | 24.0 | 3.25 | 1.95 | 228,435.2 | 0 |
| **HADLEY2** | 6 | 250 | 95 | 5 | 25.8 | 3.25 | 1.95 | 245,546.4 | 7 |
| **UKMOTR** | 6 | 250 | 95 | 5 | 25.5 | 3.25 | 1.95 | 242,124.2 | 6 |
| **CSIRA** | 6 | 250 | 95 | 5 | 25.3 | 3.25 | 1.95 | 240,413.1 | 5 |
| **ECHAM4** | 6 | 250 | 95 | 5 | 25.6 | 3.25 | 1.95 | 242,979.8 | 6 |
| | | | | | **2100** | | | | |
| **Scenario** | B | W | L | R | k1 | k2 | k3 = (2L+R)/100 | K=B*W*(k1*k2*k3) | Percent |
| | | (metres) | (%) | (%) | ($^0$C) | ph | | (Kg/km of River) | Variation |
| **CURRENT** | 6 | 250 | 95 | 5 | 24.0 | 3.25 | 1.95 | 228,435.2 | 0 |
| **HADLEY2** | 6 | 250 | 95 | 5 | 26.2 | 3.25 | 1.95 | 248,968.7 | 8 |
| **UKMOTR** | 6 | 250 | 95 | 5 | 25.8 | 3.25 | 1.95 | 245,546.4 | 7 |
| **CSIRA** | 6 | 250 | 95 | 5 | 25.6 | 3.25 | 1.95 | 242,979.8 | 6 |
| **ECHAM4** | 6 | 250 | 95 | 5 | 25.8 | 3.25 | 1.95 | 245,546.4 | 7 |

**Figure 4.21: Projected MSY and yield as temperature changes influence concentrated at 2100 relative to 1961 -1990 average temperature**




### 4.3.6.6. Assessing the Effects of Temperature Change on Shrimp yield and Parameters

Using empirical data from several sources, Regier et. al. (1990) developed the following model for penaced shrimp yield:

$$\text{Log}_e \text{ SCSY} = 52.0 - 14312\ (1/T)$$

Where SCSY = stabilized commercial shrimp yield (kg/ha of intertidal vegetation) and T = mean annual air temperature ($^{O}$K). The basis for this approach is development of regression equation of the form:

$$\text{Log}_e \text{ ki} = a - b(1/Ti)$$

where k = rate constant, T = absolute temperature ($^{O}$K), and a (y-intercept) and b (slope) are coefficients estimated by regression analysis.

Data required for this method includes:

- Historic data on shrimp yield in Kg/ha of intertidal vegetation;
- Historic mean annual air temperature; and GCM – predicted temperature for input to models to predict shrimp yields under different temperature

| Table 4.10 : Estimation of Shrimp Yield from Temperature Changes due to Climate Changes | | | | | |
|---|---|---|---|---|---|
| Model Scenario | MEAN ANNUAL AIR TEMPERATURE | | NATURAL LOG SCSY | SCSY | PERCENT INCREASE |
| | (degrees C) | degrees K | | | |
| **HADLEY CENTRE MODEL (HADLEY2)** | | | | | |
| 1961-1990 | 26.7 | 299.9 | 4.3 | 71.5 | 0 |
| HADLEY2 2000 | 27.0 | 300.2 | 4.3 | 75.0 | 5 |
| HADLEY2 2010 | 27.2 | 300.4 | 4.3 | 77.4 | 8 |
| HADLEY2 2020 | 27.4 | 300.6 | 4.4 | 79.9 | 11 |
| HADLEY2 2025 | 27.6 | 300.8 | 4.4 | 82.5 | 13 |
| HADLEY2 2030 | 27.7 | 300.9 | 4.4 | 83.8 | 15 |
| HADLEY2 2040 | 27.9 | 301.1 | 4.5 | 86.5 | 17 |
| HADLEY2 2050 | 28.2 | 301.4 | 4.5 | 90.7 | 21 |
| HADLEY2 2060 | 28.4 | 301.6 | 4.5 | 93.6 | 24 |
| HADLEY2 2070 | 28.6 | 301.8 | 4.6 | 96.5 | 26 |
| HADLEY2 2075 | 28.7 | 301.9 | 4.6 | 98.1 | 27 |
| HADLEY2 2080 | 28.8 | 302.0 | 4.6 | 99.6 | 28 |
| HADLEY2 2090 | 28.9 | 302.1 | 4.6 | 101.2 | 29 |
| HADLEY2 2100 | 29.1 | 302.3 | 4.6 | 104.4 | 32 |
| **UK MET. OFFICE TRANSCIENT MODEL (UKMOTR)** | | | | | |
| 1961-1990 | 26.7 | 299.9 | 4.3 | 71.5 | 0 |
| UKMOTR 2000 | 26.9 | 300.1 | 4.3 | 73.8 | 3 |
| UKMOTR 2010 | 27.1 | 300.3 | 4.3 | 76.2 | 6 |
| UKMOTR 2020 | 27.3 | 300.5 | 4.4 | 78.6 | 9 |
| UKMOTR 2025 | 27.4 | 300.6 | 4.4 | 79.9 | 11 |
| UKMOTR 2030 | 27.5 | 300.7 | 4.4 | 81.2 | 12 |
| UKMOTR 2040 | 27.7 | 300.9 | 4.4 | 83.8 | 15 |
| UKMOTR 2050 | 27.9 | 301.1 | 4.5 | 86.5 | 17 |
| UKMOTR 2060 | 28.1 | 301.3 | 4.5 | 89.2 | 20 |
| UKMOTR 2070 | 28.2 | 301.4 | 4.5 | 90.7 | 21 |
| UKMOTR 2075 | 28.3 | 301.5 | 4.5 | 92.1 | 22 |
| UKMOTR 2080 | 28.4 | 301.6 | 4.5 | 93.6 | 24 |
| UKMOTR 2090 | 28.5 | 301.7 | 4.6 | 95.0 | 25 |
| UKMOTR 2100 | 28.7 | 301.9 | 4.6 | 98.1 | 27 |
| **CSIRA MODEL** | | | | | |
| CURRENT (1961-1990) | 26.7 | 299.9 | 4.3 | 71.5 | 0 |
| CSIRA 2000 | 26.9 | 300.1 | 4.3 | 73.8 | 3 |
| CSIRA 2010 | 27.0 | 300.2 | 4.3 | 75.0 | 5 |

| | | | | | |
|---|---|---|---|---|---|
| CSIRA 2020 | 27.2 | 300.4 | 4.3 | 77.4 | 8 |
| CSIRA 2025 | 27.3 | 300.5 | 4.4 | 78.6 | 9 |
| CSIRA 2030 | 27.4 | 300.6 | 4.4 | 79.9 | 11 |
| CSIRA 2040 | 27.6 | 300.8 | 4.4 | 82.5 | 13 |
| CSIRA 2050 | 27.7 | 300.9 | 4.4 | 83.8 | 15 |
| CSIRA 2060 | 27.9 | 301.1 | 4.5 | 86.5 | 17 |
| CSIRA 2070 | 28.0 | 301.2 | 4.5 | 87.8 | 19 |
| CSIRA 2075 | 28.1 | 301.3 | 4.5 | 89.2 | 20 |
| CSIRA 2080 | 28.2 | 301.4 | 4.5 | 90.7 | 21 |
| CSIRA 2090 | 28.3 | 301.5 | 4.5 | 92.1 | 22 |
| CSIRA 2100 | 28.4 | 301.6 | 4.5 | 93.6 | 24 |

| **ECHAM4 MODEL** | | | | | |
|---|---|---|---|---|---|
| 1961-1990 | 26.7 | 299.9 | 4.3 | 71.5 | 0 |
| ECHAM4 2000 | 26.9 | 300.1 | 4.3 | 73.8 | 3 |
| ECHAM4 2010 | 27.1 | 300.3 | 4.3 | 76.2 | 6 |
| ECHAM4 2020 | 27.3 | 300.5 | 4.4 | 78.6 | 9 |
| ECHAM4 2025 | 27.3 | 300.5 | 4.4 | 78.6 | 9 |
| ECHAM4 2030 | 27.4 | 300.6 | 4.4 | 79.9 | 11 |
| ECHAM4 2040 | 27.7 | 300.9 | 4.4 | 83.8 | 15 |
| ECHAM4 2050 | 27.7 | 300.9 | 4.4 | 83.8 | 15 |
| ECHAM4 2060 | 28.1 | 301.3 | 4.5 | 89.2 | 20 |
| ECHAM4 2070 | 28.3 | 301.5 | 4.5 | 92.1 | 22 |
| ECHAM4 2075 | 28.4 | 301.6 | 4.5 | 93.6 | 24 |
| ECHAM4 2080 | 28.4 | 301.6 | 4.5 | 93.6 | 24 |
| ECHAM4 2090 | 28.6 | 301.8 | 4.6 | 96.5 | 26 |
| ECHAM4 2100 | 28.7 | 301.9 | 4.6 | 98.1 | 27 |
| **Stabilized Commercial Shrimp Yield = SCSY in units of kg/ha of intertidal vegetation and degrees K = C + 273.15** | | | | | |

In this assessment the Stabilized Commercial Shrimp Yield was estimated for current climate, taken as average climate for the period 1961 to 1990 and for simulated climate change to 2100 based on model output from four General Circulation Models (HADLEY2, UKMOTR, CSIRA and ECHAM4) downloaded from the IPCC Data Distribution Centre (ipccdcc@wmo.ch).

The Stabilized Commercial Shrimp Yield (SCSY) under current climate with an average annual temperature of about 26.7$^{O}$C is 71.5 Kg/ha. Simulation based on the warming of the atmosphere by 2075 to about 28.7$^{O}$C under the HADLEY2, 28.3$^{O}$C under the UKMOTR, 28.1$^{O}$C under the CSIRA and 28.4$^{O}$C under the ECHAM4 models shows increases from current climate SCSY of 71.5kg/ha to 98.1 Kg/ha (27%), 92.1 Kg/ha (22%), 89.2Kg/ha (20%) and 93.6 Kg/ha (24%) for the models respectively.

Table 4.10 above show these variations with temperature as climate changes to 2100.

Assessing the Effects of Precipitation on Catch - Catch vs. Floodplain Area

This approach uses regression analysis to develop empirical models to predict catch. In the absence of sufficient historic catch and floodplain data, either of the following relationships may be used:

$$C = 2.65A - 0.98 \qquad (r^2 = 0.828)$$
$$C = 3.83A \qquad (r^2 = 0.865)$$

Where C = annual catch (metric tons) per km reach of river and A = floodplain area ($km^2$) per km reach of river.

The vulnerability is assessed by estimating its catch and floodplain area for predicted precipitation regimes. Total catch is estimated by inputting the predicted floodplain area to the appropriate empirical model. Vulnerability is assessed by comparing historic yields under current and each climate scenario.

The floodplain area of the Rokel River is 259 $km^2$ at an average annual rainfall of 2,746 mm of annual rainfall. This floodplain area is assumed to vary linearly with the projected annual precipitation. From the projected annual rainfall scenarios the floodplain area is determined as 261 $km^2$ under the HADLEY2 scenario, 234 $km^2$ under the UKMOTR scenario, 252 $km^2$ under the CSIRA scenario and 261 $km^2$ under the ECHAM4 scenario. These values are input into the Floodplain Area – Catch Equations to project Catch from the Rokel River as climate changes.

The simulation results using the UK Transcient and CSIRA scenarios show projected decrease in rainfall and floodplain area by 10% and 3%, respectively. The results from the HADLEY2 and ECHAM4 scenarios show an increase in rainfall and floodplain area by 1%. Based on these variations in rainfall and floodplain area, floodplain fishery catch for the Rokel River within Sierra Leone of 992 metric tons per year under current climate will increase to 999.6 tons/yr under the HADLEY2, 896 tons/yr under the UKMOTR, 965.2 tons/yr under the CSIRA and 999.6 tons under the ECHAM model scenarios. Figure 6 below illustrates these variations in floodplain area and catch as climate changes at 2100.

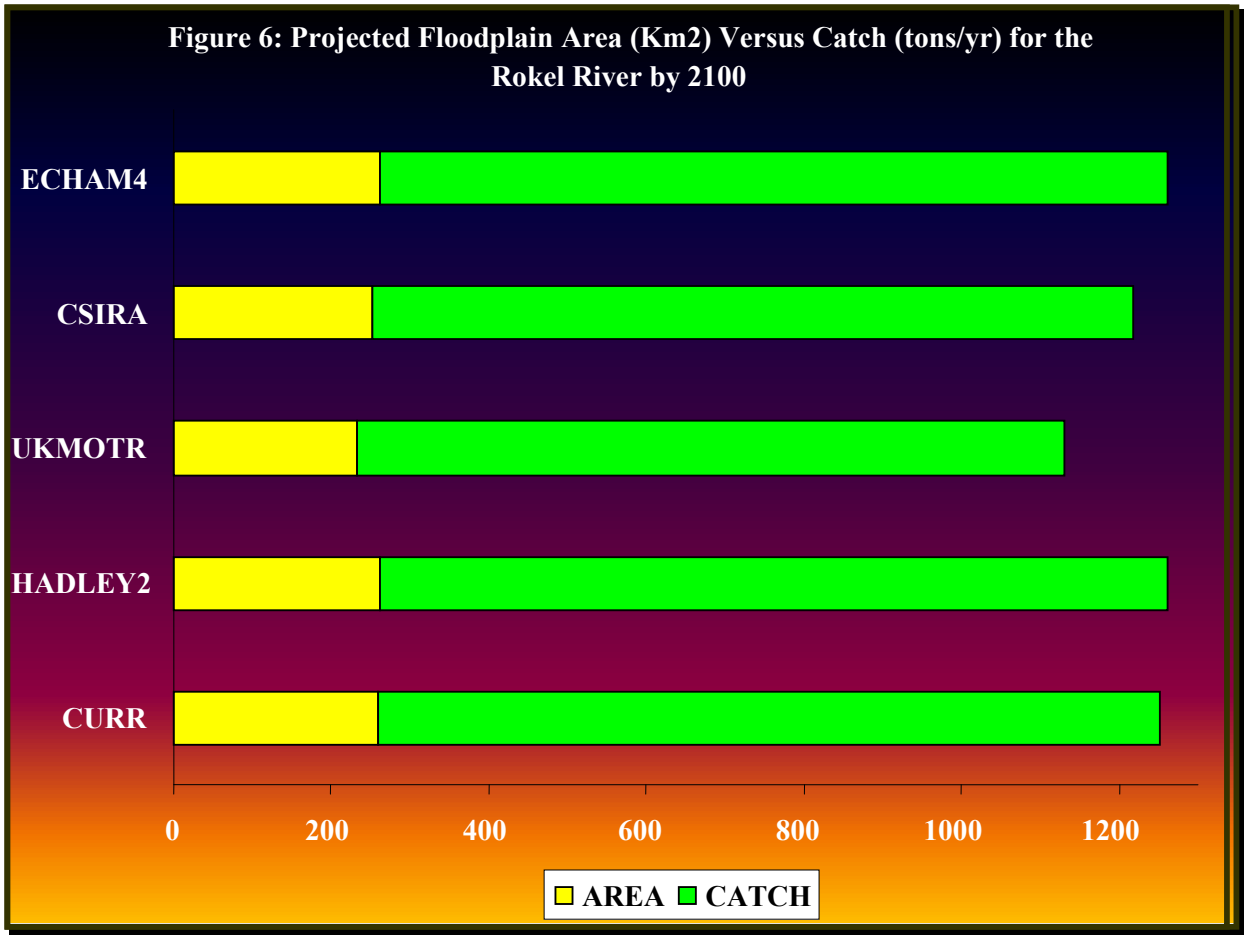



Figure 4.20 Projected floodplain area (Km2) Versus Catch (tons/yr) for the Rokel River by 2100

### 4.3.6.7. Assessing the Effects of Temperature and other parameters of a water body on Maximum Sustainable Yield (MSY).

Maximum Sustainable Yield of a water body is related to the temperature (T) and Morphoedaphic Index (MEI), and the MEI is also related to total dissolved substance (TDS), concentrates (CON), alkalinity/salinity (AKL) and depth (z) of the water body. In this study the effects of temperature on MSY is investigated using the MEI – Yield relationships indicated below.

Prediction of MSY based on Temperature Effect only:

$$\text{Log}_{10}\, MSY_{(T)} = 0.061*T + 0.043 \qquad \text{Equation 1}$$

Prediction of MSY based on effect of Temperature, Total Dissolved Substance (TDS) and depth (Z) is given as:

$$\text{Log}_{10}\, MSY_{(T,\, MEI\,(TDS/Z)))} = 0.05*T + 0.28*\text{Log}\,(MEI_{(TDS/Z)} + 0.236) \qquad \text{Equation 2}$$

Prediction of MSY based on effect of Temperature, Concentration (CON) and depth (Z) is given as:

$$\text{Log}_{10}\ MSY_{(T,\ MEI\ (CON/Z))} = 0.05*T + 0.28*\ \text{Log}\ (MEI_{(CON/Z)} + 0.236) \qquad \text{Equation 3}$$

Prediction of MSY based on effect of Temperature, Alkalinity (AKL) and depth (Z) is given as:

$$\text{Log}_{10}\ MSY_{(T,\ MEI\ (AKL/Z))} = 0.05*T + 0.28*\ \text{Log}\ (MEI_{(AKL/Z)} + 0.236) \qquad \text{Equation 4}$$

Prediction of MSY based on effect of Temperature, Total Dissolved Substance (TDS) and depth (Z) is given as:

$$\text{Log}_{10}\ Yield_{(T,\ MEI\ (TDS/Z)))} = 0.051*T + 0.358*Effort + 0.161*\ \text{Log}\ (MEI_{(TDS/Z)} - 0.383) \qquad \text{Equation 5}$$

Prediction of MSY based on effect of Temperature, Concentration (CON) and depth (Z) is given as:

$$\text{Log}_{10}\ Yield_{(T,\ MEI\ (CON/Z))} = 0.051*T + 0.358*Effort + 0.161*\ \text{Log}\ (MEI_{(CON/Z)} - 0.383) \qquad \text{Equation 6}$$

Prediction of MSY based on effect of Temperature, Alkalinity (AKL) and depth (Z) is given as:

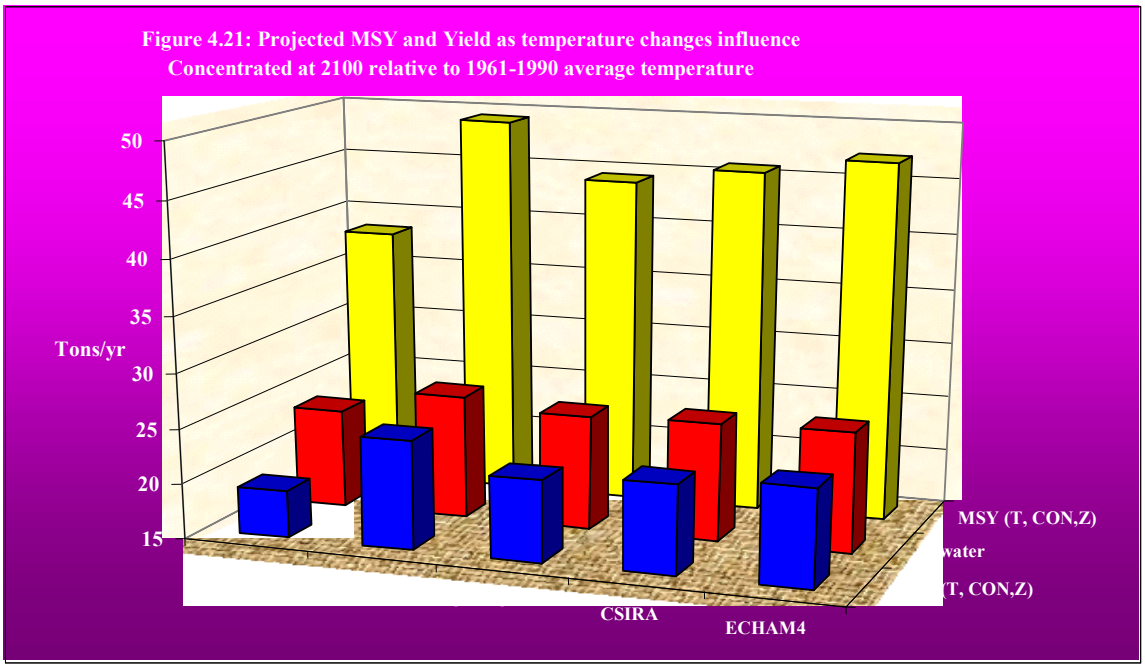
$$\text{Log}_{10}\ Yield_{(T,\ MEI\ (AKL/Z))} = 0.051*T + 0.358*Effort + 0.161*\ \text{Log}\ (MEI_{(AKL/Z)} - 0.383) \qquad \text{Equation 7}$$

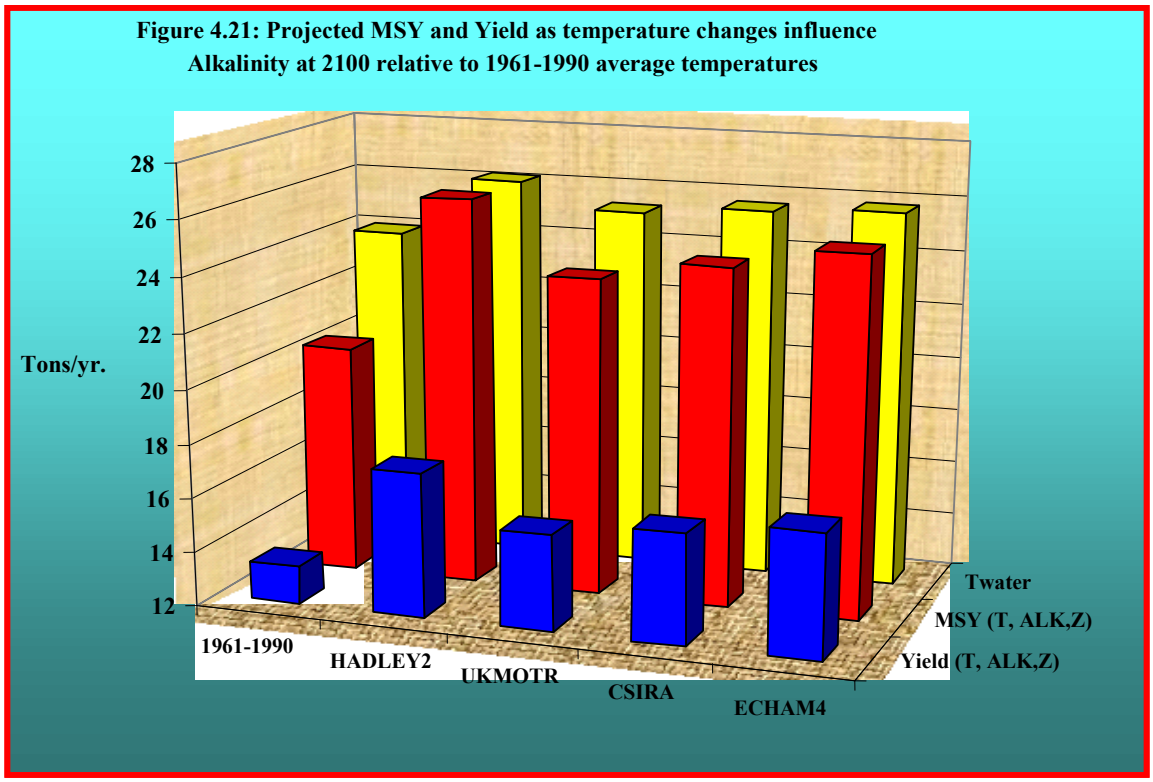
Microsoft EXCEL Spreadsheet versions of these equations were constructed and current climate and climate change scenarios input in the spreadsheet. Table 4.10 and Figures 7 to 10 show the results of the effects of temperature change at 2100 compared to current climate averaged for the period 1961 to 1990.

Table 4.10: Projected Yield (tons/year) and Maximum Sustainable Yield (tons/year) of the fishery of Rokel River as climate changes at 2100

| | Temperature | | Maximum Sustainable Yield | | | | Yield | | |
|---|---|---|---|---|---|---|---|---|---|
| | Tair | Twater | MSY ($_T$) | MSY ($_{T,TDS,Z}$) | MSY ($_{T,\ CON,Z}$) | MSY ($_{T,\ ALK,Z}$) | Yield ($_{T,\ TDS,Z}$) | Yield ($_{T,\ CON,Z}$) | Yield ($_{T,\ ALK,Z}$) |
| 1961-1990 | 26.7 | 24.0 | 32.27 | 33.25 | 38.47 | 20.45 | 17.74 | 19.29 | 13.42 |
| HADLEY2 | 29.1 | 26.2 | 43.71 | 42.64 | 49.34 | 26.23 | 22.86 | 24.87 | 17.29 |
| UKMOTR | 28.7 | 25.3 | 38.52 | 38.44 | 44.48 | 23.65 | 20.57 | 22.37 | 15.56 |
| CSIRA | 28.4 | 25.6 | 40.01 | 39.65 | 45.89 | 24.39 | 21.23 | 23.09 | 16.06 |
| ECHAM4 | 28.7 | 25.8 | 41.56 | 40.91 | 47.33 | 25.16 | 21.92 | 23.84 | 16.57 |

Conclusion: Please include an adaptation considerations and a concluding section for the shrimp sector,




### 4.3.6.8 Assessing the Effects of Precipitation, Temperature and Dissolved Oxygen on habitat. Whose habitat

## 4.4 Other Crosscutting Sectors

This is a species-specific approach, which includes the development of Habitat suitability Index (HIS) models for individual species of concern. These models incorporate environmental variables such as water temperature, current velocity, floodplain inundation duration, dissolved oxygen (DO) concentrations, and substrate composition. The models produce an index of habitat suitability. Following construction of species-specific models, habitat suitability indices (HSI) was estimated for specific habitats using historic (or current) climatic, hydrological and ecological data. Habitat Suitability Indices will then be calculated for the predicted climatic and hydrological conditions associated with each climate change scenario.

The data required include:

- Species-specific habitat and physiology data;
- Habitat characteristics, but not limited to temperature, DO, substrate, stage and flow and predicted temperature and precipitation.

Vulnerability will be assessed by comparing the HSI under current with those of climate change scenarios. However due to lack of appropriate data work was not done using the Habitat Suitability Index.

The Habitat suitability Index model was used to assess impacts of climate change on fisheries.

Fish productivity is projected to increase by $14.4*10^6$ kg/km of the river by 10% under GFDL30 equilibrium model, 11% under the CCCM and the HCGS, and 14% under HCGG and the Transient GFDL.01 models using a Habitat Suitability Index, it was found that potential warming of $1.5^C$…to $2^{0C}$ over the next century will have little or no effect on the suitability of the present habitat for the pelagic species of shad and catfish. For shrimps, grouper, and lady fish, a projected by the various General Circulation Models, shrimps yield is estimated to increase.

Analysts suggest the suitability of the habitats of the species will remain favourable especially within the protected areas. The suitability of the habitats for the will be highly reduced under the projected climate change scenarios. Migratory species such as the may be especially vulnerable because they require separate breeding, wintering, and migration habitats. In many cases, one or more of these habitats could be at risk because of climate change and other habitat loss.

By the end of the next century, yield increases over the baseline scenario values are expected to vary.

Suggested adaptation measures include stricter control on exploitation of resources, safeguard the spawning sites, halting the destruction of mangroves, organizing sensitization workshops on conservation, and conducting research to further assess the feasibility and scope of fish farming in Sierra Leone.

# Chapter 5

## Other Information Considered Relevant to the Achievement of the Objective of The Convention

### 5.1 Introduction

Within the framework of the implementation of the convention on climate change and in accordance with parties' obligation in educating, training and raising awareness of populations, institutional, legal frameworks have related programs within them.

The specific strategies to implement the sector plans are given below. The major strategy will be to mainstream the Mitigation and Adaptation measures identified in the SNC. The implementation of the Mitigation and Adaptation measures identified in this National Communication will be coordinated by the EPA-SL and the UNFCCC Focal Point for Sierra Leone. The relevant Ministries, Agency and Departments (MDAs) will implement the sector plans in collaboration with the relevant institutions, NGOs, Local Government Authorities and Community Based Organisations.

### 5.1.1 Energy sector

- fine-tune data to make a better assessment of emissions through the sector method; conduct a survey following a relatively less expensive methodology to establish a baseline case with more elaborate collection tools and;
- use this survey to make a better assessment of the technical characteristics of production tools in anticipation of mitigation measures

**Implementation Strategy**

The Ministry of Energy and Water Resources will lead the implementation of activities developed under the Energy and Water Resources Sector.

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### 5.1.2 LULUCF sector- Priority Actions for Forestry and Wetland Ecosystems

- Realize a national forest inventory with a view to having a better knowledge of the sequestering potential;
- Conduct surveys to fine-tune the estimate of trees outside forests, in particular trees in urban and rural centers.

**Implementation Strategy**

The Division of Forestry in the Ministry of Agriculture, Forestry and Food Security in Collaboration with the Universities and Conservation NGOs, will lead the implementation of activities for the Forestry Sector.

### 5.1.3 Agriculture- Implementation Strategy

- Integrate into the next agricultural and livestock censuses the concerns related to the agricultural sectors inventories;
- Set up an efficient monitoring mechanism of the progression of cultivated areas and bush fires.

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

### 5.1.4 Waste Management Sector-
**Priority Actions in the Waste Management Sector:**

- Conduct a survey to know the composition of urban wastes;
- Landfill/dump site management'
- Alternative waste-management strategies;
- Wastewater treatment;
- Aerobic treatment; and
- Recovery and utilization of methane from anaerobic digestion of wastewater or sludge.

**Implementation Strategy:**

The Ministry of Local Government and Rural Development will lead implementation of elements of Waste Management Action Plans by using the Municipal Councils countrywide and collaborating with the Ministries of Health and Sanitation, Energy and Water Resources, Youth and Sports.

### 5.1.5 Coastal Zone of Sierra Leone- Priority Actions -

- Improvement on the quality of topographic data for the Coastal Zones.
- Studies on Coastal erosion in Sierra Leone.
- Delineation of flood and erosion hazard areas.
- Strengthening of 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, EPA-SL, the Institute of Marine Biology and Oceanography, University of Sierra Leone, Disaster Management Department of the Office of National Security and the Maritime Administration of the Ministry of Transport and Aviation will implement these strategies.

### 5.1.6 Fisheries Sector: - Priority Actions

- Introduction of biological monitoring.
- Enforcement of fishing control measures in the country
- Promotion of aquaculture.

- Modification and strengthening of fisheries management policies and institutions.
- Strengthening and expansion of catchments.

**Implementation Strategy: -**

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

**5.1.7 Environment Sector: -**
**Priority Actions include:**

- conduct surveys to have: (i) the total amount of soda used in the country; (ii) data on activities relating to the consumption of halocarbons (HFC and PFC) and sulphur hexafluoride;
- conduct surveys to obtain: (i) handicrafts production of oil; (ii) the baking of bread through the number of bakeries and total consumption at national level.

**Implementation Strategy: -**

The Environment Protection Agency- Sierra Leone (EPA-SL) in collaboration with the relevant Institutions will lead implementation on this sector.

**5.1.8 Cross-Cutting Issues (Education, Training and Public Awareness, Research and Systematic Observations): -**
**Priority Actions on Cross Cutting Issues: -**

- Sensitization of political, economic and industrial decision makers with the aim of sensitizing national parliamentarians, members of government and executive of the administration as well as economic operators on climate change, the Kyoto convention and protocol: challenges and prospects, CDM: investment opportunities and prospects for national companies;
- Education and training of the civil society and technical executive on the preparation procedures of projects in the area of climate change, and funding procedures;
- Clean Development Mechanism and adaptation strategies and mitigation measures;
- Education, information and sensitization of producers on the effects of changes on their environment, the opportunities that the CDM offers, and adaptation strategies and mitigation measures;
- Education and training of school children and scholars on the adverse effects of climate change on the environment, mitigation and adaptation measures and the CDM;
- Setting up an information exchange operations center;
- Revitalization of websites;
- Setting up thematic networks on exchange and reflection;
- Development and (or) reinforcement of exchange programs between parties.

**Implementation Strategy**

The Ministry of Education, Science and Technology, Ministry of Information and Communications, the Universities (Freetown and Njala), NGOs, Drama groups, etc.

## Conclusions and Recommendations

### 5.2 Technology Transfer

#### 5.2.1 Introduction

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.

By its Decision 4/CP.7the COP adopted the framework for meaningful and effective actions to enhance the implementation of Article 4, para 5 of the Convention by increasing and improving the transfer of and access to environmentally sound technologies (ESTs) and know-how. The successful development and transfer of ESTs and know-how 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.

#### 5.2.2 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 and post Kyoto Protocol process.

#### 5.2.3 Activities Undertaken

Since 2003, the capacity of the task forces of the NCCC has been built through training workshops. These 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 UNDP, and the IPCC under the INC and SNC communications. The task forces of NCCC are, 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 the UNFCCC and GEF through UNDP. This has particularly improved access to global environment information and communication between the UNFCCC Focal Point. IPCC and other multilateral environment organizations.

The GEF has provided financial and technical resources to Sierra Leone to enable the Task Forces of the MEAs 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 EPA-SL which is the GEF Focal point is coordinating these activities. The NCCC will pay particular attention to the capacity development framework annexed to decision 2/CP-7 of the UNFCCC. The NCCC 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.

During the past 10 years. Sierra Leone has promoted and encouraged the shift to more environmentally friendly technologies based on the awareness of the consequences of environmental degradation after the war which lasted from 1990-2000s. The shift has been form fossil fuel to renewable (solar) energy. Penetration of solar energy technology is high in the Administrative (District and City councils), Health, Communication, Water Resources, Commercial and Residential sectors of the economy.

In the Health sector most of the facilities at the District Health Centre's are powered by solar-photo-voltaic technology. Telephone and telex facilities in the hinterland of the country are also powered by solar technology. Water lifting and supply systems are powered by diesel, and solar generators. The diesel generators are being replaced by solar generators because of reduced operational cost in addition to environmental benefits of reduced pollution. The penetration of wind energy is lower than solar energy due to lower wind speeds as one move further inland from the ocean. The commercial (mostly hotel) and residential sectors have also embraced solar technology through the use of Solar Home systems for lighting and heating. Penetration of solar systems in the residential sector is lower due to the attached initial cost of acquisition and installation of facilities. There is a potential move to the use of LPG for cooking in the residential sector to displace biomass (wood and charcoal) fuel although the issue of pricing is a major concern. 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.

### 5.2.4 Technology Transfer

Activities that need to be undertaken include, among others:

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

### 5.2.5 Activities undertaken

### 5.2.6 Activities to be undertaken

Activities that need to be undertaken include, among others:

- Improving the quality of activity data for future GHG inventory studies;
- Improving the quality of agricultural data for climate change impact analysis;
- Abating $CO_2$ emissions in the energy sector;
- Sequestering carbon and improving on the $CO_2$ sink base of the country; and

- Adapting to possible climate change effects on water resources, coastal zone and agriculture;

It is envisaged that the international community will select and fund these projects to allow Sierra Leone attain sustainable development whilst contributing effectively to global initiatives in addressing climate change.

## 5.3 Research and Systematic Observations

### 5.3.1 Introduction

The climate research aims to obtain well-founded statements on global climate development (trends and fluctuations), and on concomitant regional effects, including weather extremes.

### 5.3.2 Assessment of the Systematic Observation System and Information Dissemination

Climate Change science is new in most Least Developed Countries (LDCs). The capacities of such countries to undertake meaningful Climate Research is very limited due to data gap, the lack of necessary trained personnel in respective Climate Change related disciplines, the unavailability of relevant Climate Data collection platforms, public ignorance on most Climate related matters, lack of the required legislation to enforce Climate Change Mitigation options and very limited logistics that will facilitate these actives.

The capability of the Meteorological Department to cope with the task of weather monitoring, data collection, data analysis and storage was greatly affected by the war.

The picture is not different from that in the Hydrological, Marine or Agro MET Sectors.
There is a partial disconnection between various institutions on climate issues and the lack of necessary legislature has not put CC to its rightful place.

### 5.3.3 Sector Policy

The Meteorological Sector is the sole institution enacted by the government for the collection, analyses, dissemination and storage of meteorological data for the country.
The meteorological sector on behalf of the Sierra Leone government signed and ratified the United Nations Framework Convention on Climate Change (UNFCCC), as the country's clear manifestation of concern for climate change issues.

Sierra Leone is also a signatory to the ratification of the other two conventions of Desertification and Biodiversity both of the United Nations Environment Program (UNEP) and the World Meteorological Organization (WMO).

The main aim of the Global Observation System on Climate (GCOS) is to ultimately get in the long run a good network of systematic climate observation system the enhance Climate related scientist the necessary data for various investigation for the proper understanding of the climate for proper climate predictions.

### 5.3.4. The Capacity Building Needs

Least Developed Countries (LDCs) like Sierra Leone must filled out the wide data gap faced by African scientist and its impacts on the climate modeling capacities of Africa. Thus improving the systematic observation system of Sierra Leone will help address specific challenges faced by the country regarding:

1. The general observation of the present climate bringing out its inherent extreme events and variability
2. Getting the necessary information that will assist in the determination of climate change and its effect
3. The provision of observation that will help us determine the specific climate forcing caused by the specific Green House Gases present (GHGs) in the atmosphere of Sierra Leone.
4. The establishment of a good network of systematic observation will help to not only provide climate modelling data but also help to validate them and other models previously developed.
5. We can use these data from the observation to quantify the impact/effect of the perceive climate variability and climate change

In order to be able to manage data information and other activities the following capacity building needs must be addressed;

a. The provision of the necessary financial resources to key of the country charged with the responsibility of data collection such as the Meteorological Department and the Water Resource Department
b. The streamlining the roles of various state actors in the different engagements in climate investigations and activities
c. The provision of a structured institutional body charged with the implementation of systematic observation and research as Article 6 of the Convention hopes to address.
d. Enhancing the already existing structure for the enhancement of the exploitation of satellite data for climate studies and services.
e. The sensitization of the general public of Sierra Leone and other stakeholders on the climate issues at all levels ranging from local to central government.
f. The strengthening of the institutional capacity of both the data collection departments and the university for undertaking climate research.
g. The training of the relevant personnel of the various institutions for them to carry out their respective roles.
h. Enhance both the government and respective institutions in mainstreaming these activities in the governance structure of the country such as necessary legislation on water catchment areas, ready provision of the needed counterpart funding for the projects identified below
i. Enhancement of a permanent sustainable structure for systematic observation strategies and policies.
j. The harnessing of the socio-economic and meteorological data should also be complemented with the assimilation and management of the knowledge gained for the country's sustainable development

### 5.3.5 Plan for Systematic Observation

In Sierra Leone the need for **technology transfer** in the field of earth data collection cannot be over emphasized. This includes the hardware setup of the stations, the operating software and the necessary training of personnel in working with the supplied tools.

**The following observational and related activities are planned:**

### 5.3.6 Technical Projects

The following identified projects include: a) Network of Observation b) Research and Capacity Building

**A. Observation Networks**

1. It is necessary to strengthen the Network of Observations for measuring of Agro, Marine and Hydrological Meteorological Data sets together with that of the present Synoptic and Rainfall stations and the means for transmission of these data to relevant users either in the raw form or in the processed form that will enhanced action and planning for National Development (ND)
2. Reinstituting the Upper-Air (Altitude) data collection through the use of Radiosonde and Pilot Balloons for the Measurement of the various layers of average Temperatures, humidity, wind and pressures
3. Observation of Aerosols and its measurement in various parts of the country
4. Strengthening the Remote sensing capacity of the Meteorological/Hydrological Institutions through the use of Radar and Satellite data.
5. The initiation of Ozone observation in the country
6. Strengthening the assessment and monitoring of underground water measurement, and the country' Water Resources

**B. Research and Capacity Building**

1. Establishment of Network of Applied Meteorology and Climate Study with Higher Educational institution in the country and sub region.

2. Establishment of Network with Local Grassroots organizations and International Non-Governmental Organizations for the enhancement of development and use of Climate information and services.

3. Undertaking Various Climate Researches in our universities that will address different Climate Concerns for Development

4. Building the capacity of policy makers on Climate issues and legislation that will enhance compliance of the convention and its accompanying protocol(s)

Sensitization of the general public on Climate and Climate Change issues and the use of Climate Information and Services in National Development.

To support and complement the above activities, it is necessary to improve/rehabilitate or establish new monitoring systems such as the following:

**Upper Air Observation**

The rehabilitation of two upper air observations and provision of additional two in the remaining regions of south and north will support our quest to turnaround the MET Department's sparse data availability in upper air phenomena.

**The Monitoring of the Water Resources**

There were plans to fully gauge all the main rivers and catchment areas of the country. At each gauge site/station, the needed weather parameters of temperature and rainfall will also be measured. This will enhance the World Weather Watch (WWW) that will complement the basic climate observation data base of the country.

We hope to integrate these set of data collection for our sub regional grouping of the Mano River Union (MRU) States of Sierra Leone, Guinea and Liberia.

**GUAN Station Monitoring**

The World Meteorological Organization (WMO) setup the GUAN System as a component of the GCOS aerological network set up in each of the WMO six regions. The one for RA1 is set up in Niamey, Nairobi, Cairo and South Africa. States of each sub region usually assign personnel for short time attachments to these stations. The necessary training of Sierra Leonean will greatly enhance this collaboration among states in each RAs.

**Satellite and Aircraft monitoring System**

The country's meteorological Department uses the European Union Meteorological Satellite System (EUMETSAT). We have the PUMA and AMSED stations. The training of more personnel to handle these data for the respective service delivery is a dare need of the department especially when they have just recruited some 35 Weather Observers, 5 Meteorological Forecasters-in-training and 3 Pupil Meteorologists after a big gap created by retirement and long period of non-recruitment.
The integration of this with aircraft observation over our country will bridge the gap presently existing in this area.

**Surface Weather and Climate Observation System**

These are collected at our synoptic and CLIMAT stations established at some ten (10) sites at the moment though with some a little below standard.

The Spanish Government through the United Nations Development Programme (UNDP) and the World Meteorological Organization (WMO assisted the department's data collection platform by providing six s of the arts Automatic Weather Stations (AWSs). The United Kingdom Meteorological office (UK

MET Office) provided the technical assistance for the training of our personnel for the use and maintenance of the stations.

However the department still needs to increase its data collection platform for the expected service delivery. This will fill the gap of data collection platform of the Meteorological Department to re establish its data collection, analysis and achieving of these information and for highest quality services delivery to end-users.

The surface weather/climate observation system will therefore include:
The establishment of six (6) in the remaining university campuses and colleges throughout the country.

- The establishment of thirteen (13) automatic stations in each districts of the country to
- The training of the respective personnel to man these stations;

**Cloud Observation**

The rehabilitation of these stations together with the setting up of the remaining stations will greatly capacitate weather department.

**Rainfall Observation**

Each synoptic station measures rainfall. There were series of rainfall stations established all over the country totaling some eighty but that was as far back as 1975. Over the years some of them were not maintained and the war destroyed the rest.

**Atmospheric Data Collection**

WMO international data collection and dissemination mechanism is referred to as the Global Atmospheric Watch (GAW). There at the moment no component in either the GAW or GCOS for measuring the atmospheric composition and chemistry. The bridging of this gap will help us to contribute to our obligation of atmospheric chemical composition determination over our country.

**Observation of Greenhouse Gas Composition**

As mentioned above there is none at the moment but the setting up of such stations will help us to determine their respective concentrations in atmosphere above Sierra Leone. This will include Carbon Dioxide (CO2), Methane (CH4), water vapor and Ozone (O3). To **do** these, the collaboration with the university and other higher institutions is key here.

**Ozone Observation**

The presence and use of this layer in the stratosphere in the absorption of the high energy ultra violet (UV) radiation cannot be over emphasized. Thus the setting up of an ozone monitoring system will expand the sparse data collection on ozone around the globe.

**Aerosol Measurement**

The role played by aerosols in the atmosphere has long been documented and the Inter-Governmental Panel on Climate Change (IPCC) report of 1996. There is still the task of expanding the limited knowledge on the extent of its impact on the climate system. The establishment of monitoring stations for these parameters will greatly improve our understanding of their influence on the climate system. This will also be done with other line ministries and institutions like the water resource department, the university and other development partners.

### 5.3.7 Other constraints and gaps

The Sierra Leone meteorological department has not been giving the due supports needed in the carrying out its huge scheduled tasks. This is not due to neglect on the side of the government, but as an LDC, emerging from war, the hands of the government were too full for the limited resources available that some components have to be put on hold awaiting resources.

Thus the climatological, meteorological, hydrological, satellite data monitoring and use in service delivery have not been as expected though they are very necessary.
The small number of observation network could not allow us to rightly play our part in the WWW.

The following problems could therefore be summarized as follows:

1. **Country Level**

    a. Low level skilled manpower both in quality and quantity at all levels in the Meteorological Department and similar institutions.

    b. As a war affected country, with limited financial resources, the meeting of basic financial commitments have not been easily met

    c. The war destroyed the entire observation network including the meteorological radar in Freetown. The presence of infrastructure in these places is very limited.

    d. There is no sustainable research mechanism in most of the institution of higher learning. The various researchers are mostly donor driven and not based on the innate tendency of the researcher inner satisfaction. This has not produced the desired effect that country driven researches are supposed to give.

    e. The lack of coordination among various institutions keeps them far apart from each other and thus prevents the inter-disciplinary research that climate issues required.

    f. The high cost of meteorological equipment and present high cost of Sierra Leone telecommunication data transfer have compounded to the above problem.

g. Climate Change issues have not been extended to include the necessary human dimension needed to attract the needed attention and resources for investigation or streamlining the socio-economic, political and dynamic effects.

h. Article 6 of UNFCCC convention is a relatively new concept that the country is only now considering for full implementation.

**2. Regional Constraint**

a. There is no permanent coherent system for systematic data observation was a given standard has been set for various states compliance: eg, minimum number of synoptic stations each country should operate at any given time.

a. The absence of a reliably coordinated telecommunication network for the easy real-time transmission of data.

b. The countries operate individual radar and no network of such operation.

c. There is very low integration of weather/climate issues into policies and strategies of national development.

### 5.3.8 Priority Needs for Adaptation identified in the National Adaptation Programme of Action (NAPA)

Given the Low GHG emissions in LDCs and the high cost of mitigating actions, combined with the high vulnerability to climate change of LDCs, adaptation options/measures represent the highest priority in Sierra Leone. Adaptation actions at the local level can increase the resilience of the most vulnerable members of the country/communities. Thus the identified measures will seek to not only will reduce the impact of climate change but also address the urgent development needs of the most vulnerable population. The identified actions have provided the basis of the NAPA document. If implemented as planned, they will greatly reduce the adverse effect of climate change in the country. Once prepared, these adaptation options/activities are prioritized for implementation on the basis of an agreed set of criteria under the NAPA process.

### 5.3.9 Articulation of NAPA options in terms of Technological Options

This will include the cross-cutting activities that the Meteorological Department will do in collaboration with other institutions in addressing the adaptation needs to climate change.

**Table 5.1 Technological options in the NAPA**

| NAPA options | Development Sector of Concerned | Type of technology | Availability | Observation |
|---|---|---|---|---|
| Observation Network | Agriculture Water Resources | Real-time data transfer Complete data availability | Could start crop modeling Water resource mapping done | Farmers could get more yield |

| | | | | |
|---|---|---|---|---|
| | | and storage | | |
| Production and Dissemination of Agro/Hydro-Meteorological information | Agriculture/ Water Resources | Radio, TV, Internet and RANET | Technology developed by ACMAD and AGRHYMET | Coupling with community media network |
| Fight against some crop prone to climate-sensitive disease | Human health | The integration and use of the RANET System for issuing warnings in development planning | The management of both the rural and urban areas using the ACMAD/ AGRHYMET technology eg. AMSED crop and vegetation monitoring | The integration of Climate issues in the management of major endemic diseases |
| Extreme weather/climate events e.g. the dense haze of February, 2012 in the country | Human Health | The integration of clinical diagnosis of certain outbreak of diseases and the extreme weather events for future forecast | The Medical record management integrated into the weather data management. We mostly use the ACMAD/AGRHYMET technology | Medical Doctors and other practitioners working with the Meteorological department and the university |
| Popularization of animals and plant species with weather suitability | Agriculture and Livestock Production | Seeds resistant to Climate, Fight against parasites, promotion of crops adaptable to climate change as well as similar animal production | Work with MAFFS and Sierra Leone Agricultural Research Institutes (SLARI) of Njala and Rokpur | High economic gain and enhancement of Public research previously done in the country |

The mainstreaming of environmental issues into governance is a project funded by the European Union that will set up a coordinating office for climate change activities in collaboration with other line institutions both within and without the country.
The need to fast-track development and poverty reduction of the government Agenda for Change is about to end this year since it was a four years development plan. It is going to be replaced by the perceived Agenda for Prosperity which will possibly roll over some of the unfinished tasks.
We have therefore included the overall development of the meteorological and other climatic issue related institutions in this document in keeping with the government's concern for our climate system.

## 5.4 Education Training and Public Awareness

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.

Education plays a crucial role in the socio-economic development in any nation. Weather, climate and all other related environmental issues should be incorporated into the university curricula and treated to such depths as to reveal the consequences of anthropogenic activities on climate change. The necessary adaptation and mitigation measures should also be incorporated in the curricula.

### 5.4.1. Formal Education

The formal education system will play a pivotal role in mainstreaming Climate Change studies into our educational system. Currently, Climate Change studies are treated as subsections in subjects like Geography, Environmental Physics and Energy studies.

### 5.4.2 Informal Education

The Informal Education sector is less capacitated for climate change education. Thus should be treated as a universal problem and therefore be incorporated into the informal sector activities. 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 encouraged to participate in climate change activities. Mass media techniques such as video/television, radio, print media, traditional communicators and extension agents are already being used in well designed campaigns aimed at achieving favourable results on climate change related issues. These activities should be scaled up.

### 5.4.3. Training

A series of workshops and seminars was held by the Climate Change Office, 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. These trainings need to be formalised and scaled up.

### 5.4.4 Training on Assessment of Greenhouse Gas Mitigation Options.

An International Consultant/Trainer was recruited from the sub-region to provide services to GOSL/GEF/UNDP project on the development of the Second National Communications for Sierra Leone, with particular reference to training on Mitigation tools (LEAP, COMAP etc.). This training lasted for about five (5) days and consisted of lectures, discussions and hands on deck exercises. Data requirements for each software package were treated in some detail.

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 identify 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 options.
- Development and evaluation of policies, institutional arrangements and incentives necessary for the implementation of the cost-effective mitigation options;

The experts were able to easily identify data requirements for each software and the results of the analysis were reported in Chapter 3 of the National Initial Communications report.

The Consultant advised that the models for now should not be included in the report due to time constraints. They will hopefully be included in the 3nd Communication Report pending improvement in both quantitative and qualitative data.

### 5.4.5 Public Awareness

During the implementation of the SNC various studies, sensitization and public awareness campaigns were carried out by the project throughout the country. These campaigns took the form of workshops, seminars, panel discussions and question and answer sessions. These deliberations were mostly conducted in the lingua franca, Krio, with relevant translations depending on the type of audience. This encouraged members of grassroots communities to participate actively. The workshops and seminars were organised by the Local Councils and attended by Government Ministers, high level Government officials, representatives of NGOs, CBOs, farmers, teachers, students, Heads of Government , Civil Society Organisations, etc.

### 5.4.6 Development of sensitization materials to enhance public awareness of climate change.

Bill boards carrying messages related to Climate Change were erected at key sites in and outside the city.

### 5.4.7 Translation of the sensitization material into the various local languages.

Jingles and short skits highlighting the causes and effects of Climate Change were aired on both national and private radio stations nationwide.

As a sign of Government's continued commitment and support to the climate change process, his Excellency the Vice President of the Republic of Sierra Leone launched the project early in 2010. The Resident Representative of the United Nations Development Programme, Government Ministers and other important dignitaries graced the occasion.

Three national status reports were produced detailing Sierra Leone's achievements and aspirations in implementing the UNFCCC to COP 15, 16 and 17 respectively.

One of The main constraints in enhancing public awareness is the inadequate human and institutional capacity within the NCC to develop sensitization materials to enhance public awareness on climate change.

In order to address many issues highlighted previously the following response actions have been proposed:

1. The education of the policy and legislative authorities on the climate change issues for possible policy formulation.
2. The education of the media on climate change and how to report on them.
3. The training of the civil Society and local government authorities on the adverse effect of climate change, its contributing actions and how to disseminate the climate change information to the grassroots people.
4. The formulation of policy on CDM undertakings and tailoring development paths through renewable energy resources.
5. The use of the above in most mitigation and adaptation measures.
6. Diversification of our educational system to involve the school children in knowledge on climate and environmental matters.
7. The creation of the secretariat and website that will serve as a clearing house for information sharing on climate change.
8. Collaboration among parties on common issues in addressing climate change matters.
9. Getting producers involve in using alternative environmentally friendly products. E.g., using re-circled paper for packaging instead of plastics.
10. Development of a Newsletter and Website for greater dissemination of information to the general public. With the installation of Internet facilities and training provided to the members of the NCC the development of a Website could be achieved in the very near future.

### 5.4.8 Conclusion

Article 6 of the convention is specific in addressing the capacity needs especially the LDCs in Training, Education (awareness rising) and research. The country has various laws and policies on some matters of concern in environmental matters, but there was formulated outside the convention. There is need to mainstream all these isolated ordnances into a more coherent one that will help us to address some of the key issues of our mitigation and adaptation measures to climate change events.

The policy formulation should consider the grassroots and most venerable members of our society but in terms of information and response measures in addition to the technical capacity building. Thus the target should among others include: a) Policy and legislative officials, b) Educational institution, c) economic sectors such as the producers and d) the civil society.

The achievement of such goal should include programmes of actions that involve the following:

1. Targeting the politicians and other policy makers for their proper understanding of both the convention and its accompanying protocols or actions.
2. The inclusion in the national development plan by the above the green economy where CDM pathways are selected for alternative development.
3. The training of both the media and civil society on key issues of the convention and how to disseminate this information to the local communities.
4. Capacitating various institutions to adequately contribute to addressing climate change information collection, processing and dissemination

5. Involving the school children in the training on extreme climate issues and needed response measures. We can even involve them in the collection of climate data by establishing weather stations in schools
6. Creating a link between institutions to work jointly in both research and response measures in climate change.
7. The development of platform for exchange of views between parties and other development partners.

# Chapter 6

## Constraints and Gaps, and Related Financial, Technical and Capacity Needs

### 6.0 Financial, Technical and Capacity Needs

### 6.1 Introduction - Implementation Strategy of the UNFCCC

For Sierra Leone, Climate Change is viewed as a development path. Hence, the UNFCCC is being implemented with sustainable development guiding all future activities and programmes. Based on the identified Mitigation and Adaptation measures in the preceding chapters of the National Communication, the following strategy was developed for the future implementation of the Convention in Sierra Leone. The successful implementation of the strategy and the Convention depend on the availability of the human and financial capacities in the country, and the required International Cooperation.

The major area of difficulty is in the economic analysis and presentation of the cost of the activities and their implementation. The first task therefore is the finalisation of the Plan. The collaborating institutions are constrained by inadequate human and institutional capacity.

The specific needs to implement the sectors plans are given below.
The identified financial resources will need to be met by Government and Donors contributions.

### 6.2 Capacity Building Needs

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 Change Office under the Ministry of Transport and Aviation and the EPA of the Sierra Leone is limited to coordination of national communications. Thus, it is a high priority in establishing and strengthening of the capacity of the national climate secretariat to enable the effective participation in the implementation of the Convention. 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 objectives 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 Task Forces has been developed to execute climate change scenario development tools and biophysical models (DSSAT, WATBAL) in the assessment of vulnerability (impact 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 through workshops. The experts need to be trained on modeling at institutions of higher learning through fellowships and/or internships. There is need for the leading global climate modeling groups to collaborate with the Sierra Leone in building the capacity of members of the Task Forces in the development and execution of climate change and biophysical models. The collaborative efforts should include the transfer of the model technology Sierra Leoneans.

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 (less than 50 years) and the meteorological and hydrological networks established in the late 1970s and 1980s 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 variables to model and simulate climate and climate change. At the current rate of deterioration of the observation networks in Sierra Leone, the future contribution of data for national, regional and global climate change simulation will be limited. It is thus a priority in Sierra Leone to reverse this deterioration of the observation networks and improve the data and information availability. Improvement will entail acquisition of additional automatic recording equipment and establishment of hydrological networks and their expansion to get more representative coverage of the country.

## 6.3 Information on Financial Resources and Technical Support Provided for the preparation of the SNC

### The Global Environment Facility

The Global Environment Facility (GEF) provides financial assistance to non-Annex I Parties to prepare their national communications under guidance from the COP. This financing is made available under projects called 'enabling activities for the preparation of Sierra Leone's Second National communciation to the united nations framework convention on climate change (UNFCCC)' which are implemented through the United Nations Development Programme (UNDP).

Sierra Leone received up to $405,000 from the GEF. For Second National Communications and $ 30,000 from Govt of Sierra Leone in kind.

### The Secretariat of the United Nations Framework Convention on Climate Change

One function of the UNFCCC Secretariat is to facilitate the provision of financial and technical assistance to non-Annex I Parties as they prepare national communications.

### The UNDP/UNEP National Communications Support Programme

The National Communications Support Programme (NCSP) is a NDP/UNEP project, funded by the GEF, which provides technical and policy support to non-Annex I Parties for the preparation of national communications. The NCSP is based at the UNDP office in New York. The governments of Switzerland and the USA have co-financed NCSP activities. During its second phase (2005-2010), the NCSP is sustaining capacity-building efforts through technical and policy support, knowledge management, and communications and outreach. The NCSP offers an integrated package of technical and policy support to enhance capacity in non-Annex I countries and to better meet the needs of countries, such as targeted, in-depth and issue-specific workshops and technical backstopping. The NCSP also promotes the quality and comprehensiveness of national communications and the timeliness of their submission, and assists non-Annex I Parties to better incorporate climate change into national development policies.

### Other Resources

Mainstreaming Adaptation to Climate Change into National Development Planning. In Sierra Leone, the European Union intends to implement a project, *Mainstreaming Adaptation to Climate Change into National Development Planning*, which aimed to integrate climate change and variability into the agendas of the tourism, agriculture, fisheries and infrastructure sectors.

## 6.4 Information on Implemented Adaptation Measures and/ or priority areas for Adaptation

The following adaptation measures from Sierra Leone NAPA are currently on-going.

**UNDP-UNEP project "**Strengthening Climate Information and Early Warning Systems in Africa for Climate Resilient Development and Adaptation to Climate Change"

**Ongoing with UNDP** Establishment of National Early Warning System.

**Ongoing with UNDP, IFAD and AfDB** Rehabilitation & Reconstruction of meteorological/climate Monitoring stations throughout the country.

**Ongoing with UNDP** Capacity building of the Meteorological Department through training of personnel for the country's adaptation to climate change.

**Ongoing with UNDP and EU Project** Sensitization and awareness raising campaigns on climate change impacts on women relating to the three conventions of biodiversity, desertification and UNFCCC.

**Ongoing with IFAD project.** Development of Inland Valley Swamps for Rice Production in the Moyamba District.

**Ongoing with UNDP** Institutional Strengthening of the Water Resources Sector in Sierra Leone.

**Ongoing with UNDP** Promotion of Rain Water Harvesting and Development of An Integrated Management System for Fresh Water Bodies.

**Priority areas for Adaptation**

Some priority areas from the NAPA include not restricted to:-

Promotion of the use of renewable energy (Solar Energy) in Sierra Leone and improvement of energy efficiency and conservation of energy resources

Rehabilitation of degraded coastal habitats in the Northern Province/Kambia district.

Health sector projects

## 6.5 Priority Needs for Adaptation identified in the National Adaptation Programme of Action (NAPA)

Given the Low GHG emissions in LDCs and the high cost of mitigating actions, combined with the high vulnerability to climate change of LDCs, adaptation options/measures represent the highest priority in Sierra Leone. Adaptation actions at the local level can increase the resilience of the most vulnerable members of the country/communities. Thus the identified measures will seek to not only will reduce the impact of climate change but also address the urgent development needs of the most vulnerable population. The identified actions have provided the basis of the NAPA document. If implemented as planned, they will greatly reduce the adverse effect of climate change in the country. Once prepared, these adaptation options/activities are prioritized for implementation on the basis of an agreed set of criteria under the NAPA process.

### 6.6. The Selection of ranking of the priority of activities of the NAPA

The document was prepared with series of workshops where the input of the people at all levels formed the core items/activities selected. It was validated by the people at the various levels from urban to remote rural villages in order to ensure that their concerns were all articulated.

The following guidelines for the NAPA preparation was therefore very helpful

1. The quantification of the level of the adverse effect of climate change that are linked to the vulnerable indicated previously selected or formulated
2. It must reduce poverty in order to increase their adaptation to the adverse effect of Climate Change.
3. The actions should be mainstreamed into the government development plans for collective action.
4. It must have synergy with other multilateral agreements.
5. We must also consider the cost-effectiveness of the adaptation activity.

The development of the first NAPA was in line with the country's Poverty Reduction Strategy Paper (PSRP) 1 and its successor PRSP 2 specifically code-named the Agenda for Change. Their preparations involve various stakeholders in All Works of Life (AWOL).

The following criteria were used for the documentation of the concerns.

1. The perceived impact on groups together with the most venerable group and resources.
2. The impact on the economy of the country as well as on the poor people
3. It has to reduce/avoid the damages or losses of the poor people
4. It must be in line with multilateral environmental agreements that the country has signed.

We have used here the people's choice method where various groups worked together to come out with their list and the statistical ranking done on them to categorize them for implementation.

**Table 6.1 - Prioritized Adaptation options and their ranking according to NAPA Classification[14]**

| Project Number | Name of Option and Option Description | Rank |
|---|---|---|
| **Technical Projects on Network of Observation and capacity building** | | |
| Project 1 | Strengthening the assessment and monitoring of underground water measurement, and the country' Water Resources | 1 |
| Project 2 | Establishment of Network of Applied Meteorology and Climate Study with Higher Educational institution in the country and sub region | 2 |
| Project 3 | Establishment of Network with Local Grassroots organizations, International Non-Governmental Organizations line ministries for the enhancement of development and use of Climate information and services. | 5 |

| | | |
|---|---|---|
| Project 4 | Undertaking Various Climate Researches in our universities that will address different Climate Concerns for Development | 6 |
| Project 5 | Building the capacity of policy makers on Climate issues and legislation that will enhance compliance of the convention and its accompanying protocol(s) | 7 |
| Project 6 | Capacity building for the activities of Article 6 coordination team | 8 |
| Project 7 | Sensitization of the general public on Climate and Climate Change issues and the use of Climate Information and Services in National Development | 9 |
| Project 8 | Observation of Aerosols and its measurement in various parts of the country | 10 |
| Project 9 | The initiation of Ozone observation in the country | 11 |

## 6.7 Information on Projects for Financing

### 6.7.1 Proposed Pilot Projects

The proposed projects are some of the mitigation and adaptation undertakings that have been developed in accordance with the priorities of the national strategic framework and development plans. They have been divided into two categories:

1. Technical Projects on Network of Observation and
2. Technical Projects on Research and Capacity Building

They are given as attachment or annex to this report

## 6.8. Capacity Building Needs

## 6.9. Shortcomings, Constraints, and Priority Needs

The Agenda for Change document together with this present Second National Communication brought the focus on Climate Change effects. This led to the creation of the Disaster Management Department (DMD) under the Office of National Security (ONS) which is supervised by the Vice President. During the past years, weather/climate disasters such as flooding (resulting in fatalities and crop damage) on the one hand and shortage of water at the GUMA Dam (GUMA supply water to the City of Freetown) This show the importance that extreme events have on and the willingness for collaborative actions to address some of the perceived effect through mitigation and adaptation.

Despite this effort, the limited resources of the government in the post war reconstruction have made some of these vital issues to shelf level. Thus the following constraints need attention which some of the projects will address if implemented.

1. The concept of Climate Change is new. Many do not understand the issues (even some so called educated men) and as such, some stakeholders first of all need to be educated before using them to sensitize the general public.
2. As a new concept, there is inadequate staff knowledgeable in the science of climate change.
3. The media alone is inadequate in this venture due to the partial coverage of most media houses
4. In Sierra Leone, more that 60% of the people are illiterate and therefore need other means of information dissemination.
5. The high cost of such learning materials hinders learning.
6. The resources put into Climate Change issues is not commensurate with the task that needs to be addressed.
7. Most players act in isolation as various Ministries are responsible for different aspects of Climate Change. For example, the Forestry Man does not see the link of meteorological observation to his line of work.
8. The civil society organizations have not shown the due interest in the implementation of the UNFCCC as is done for Health and Education.
9. There is problem with information dissemination both within the country and between similar institutions in the sub region.
10. The funding mechanism of UNFCCC (especially GEF) and other multilateral organization are so complex that access to them has not been easy for most countries. E.g. very few countries have accessed the LDC special Adaptation fund, Somalia representative at the June, 2012 Article 6 planning workshop in Bonn said that they have never assessed GEF yearly grant.
11. In most LDCs the cost of media service (from newspaper to TV through radio and advertisement) is very high which prevent the use though regrettably powerful.

ANNEX 1: **Pilot Projects on Technical Assistance on Systematic Observation and capacity Building**

## Briefs of technical Projects on Network of Observation
## Project 1a

Those strengthening the Network of Observations for measuring of Agro, Marine And Hydrological Meteorological Data sets and the means for transmission of these data to relevant users either in the raw form or in the processed form that will enhanced action and planning for National Development (ND)

| | |
|---|---|
| **Project Background Justification** | The Meteorological Department used to have eleven (11) synoptic stations, three (3) Agro Met stations and two (2) upper air stations all over the country for monitoring of the country's weather/climate phenomena. There were plans to open five (5) more synoptic stations in other to get an even distribution of stations in consonance with WMO improved standard of 1994.<br>However, during the war almost all of the existing stations were destroyed. At the moment only five (5) are operational (Lungi Air Port, Bonthe, Bo, Freetown and Makeni), with none of the upper air functional.<br>In order to fully monitor and contribute to the proper monitoring of the weather and climate capability of the country to positively contribute to the provision of better service<br>to end users, a good network of meteorological stations fully equipped to adequately monitor the parameters responsible for initiating and propagating the weather/ climate change is therefore very imperative. The Sierra Leone government is expected to establish the two upper air stations at Lungi and Daru as local contribution apart from the payment of the salaries of these staffs.<br>The Spanish Government through the United Nations Development Programme (UNDP) and the World Meteorological Organisation (WMO), assisted the department's data collection platform by providing six state of the arts Automatic Weather Stations (AWSs).<br>The United Kingdom Meteorological office (UK MET Office) provided the technical assistance for the training of our personnel for the use and maintenance of the stations.<br>These stations have been successfully installed at Freetown {Fourah Bay College (FBC)}, Lungi Airport, Njala University College, Kenema, Rokpur and Kabala.<br>However the department still needs to increase its data collection platform for the expected service delivery.<br>The present project is therefore to fill the gap of data collection platform of the Meteorological Department to re establish its data collection, analysis and achieving of these information and for highest quality services delivery to end-users.<br>To meet this objective, the following specific objectives will be achieved by the end of the project phase: |

| | |
|---|---|
| | 1. The establishment of six(6) weather stations in the remaining university campuses and colleges throughout the country i.e. at: MMCET-Goderich; Eastern Polytechnic, Kenema; Port Loko Teachers College; Makeni Teachers College; Bo Campus and Bunumbu Campus of eastern polytechnics.<br>2. The establishment of thirteen (13) automatic stations in each districts of the country o help enhance the department's contribution to Agriculture and food security activities and other end users in order to give a full coverage of station network representative of WMO standard.<br>3. The provision of adequate equipment and logistics for each of these stations to function properly.<br>4. The provision the necessary tools and office logistics for the collection, analysis, storage and dissemination to end-users of weather/climate data and information.<br>5. To help the department to digitalize its remaining stock of climatic data collected over the years by employing five (5) data entry clerks and one data verifying officer. |
| ***Executing Agency*** | Meteorological Department |
| **Possible Partners** | Water Resource Department, Fourah Bay College Hydrology Department, Environment Department, Faculty of Environmental Science, Njala University, Guma Valley Water Company, Sierra Leone Water Company (SLWACO) |
| **Project Objectives** | The main objective of the Project is to establish and improve the Meteorological/Climatic dater collection, data analysis and storage of the country in order for the department to carry out its obligations of better service provision to end-users that will safe guard lives and property |
| **Expected Outcomes** | 1. The Presence of the various station for their respective data collection<br>2. The functioning of these station<br>3. The availability of the data collected from these stations for use in service delivery |
| **Project Activities** | There are three (3) Components to this project viz: (a) establishment of these stations to meet WMO standard (b) The provision of tools and equipment for these stations and (c) provision of logistics for the running of the established stations which include those for: data analysis, dissemination to end users and data storage. The components involve are outlined in the detail budget. |
| **Risks and Sustainability** | Some of the risks involve are the remoteness of some of these stations which make them venerable to thieves especially at night when the observer is off duty. The involvement of the local people |

| | |
|---|---|
| | of the areas in the provision of security for the said stations will clear this risk. The sustainability of the project is certain as after the provision of the various components mentioned the simple task of maintenance and daily administrative cost of these stations could be met from that of the department's annual allocation from the central government |
| **Project Demonstrative Value** | The Project can be replicated to other parts of the country with time by establishing more station in other parts of the country in order to increase the data collection base of the department. This will empowered the country to meet up with the challenges of both national and international climate date collection, management and dissemination to end users. |
| **Project Financing and Duration:** | The Total cost of the project is ***Five hundred and Three Thousand, Eight Hundred and Seventy-five United State dollars*** **(US$ 503,875)** and the total duration of the project is ***Three*** **(3)** ***Years*** after which, the Sierra Leone Meteorological Department will fully take over the stations. |

**Project 1b**

***Reconstruction of Hydro-Meteorological/Climate Monitoring stations on the nine (9) main rivers throughout the country***

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| ***Project Background Justification*** | The Meteorological Department used to works with the water resource Department in hydrological data collection. However for the past twenty or so years, there have been no organized hydrological data collection systems in the country. As WMO covers both Meteorological and Hydrological services, we hope to partnership with other institutions in the country that are involved in the water resource management and studies in establishment that much needed data collection that their respective work depends upon. There were plans to fully gauge all the main rivers and catchment areas of the country. At each gauge site/station, the needed weather parameters of temperature and rainfall will also be measured |
| ***Executing Agency*** | Meteorological Department. |
| ***Possible Partners*** | Water Resource Department, Fourah Bay College Hydrology Department, Environment Department, Faculty of Environmental Science, Njala University, Guma Valley Water Company, Sierra Leone Water Company (SALWACO) |
| **Project Objectives** | The main objective of the Project is to establish Hydro-Meteorological/Climatic dater collection, throughout the country and its accompanying data analysis and storage facility for the |

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| | department to carry out its obligations towards the Climate Change Mitigation project.<br>To meet this objective, the following specific objectives will be achieved by the end of the project phase of two (2) years:<br>1. The establishment of six (27) Hydro-Meteorological stations (three on each ricer with one at the top, middle and bottom end of the river) at Rokel, Little and grate Scarcise, Mano, Sawa, Moa, Wanjah, Mano.<br>3. The provision of adequate equipment and logistics for each of these stations to function properly.<br>4. The provision the necessary tools and office logistics for the collection, analysis, storage and dissemination to end-users of weather/climate data and information. |
| **Expected Results** | (a) Four (4) old Hydro-MET, and two (2) Marine- MET Stations Rehabilitated<br><br>(b) Ten (10) new Hydro-MET stations and four (4) Marine-MET Stations opened to meet WMO standard<br><br>(c) Availability of tools and equipment for these stations together with necessary logistics for the running of the established stations which include those for: data analysis, dissemination to end users and data storage.<br><br>1. The Presence of the various station for their respective data collection<br>2. The functioning of these station<br>3. The availability of the data collected for use in service delivery |
| **Activities** | A) Selection of sites for the location of the stations on the various rivers (9x3=27 Sites)<br>B) Selection of sites on the five catchment areas (5x1=5 sites)<br>C) Selection of sites for the five Marine stations (5x1=5 sites)<br>Site Preparation including the construction of concert slabs, cutting of trees etc.<br><br>Purchase<br>1. Equipment and transportation to project site.<br>2. Installation of the station equipment.<br>3. Deployment of Hydro/Marine Meteorological Personnel at each of their respective station for routine observation and recording. |
| **Risks and Sustainability** | Some of the risks involve are the remoteness of some of the stations which make them venerable to thieves. The involvement of the local people of the areas in the provision of security for the said stations will clear this risk. The sustainability of the project is certain as after the provision of the various components mentioned |

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| | the simple task of maintenance and daily administrative cost of these stations could be met from that of each of the respective departments' annual allocation from the central government. |
| **Stakeholders Participation** | The reluctance of some personnel to work in some isolated areas made the department to come out with the idea of recruiting the locals of the area as station meteorological, Hydro-MET Agro-MET and Marine-MET and observers. For some stations joint data collection will be done such as the rainfall stations in conjunction with the ministry of Agriculture, Water Resource Development and the Education Ministry.<br>The Climate model runs of climate date will be done jointly with other institution such as the Environment department, Statistics Sierra Leone, and the University etc |
| **Project Duration** | **Three (3) Years** |

**Project 2**

***Reinstituting the Upper-Air (Altitude) data collection through the establishment of Radiosonde and Pilot Balloons observations***

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| **Project Justification** | There used to be upper air observations in the country but there none at the moment. The use of upper air data in the monitoring of understanding of our atmosphere cannot be overestimated. This will support our quest to turnaround the MET Department's sparse data availability in upper air phenomena. |
| **Objectives** | 1. To ensure national coverage in connect with upper air temperature, wind, pressure humidity and related data reports.<br>2. To be able to determine the current climate characteristics using the release of two daily pilot balloons at each of the two (2) station at 1200Z and 0000Z.<br>3. To Use the Data collected to validate model products and use it to make forecast for daily operation and future climate perditions. |
| **Expected Results** | 1. Two upper air observation stations established at Lungi and Daru/Kailahun.<br>2. Functional upper air station available.<br>3. Upper air Data now available on the country. |
| **Activities** | 1. Site preparation/construction.<br>2. Obtaining the various equipments.<br>3. Installation of equipment.<br>4. Training of station operation personnel.<br>5. Deployment of station operation personnel and start of routine observation. |
| **Project Cost** | **$ 300,000** |
| **Project Duration** | **Three (3) Years** |

**Project 3**

***Observation of Aerosols and its measurement in various parts of the country***

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| **Project Justification** | 1) The air quality measurement is very poor in the country and the quality of air has various health factors. aerosols in the atmosphere alters the natural dynamic processes of the atmosphere in terms of chemical composition and reactions.<br>2) It has been acknowledged in the various assessments by the Inter-Governmental Panel on Climate Change (IPCC) the unequivocal important roles played by the aerosols in the atmosphere. |
| **Objectives** | 1) For Sierra Leone to meet its obligation by playing active role in the implementation of aerosol measurement<br>2) To establish Four (4) aerosol measuring/assessment stations at Freetown (the industrial area), one at each of the mining sites of Sierra Rutile, London Mining and African Minerals |
| **Expected Results** | 1. Aerosols measuring stations established and running<br>2. Aerosols data available on the country and collected in the country<br>3. The use of the country aerosols information in the provision of various climate services. |
| **Activities** | 1. Site Selection and preparation/construction<br>2. Obtaining the various aerosol equipments<br>3. Installation of equipment<br>4. Training of station operation personnel.<br>5. Deployment of station operation personnel and start of routine observation<br>6. Transmission of data MET and other end users |
| **Project Cost** | **$250,000** |
| **Project Duration** | **Two (2) Years** |

**Project 4**

***Strengthening the Remote sensing ability of the Meteorological/Hydrological Institutions through the use of Radar and Satellite data.***

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| **Project Justification** | The country's only radar was owned by the meteorological department and dates back as far as 1980 purchased during the hosting in Sierra Leone of the then Organization of African Unity (OAU). This radar was used to forecast approaching storm, in search and rescues operations.<br><br>It must be noted that Sierra Leone is bordered by over one third (1/3) by the Atlantic Ocean and equally littered by some nine big rivers that are used for fishing, travel and other purposes.<br><br>The possession of this instrument will help the institutions of Meteorology, Marine Time Administration, Port Authority, Disaster Management and the Boat Transport Owners' and Fishermen among others |
| Objectives | 1) To replaced the much needed storm detecting radar that the war destroyed to provide that much needed function that will address some the adverse |

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| | effects of climate change.<br>2) To use remote sensing techniques in search and rescue operation |
| **Expected Results** | 1. The availability of functional radar in Sierra Leone.<br>2. The availability of radar and satellite information and services to various end-users addressing weather and climate concerns<br>3. The availability of trained personnel capable of operating the station. |
| **Activities** | 1. The training of personnel in radar meteorology<br>2. Obtaining the radar and related satellite data reception equipment equipments<br>3. Installation of equipment<br>4. Training of station operation personnel.<br>5. Deployment of station operation personnel and start of routine observation<br>6. Transmission of data to MET and other end users expected time frame |
| **Project Cost** | **$ 2,500,000** |
| **Project Duration** | **Two (2) Years** |

**Project 5**

***The initiation of Ozone observation in the country***

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| **Project Justification** | Following forth assessment by the IPCC, the important role played by the atmospheric ozone in regional climatic variations was highly acknowledged. |
| **Objectives** | 1. Support the Global Ozone data collection through the creation of two (2) ozone concentration measuring stations in Sierra Leone.<br>2. Use the data collected together with Africa Monitoring of the Environment for Sustainable Development (AMSED) and the PUMA satellite data to help in providing the necessary information on climate forcing resulting from Green House Gases. |
| **Expected Results** | 1. The availability of two ozone monitoring stations in Sierra Leone<br>2. The easy access to the data and services from these stations to end-users<br>3. The availability of trained and capable personnel to man the stations |
| **Activities** | 1. Setting up of the station<br>2. The training of required personnel fot the management of the station.<br>3. Regular ozone observation |
| **Project Cost** | **$ 400,000** |
| **Project Duration** | **Three (3) years** |

**Project 6**

***Strengthening the assessment and monitoring of underground water measurement, and the country' Water Resources***

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| **Project** | Various studies have been done on the waters of Sierra Leone but none |

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| **Justification** | comprehensive enough to give a holistic picture of situation that is reliable enough in climate mitigation/adaptation and prediction. No proper assessment and monitoring have been done on ground water and the water resources of the country. In most rural areas the people on bole holes as their main sources of water for drinking, irrigation and the like.<br>It must be noted that the president raise the concern of the drying of a river near Makeni that has never dried up expect for the past two or three years. This negatively affected the agricultural practices of the people that depended on this water.<br>He mentioned that for agriculture to thrive, the knowledge of the country's water resources was therefore very necessary.<br>This will complement the current activity by the water resource department and other stake holders. |
| **Objective** | 1. To characterize the current state of our hydrologic system from availability of current data, assessment tools.<br>2. To use analytic tools, measurements and Modeling<br>3. To provide information that would promote prospective information and discussions on the mode of extraction and exploitation of the resources.<br>4. To contribute to the improvement of the living standard of the people through the provision of Hydrologic information in real time for protection of life and property. |
| **Expected Result** | 1. The availability analyzed country data on Piezometry and Hydro chemical situation of the country<br>2. The availability of specific quantitative and qualitative monitoring of networks for sensitive aquifers<br>3. Piezometric data regularly collected<br>4. Pervious non-functional piezometers rehabilitated<br>5. Creation of five new piezometric data collection network<br>6. The availability of some fifteen trained for handling operations<br>7. Four (4) stations are equipped with Meteosat data collection platforms become operational<br>8. Processed Hydro-climatic date such as flow rate, rainfall, water level) is available<br>9. Technical notes on flooding and related hazards published biannually.<br>10. Quarterly and annual reports produced on the state of the country's water resources.<br>11. Instrument calibration centre established<br>12. Computers for the data processing purchased |
| **Activities** | 1. The construction and leveling piesometers and other station preparation.<br>2. All piezometric, and hydrochemical data from 1990 to 2010 collected in the country and analysed.<br>3. The rehabilitation of non-operational Piezometers nationwide<br>4. The installation five new piezometric data collection centers<br>5. Acquisition of all equipment and logistics for the project<br>6. The training of six (6) technical officers<br>7. The collection of data by the necessary personnel |

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| | 8. Processing of these data<br>9. Publication of the various reports<br>10. Calibration of the various instruments for proper measurement. |
| **Project Cost** | **$ 800,000** |
| **Project Duration** | **Two (2) Years** |

**B) Briefs of technical Projects on Research and Capacity Building**

**Project 7**

***Establishment of Network of Applied Meteorology and Climate Study with Higher Educational institution in the country and sub region.***

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| **Project Justification** | Only Njala University offer courses in environmental sciences and even these are not structured according to World Meteorological Organization (WMO) standards. We spend huge sum of money training personnel abroad on courses that our university institutions can easily accommodate.<br>This project will therefore build the capacity of our higher institutions for them to capably train personnel in the field of meteorology and climate change studies. |
| **Objective** | 1. It will capacitate our higher educational institution for the provision of necessary training for incoming Meteorology/hydrological and Climate Studies.<br>2. Government will spend less in the local training of Climate scientists as against the high cost of external training (Such savings can be used to carry out other development programs for poverty alleviation.<br>3. The shortage of trained personnel where expectorate were imported will be minimized<br>4. The country will now have store of trained personnel to capably handle respective responsibilities in most aspects of Climate data collection, processing and related services |
| **Expected Results** | 1. Our Higher Educational institutions capacitated to train the necessary personnel<br>2. Most Training of our personnel now available at our universities<br>3. Less money spent on training of personnel<br>4. Shortage of trained personnel reduced considerably |
| **Activities** | 1. Provision of external scholarship for the specialization of some members of various educational institutions for training of trainers' courses in Climate and related studies.<br>2. Provision of basic training materials and logistics to these institutions<br>3. The training in these institutions of the various interested students and others sent by various line ministries and organizations |
| **Project Cost** | **$650,000** |
| **Project Duration** | **Three (3) Years** |

**Project 8**

***Establishment of Network with Local Grassroots organizations, International Non-Governmental Organizations line ministries for the enhancement of development and use of Climate information and services.***

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| **Project Justification** | Climate Change effect affects to the greatest extent the most venerable from women and children to the rural farmers. These are most of the times remote from the discussion makers, the educational effects and implementation.<br>They can be reached only through the Media and grass root organizations (local CBOs), and other NGOs or related institutions.<br>There is need for the creation of networking with these institutions for the easy dissemination of climate change related information for development.<br>This ensure the all inclusiveness in either climate change adaptation or mitigation |
| **Objectives** | 1. To Identify at least one CBO per chiefdom for the network<br>2. To selection the media houses that can enhance the whole country coverage<br>3. Training of the network members on types of climate information, methods of climate information dissemination and other relative activities. |
| **Expected Results** | 1. Some 200 CBOs, 24 NGOs, 24 radio stations, 200 Schools and a 24 news papers identified<br>2. The network members trained as desired for climate change information dissemination.<br>3. Training and information materials developed |
| **Activities** | The respective activities done to achieve the above outcomes |
| **Project Cost** | **$200,000** |
| **Project Duration** | **Two (2) Years** |

**Project 9**

***Undertaking Various Climate Researches in our universities that will address different Climate Concerns for Development***

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| **Project Justification** | Climate Change science is new and very poorly researched in most LDCs especially Sierra Leone. Educational level and standard have greatly improved in the country where young people mostly go beyond the first degree in career oriented discipline. This opens the door to various research options and investigations.<br>Some of such thesis could be tailored to address various climate studies such as the effect of last February dense haze that lasted the longest in the country's past thirty-five (35) years. This was a key course of concern where the meteorological forecast office was called upon to give daily update and professional advice. The hospitals were requested to keep the records of all eye disease and breathing or cardiac problems reported within the eight days period of that Hazy Air Mass (HAM). Researchers are needed for such analysis.<br>There are host of such climate research out there especially in agriculture, health, water, transportation, environment and you name it.<br>Thus the universities could also be capacitated to use their research department to undertake climate modeling in association with other |

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| | established organizations such as ACMAD and AGRHYMET in Niamey, Niger. |
| **Objectives** | 1. To capacitate our universities to be able to undertake climate studies research such as climate and crop modeling.<br>2. To provide research new areas for those students that have interest in climate studies<br>3. To contribute as a country to the increase in knowledge in the field of climate change<br>4. To be able to provide scientific explanations and solutions to some hazardous climate events that may affect the country or sub-region. |
| **Expected Results** | 1. Our universities capable to do some climate studies research.<br>2. Students able to do some climate studies researches in Sierra Leone<br>3. We can provide answers and/or solutions to some extreme climate events directly affecting us or likely to impact on us.<br>4. Adaptation and mitigation options provided in such research works. |
| **Activities** | 1. Provision of logistics and training to our universities that will capacitate them to undertake climate studies research.<br>2. The training of various research students for higher degrees in climate studies.<br>3. Working with various institutions and organization in addressing some concerns of extreme climate events and change. |
| **Project Cost** | **$ 600,000** |
| **Project Duration** | **Three (3) years** |

**Project 10**

***Building the capacity of policy makers on Climate issues and legislation that will enhance compliance of the convention and its accompanying protocol(s)***

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| **Project Justification** | It is our anthropogenic activities that induces global warming and hence climate change and its unpleasant accompanying effects or consequences. We therefore need to control some those human activities that tends to have negative effect on the Climate Systems.<br>This needs in the first place getting the law and other policy makers to understand the issues of climate change and its adverse effects.<br>Once adequately sensitized, they are then capacitated through the provision of necessary logistics to make policies and laws that will mitigate those activities that negatively impact on our climate system. This also requires the mainstreaming of climate concern into the governance structure of Sierra Leone. |
| **Objectives** | 1. To conduct series of workshops and training for law and other policy makers on climate change issues.<br>2. To provide necessary logistics to these trainees that will enhance their capacity to legislate on climate change issues and also empowered to implement them. |
| **Expected Results** | 1. Law and other policy makers adequately knowledgeable on climate change issues.<br>2. Laws enacted, policies formulated to address climate change issues. |

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| | 3. The relevant state institution empowered to implement the policies and laws on climate change issues. |
| **Activities** | 1. Selection of participants for the workshops and training.<br>2. Conducting the training workshops for these participants.<br>3. Providing the logistics for the enactment of law and policies that will address climate change issues.<br>4. Empowering relevant state institution to be able to implement these policies and laws on climate change issues |
| **Project Cost** | **$300,000** |
| **Project Duration** | **Two (2) Years** |

**Project 11**

***Sensitization of the general public on Climate and Climate Change issues and the use of Climate Information and Services in National Development***

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| **Project Justification** | It is true that some of the activities of general public or citizenry's within Sierra Leone will either impact directly or indirectly on climate change and our development. The indiscriminate bush burning and cutting down of trees together with atmospheric pollution are recipes for global warming and climate change together with its adverse effects.<br>Most people are ignorant about such actions and consequences including even some so-called educated people. The need for mass campaign and sensitization on climate change issues is therefore imperative.<br>The development of programs that offers alternative livelihoods to those whose daily lives will be affected is also essential. These are made to be parts of the Government development plan in the Agenda for Change or is it Agenda for Prosperity? |
| **Objectives** | 1. To organize Regional, Districts and Chiefdom workshops and sensitization on climate change issues.<br>2. To develop training materials and methods respectively ranging from bill boards/hand bills to jingle/drama on the above issues.<br>3. To identify those livelihoods that will be affected by the legislation and policies on climate change issues.<br>4. To undertake activities that will address the damages caused such as deforestation<br>5. To design programmes that will provide alternative livelihoods to those affected.<br>6. To mainstream objective 4 in the government development plan. |
| **Expected Results** | 1. The majority of people in Sierra Leone now know about climate change.<br>2. The drastic reduction of wide fires and deforestation noticed in the most parts of the country.<br>3. The obeying of environmental and related laws and policies.<br>4. Projects developed to address the damages done such as reforestation.<br>5. Projects developed that will provide alternative livelihoods to those affected by the climate change.<br>6. The inclusion of the above projects in the government development |

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| | agenda. |
| **Activities** | 1. Selection of participants for the workshops and training.<br>2. Conducting the training workshops for these participants at regional, district and chiefdom levels throughout the country.<br>3. The production of relevant training and educational materials on Climate Change issues<br>4. Providing the logistics for the inclusion of projects developed to address the identified together with the alternative livelihood programmes.<br>5. Empowering relevant state institution to be able to implement these policies and laws on climate change issues participants |
| **Project Cost** | **$500,000** |
| **Project Duration** | **Three (3) Years** |

**Project 12**
***Capacity building for the activities of Article 6 coordination team***

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| **Project Justification** | Sierra Leone belongs to the Least Developed Country Grouping in UNFCCC.<br>1. Article 6 was specifically drafted to address the low adaptive capacity in terms of Education, Training and Research. At the just concluded workshop in Bonn 19-21 June which was called to provide a work plan for the implementation of Article6, it seen that there is need for setting up of an institutional framework for the implementation of Article 6. To effectively coordinate these activities, there is need to capacitate this focal point institution for carrying out the needed coordination that is required. |
| **Objectives** | 1. To organize Regional, Districts and Chiefdom workshops and sensitization on climate change work plan for the implementation of Article 6<br>2. To coordinate the activities of the various players for the implementation of Article 6<br>3. To provide support for the institutional setup for the implementation of Article 6<br>4. To undertake activities that will promote the implementation of Article 6.<br>5. To mainstream objectives of Article 6 in the government development plan. |
| **Expected Results** | 1. The different players of climate change will be able to address the implementation of Article 6.<br>2. A proper functional institution for Article 6 implementation set up.<br>3. Various programmes done for the implementation of Article 6. |
| **Activities** | 1. Setting up the coordination office for Article 6.<br>2. Coordinating the activities of the various players of Climate Change activities dealing with Article 6.<br>3. Mainstreaming Article 6 activities in all climate change activities in the |

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| | country.<br>4. Providing the logistics for the inclusion of projects developed to address the identified programmes of Article 6.<br>5. Empowering relevant state institution to be able to implement these policies and laws on Article 6 on climate change issues participants |
| **Project Cost** | **$300,000** |
| **Project Duration** | **Three (3) Years** |

## ANNEX 2: Sample of the DETAILED BUDGET of the first two projects under the systematic observation

**Project 1a: *Strengthening the Network of Observations for measuring of Agro, Marine and Hydrological Meteorological Data sets and the means for transmission of these data to relevant users either in the raw form or in the processed form that will enhanced action and planning for National Development (ND)***

**Detailed Budget**

| No | Item Description | Qty | Unit Cost (Le'000)$ | Total Cost (Le'000) | Total Cost ($ USD) |
|---|---|---|---|---|---|
| 1) Reopening of Meteorological Stations in Universities/Colleges<br>1 stations each at MMCET-Gogerich; Eastern Polytech-Kenema; Port Loko Teachers College; Makeni Teachers College; Bo Campus, Bunumbu | | | | | |
| i) | Standard Instruments, | 8 | 48,000 | 384,000 | 96,000 |
| ii) | Solar Panel and Battery | 8 | 6,400 | 51,200 | 12,800 |
| iii) | Stevenson Screen | 8 | 1,000 | 8,000 | 2,000 |
| 2) Agricultural Stations at main food crop production areas<br>1 Automatic stations each at -Mambolo; Makali; Bakuma; Kamakwie; Lunsar; Tormabum; Newton; Sulima; Mattru; Tongo Field; Gardorhun; Koindu- | | | | | |
| i) | Standard automatic Agro-Met Station, | 13 | 28,000 | 364,000 | 89,000 |
| ii) | Solar Panel and Battery and other consumables | 13 | 6,000 | 78,000 | 19,500 |
| iii) | Ranet system for Community weather information system | 4 | 10,000 | 40,000 | 10,000 |
| iv) | SSB and Radio for Community Weather information System | 21 | 20,000 | 420,000 | 105,000 |
| v) | Motor bikes for Station Monitoring and Supervision | 4 | 10,000 | 40,000 | 10,000 |
| vi) | Utility vehicle for transport of | 1 | 40,000 | | 10,000 |

| | | | | | |
|---|---|---|---|---|---|
| | routine equipment inspection and/maintenance | | | 40,000 | |
| Vii | 5 Data Entry Secretary for input from manual to digital for 6months | 30 | 1,000 | 30,000 | 7,500 |
| Viii | Data Sorting, and verifying officer 1 person for 6 months | 6 | 1,200 | 7,200 | 1,800 |
| ix | Lap top | 1 | 4,200 | 4,800 | 1,200 |
| 3) Meteorological Forecast Office, Lungi | | | | | |
| a) | Instruments | | | | |
| i) | Digital barometer, 1 Back up and 1 Calibration | 2 | 28,000 | 54,000 | 14,000 |
| ii) | Anemometer for Wind speed and Direction | 1 | 8,800 | 8,800 | 2,200 |
| iii) | Transmitsmeter for visibility assessment | 1 | 10,000 | 10,000 | 2,500 |
| iv) | Autographic, Barograph and Charts | 1 | 3,200 | 3,200 | 800 |
| v) | Sunshine Recorder and Cards for 2 years | 1 Yr | 11,200 | 11,200 | 2,800 |
| vi) | Rain gauge- manual and Automatic | 2 | 14,000 | 48,000 | 7,000 |
| vi) | Ranet System | 2 | 24,000 | 48,000 | 12000 |
| vii) | SADIS System for Aviation Meteorological Forecast | 1 | 42,000 | 42,000 | 13,000 |
| viii) | 1 set desk top & Lap top computer, Printer, photocopier | 1 | 1 | 12,000 | 12,000 |
| ix) | SSB Set and internet facility for data transition to end-user | 1 | 1 | 5,000 | 5,000 |
| b) | Consumables | | | | |
| I) | Papers, pens, markers, recording charts etc | 2 | 3,000 | 6,000 | 1,500 |
| ii) | Floppy disc, flash drive etc | 4 | 2,000 | 8,000 | 2,000 |
| iii) | Printer ink and cartridges | 2 | 3,500 | 7,000 | 1,750 |
| c) | Air Conditioner to protect the instruments in the office | 1 | 2,500 | 2,500 | 650 |
| d) | Office Space Building for the data processing at Lungi, Freetown and Bo | 3 | 6,000 | 18,000 | 4,500 |
| Meteorological Head quarter | | | | | |
| a) | Office logistics | | | | |
| i) | computers for data entry | 4 | 2,500 | 10,000 | 2,500 |
| ii) | Scanner | 1 | 1,500 | 1,500 | 375 |

| | | | | | |
|---|---|---|---|---|---|
| iii) | Printer | 1 | 2,200 | 2,200 | 550 |
| iv) | iv) Projector | 1 | 3,500 | 3,500 | 875 |
| v) | Digital camera | 1 | 500 | 500 | 125 |
| A | TV set | 1 | 1,500 | 1,500 | 375 |
| B | V-sat modem for Lungi forecast office and SLBC | 2 | 2,000 | 32,000 | 8,000 |
| C | Video recorder with multiple channel | 1 | 800 | 800 | 200 |
| D | One set computer for editing presentation | 1 | 10,000 | 10,000 | 2,500 |
| E | Set of Furniture for above | 1 | 1,000 | 1,000 | 2,500 |
| F | C-D rom for recording broadcast | 10pkts | 500 | 5,000 | 1,250 |
| G | Flash drives for storage of broadcast for reference | 10 | 250 | 2,500 | 625 |
| H | Video Camera | 1 | ,800 | ,800 | 2,200 |
| I | Flip Chart Stand | 1 | 00 | 500 | 125 |
| J | Installation of the v-sat | 1 | 00 | 800 | 200 |
| K | Training of two MET personnel in Kenya on TV presentation (Air fare, lodging, food stipend etc) | 2 | 40,000 | 40,000 | 10,000 |
| **2** | **Consumables for the sets already supplied** | | | | |
| A | Laser Jet cartridge for the Photocopier, printer/scanner | 5 | 450 | 2,250 | 5,625 |
| B | Transport for transportation of personnel, routine supervision, utility and administrative duties.<br>One jeep assigned to MET from UNDP/other Un agencies<br>One Toyota Hillux or Land Rover purchase for the purpose<br>One pickup van | -<br>1<br>1<br>1 | -<br>28,000<br>112,000 | -<br>128,000<br>12,000 | -<br>32,000<br>28,000 |
| C | Motor bike for the station supervision by the MET superintendent ( Victor bike) | 4 | 8,000 | 32,000 | 8,000 |
| D | Fuel for bike and jeep- Contribution by MET Dept | - | - | - | - |
| E | Creation of Web Site for MET Department and one year payment | 1 | 10,000 | 10,000 | 2,500 |
| F | Four internet modem and one year subscription | 4 | 7,000 | 28,000 | 7,000 |
| **H** | **GRAND TOTAL** | | | | **567,875** |

**National/Counterpart funding for 1a)**

| No | Item Description | Qty | Unit Cost (Le'000)$ | Total Cost (Le'000) | Total Cost ($ USD) |
|---|---|---|---|---|---|
| 1 | Personnel monthly payment of salary to the various personnel at the observatories and data processing centers for three years | 50 | 18,000 | 900,000 | 225,000 |
| 2 | Running cost for the transports, four (4) bikes and three (3) vehicles for three years | 4<br>3 | 16,200<br>32,400 | 64,800<br>97,200 | 16,200<br>24,300 |
| 3 | Miscellaneous | | | 17,200 | 4,300 |
| **4** | **Total** | | | | **269,800** |

**Project 1b) Reconstruction of Hydro-Meteorological/Climate Monitoring stations on the nine (9) main rivers throughout the country**

| No | Item Description | Qty | Unit Cost (Le'000) | Total Cost (Le'000) | Total Cost ($ USD) |
|---|---|---|---|---|---|
| 1 | Site inspection for five personnel for five days<br>a) Transport<br>b) DSA for five days for 5 | <br>5<br>25 | <br>200<br>250 | <br>1,000<br>6,250 | <br>250<br>1,562.50 |
| 2 | Site preparation<br>a) Hydromet Station Sites<br>b) Marine Station Sites | <br>32<br>5 | <br>8,000<br>10,000 | <br>256,000<br>50,000 | <br>64,000<br>12,500 |
| 3 | Station Observation Equipment<br>a) Hydro-Met equipment<br>b) Marine-Met | <br><br>27<br>5 | <br><br>60,000<br>80,000 | <br><br>1,620,000<br>400,000 | <br><br>405,000<br>100,000 |
| 4 | Station running cost for one year | 37 | 10,000 | 370,000 | 92,500 |
| **5** | **Sub Total** | | | **2,703,250** | **621,436.78** |
| **6** | **Grand Total for 1a) and 1b)** | | | | **1,189,311.78** |

**National/Counterpart funding for 1b)**

| No | Item Description | Qty | Unit Cost (Le'000) | Total Cost (Le'000) | Total Cost ($ USD) |
|---|---|---|---|---|---|
| 1 | Personnel monthly payment of salary to the various personnel at the observatories and data processing centers for three years | **52** | **18,000** | **936,000** | **234,000** |
| 2 | Running cost for the transports, four (4) bikes and three (3) vehicles for three years | None as the one quoted above can be here simultaneously | | | |
| **3** | **Miscellaneous** | | | **93,600** | **23,400** |
| **4** | **Total** | | | | **257,250** |

| | | |
|---|---|---|
| **5** | **Grand Total for 1a) and 1b)** | **527,050** |

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