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FOREWORD

Ghana has been working with the global community in finding solutions to problems that threatens the very existence of humankind on the earth. It is against this background, that Ghana signed the United Nations Framework Convention on Climate Change (UNFCCC) at the Rio de Janeiro Earth Summit in June 1992, after the Convention was adopted on 9 May 1992. The climate Convention entered into force globally on 21 March, 1994 and specifically for Ghana on 5 December 1995 after ratification on 6 September 1995.

There is clear evidence that the potential negative impacts of climate change are immense, and Ghana is particularly vulnerable due to lack of capacity to undertake adaptive measures to address environmental problems and socio-economic costs of climate change. These include climate change associated health problems, climate induced disruption of agricultural systems, flooding of coastal areas which are already undergoing erosion and low operating water level of the only hydro-generating dam in the country, (which produces 80% of national electricity supply), as a result of reduced levels of precipitation.

Apart from addressing Ghana's commitment to the UNFCCC as a Party, the preparation of this initial national communication also emphasizes Ghana's preparedness to join efforts with the global community to avert the climate change threat.

Notwithstanding the lack of accurate and reliable data that confronted the preparation of the initial national communication, this document puts together both desk-top and field evidence in a coherent way. Evidently the gaps identified in the data sources should strengthen the country to improve on the next communication.

This initial national communication, therefore, is intended specifically to highlight the nation's efforts towards sustainable development and to re-emphasize the support Ghana needs if it is to fully participate in the climate debate and contribute meaningfully and effectively towards finding solutions to a global problem.

The preparation of this document has undoubtedly contributed to capacity building in the country. It is hoped that if the necessary resources are made available for the implementation of some of the programmes identified in this document, the nation could further be strengthened and empowered to pursue sustainable development pathways. The implementation of these programmes will in no doubt, bring out policies that will ensure the adoption and use of climate friendly technologies and ultimately lead to the achievement of the ultimate objective of the Convention.

Hon. Cletus Avoka
Minister, Ministry of Environment, Science and Technology
December, 2000

LIST OF ACRONYMS

ACTS	-	African Centre for Technology Studies
AIJ	-	Activities Implemented Jointly
AVVA	-	Aerial Videotape-assisted Vulnerability Assessment
COBs	-	Community Based Organizations
CDM	-	Clean Development Mechanism
CEN	-	Compliance and Enforcement Network
CEPS	-	Customs Excise and Preventive Service
CH_4	-	Methane
CII	-	Country Implementing Institution
CO_2	-	Carbon Dioxide
COMAP	-	Comprehensive Mitigation Analysis Process
COP	-	Conference of Parties
CROPWAT	-	Computer Program for Calculating Crop Water Requirements and Irrigation Requirements from Climatic and Crop Data
CSIR	-	Centre for Scientific & Industrial Research
CWG	-	Country Working Group
DANIDA	-	Danish International Development Agency
DAs	-	District Assemblies
DEMCs	-	District Environmental Management Committees
DOC	-	Degradable Organic Carbon
DSSAT	-	
ECG	-	Electricity Company of Ghana
EIA	-	Environmental Impact Assessment
EISD	-	Environmental Information System Development
EMP	-	Environmental Management Plan
ENSO	-	El-Nino/Southern Oscillations
EPA	-	Environmental Protection Agency
EPC	-	Environmental Protection Council
ERP	-	Economic Recovery Program
FAO	-	Food and Agricultural Organization
FCCC	-	Framework Convention on Climate Change
FID	-	Factory Inspectorate Department
FOB	-	Free On Board
GAMA	-	Greater Accra Metropolitan Area
GCM	-	Global Circulation Model
GDP	-	Gross Domestic Product
GEF	-	Global Environmental Facility
GERMP	-	Ghana Environmental Resource Management Project
GHG	-	Greenhouse Gas
Gg	-	Gigagrams
GIDA	-	Ghana Irrigation Development Authority
GIS	-	Geographic Information Systems
GNP	-	Gross National Product
GWh	-	Gigawatt hour
GWP	-	Global Warming Potential
ha	-	hectre
HADCM2	-	Hardly Centre Model 2

HFZ	-	High Forest Zone
IBSNAT	-	International Benchmark Sites Network for Agrotechnology Transfer
IDA	-	International Development Agency
IPCC	-	Intergovernmental Panel on Climate Change
IVM	-	Institute of Environmental Studies, Vrije Universitiet, Amsterdam
JI	-	Joint Implementation
ktC	-	kilo-ton Carbon
LPG	-	Liquefied Petroleum Gas
LUCF	-	Land Use Change and Forestry
LUCS	-	Land Use and Carbon Sequestration
MAGICC	-	Model for Assessment of Greenhouse Gas Induced Climate Change
MJ	-	Megajoule
MOP	-	Meeting of Parties
MSD	-	Meteorological Service Department
MT	-	Metric tons
MW	-	Megawatts
N_2O	-	Nitrous Oxide
NADMO	-	National District Management Organization
NEAP	-	National Environmental Action Plan
NFED	-	Non-Formal Education Division of Ministry of Education
NFWP	-	National Forest & Wildlife Policy
NGL	-	Natural Gas Liquid
NGOs	-	Non-governmental Organization
OECD	-	Organization for Economic Co-operation & Development
R & D	-	Research and Development
RFO	-	Residual Fuel Oil
RSAU	-	Remote Sensing Applications Unit
SAP	-	Structural Adjustment Program
SCENGEN	-	Scenario Generator
SCM	-	Simple Climate Model
SEI	-	Stockholm Environmental Institute
SWDSs	-	Solid Waste Disposal Sites
tB	-	ton Biomass
TCPD	-	Town & Country Planning Department
TUC	-	Timber Utilization Contract
UKHI	-	UK Meteorological Office High Resolution Model
UKTR	-	UK Meteorological Office Transient Model
UNDP	-	United Nations Development Program
UNFCCC	-	United Nations Framework Convention on Climate Change
VALCO	-	Volta Aluminum Company
WEAP	-	Water Evaluation and Application Model
WHO	-	World Health Organization
WRI	-	Water Research Institute
WWW	-	Waste Water Treatment

EXECUTIVE SUMMARY

▪ NATIONAL OVERVIEW

Ghana lies on the south central coast of West Africa between latitudes 4.5^0N and 11.5^0N and longitude 3.5^oW and 1.3^oE. It shares a common border with the Republic of Togo on the east, Burkina Faso on the north and la Cote d'Ivoire on the west respectively. Ghana covers an average area of 238,539 square kilometers. Extensive water bodies including the Lakes Volta and Bosomtwe occupy 3,275 square kilometers while seasonally flooded lakes occupy another 23,350 square kilometers. The territorial waters extend 200 nautical miles out to sea.

The country's population is estimated at 19.7 million (1999) and is believed to be growing at a rate between 2.8 and 3.0 percent per annum. The birth rate is estimated at 39 per thousand (1999) while the death rate is estimated at 10 per thousand (1999). The rate of infant mortality is approximately 66 per thousand life births while the overall life expectancy is 59 years (1999). The total fertility rate within the period 1996 to 1999 is estimated as 6.0.

All the major rivers in Ghana flow into the sea (see figure 2.4). The only area of internal drainage is found around Lake Bosomtwe, where only streams flow from the surrounding highlands into the lake. The river valleys show diverse characteristics. The valleys of all the major rivers are bordered by terraces showing the former width and height of the rivers. Whilst some of the valleys are guided in their direction by relief (Morago river for example flows east-west along the foot of the Gambaga escarpment) or by structure.

The two main sources of water supply for the rivers are rainfall and spring. In areas with single rainfall maximum as in the north, the rivers are intermittent. However, in areas with high and well distributed rainfall within the year, the rivers flow throughout the year.

Temperatures throughout the country are typically high. The mean annual temperature is generally above 24ºC, a consequence of the low latitude position of Ghana and the absence of high altitude areas. Average figures range between 24 and 30^0C although temperatures ranging from 18 to 40ºC or more are common in the southern and northern parts respectively. Spatial variability of temperature is experienced in terms of the diurnal and annual ranges as a result of distance from the modifying influence of the sea breeze.

Generally rainfall in Ghana decreases from south to north. The wettest area is the extreme southwest where annual rainfall is about 2000mm. In the extreme north, the annual rainfall is less than 1100mm. The driest area is the wedgelike strip from east of Sekondi-Takoradi, extending eastward up to 40km where the annual rainfall is about 750mm. The dry conditions in the southeastern coastal strip are anomalous and are the cause of important differences in ecology and landuse from the rest of the country.

Ghana is classified as a developing country with a per capita income GDP of US$ 390 (1996). Agriculture and livestock constitute the mainstay of Ghana's economy, accounting for 25.4% of GDP in 1996. Although cocoa is perhaps the country's best known crop, other food crops and livestock are by far the most important contributors to agricultural output and alone make up around 25% of GDP (1996).

Agriculture and livestock employs 55% of the economically active population. It is predominantly small holder, traditional and rain-fed, with 85% of the country's 1.8 million farms being smaller than 2 hectares. Only about 12% of Ghana's land area (28, 680km^2) is classified as arable or permanently cropped land. Cocoa is the main cash crop and is grown on 40% of the cropped land. It accounts for about 75% of agricultural exports. Other commercially important tree crops are oil palm, coconut palm, rubber, kola and robusta coffee.

The strong dependence on agriculture for economic development is of great concern with respect to potential climatic changes. Since almost all the national agricultural production is based on rainfall, the country's agricultural output is directly influenced by weather patterns. During periods of severe drought crop production and livestock herds decline quite significantly. The severe food shortage experienced in the country in the early 1980's is a clear testimony of the dependence of the country's agriculture on climate change.

▪ INVENTORY OF GREENHOUSE GASES

Obligation under the UNFCCC

The national greenhouse gas inventories has been prepared to meet Ghana's obligation under Article 4.1 paragraph (a) of the United Nations Framework Convention on Climate Change (UNFCCC). The Article commits all Parties, taking into account their common but differentiated responsibilities and their specific national and regional development priorities, objectives and circumstance, to develop, and periodically update national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies. The Article further obligates Parties to publish and make available the national inventories of anthropogenic emissions by sources and removals by sinks to the Conference of the Parties in accordance with Article 12 of the Convention.

Meeting Ghana's Obligation

Ghana, a signatory to the UNFCCC, accordingly undertook country study of greenhouse gas inventories and analysis for the year 1990 to 1993 under Climate and Africa Project conducted by the erstwhile Environmental Protection Council (EPC), Ghana, in collaboration with the African Center for Technology Studies (ACTS) and Stockholm Environment Institute (SEI). The study was published as Country Report of Ghana for the African Conference on Policy Options and Responses to Climate Change (December 1994).

The preliminary study in 1990 considered GHG emissions by sources namely: Energy, Industry, Agriculture and Waste Sectors. The study did not include Land Use Change and Forestry (LUCF), and thus did not estimate net carbon dioxide removal by sinks. The present GHG inventories cover the period 1990 – 1996 and was undertaken within the framework of the GEF/UNDP Climate Change Capacity Building Project (RAF/GA/93).

The economic sectors or GHG sources of emissions and removal by sinks considered in the inventory are Energy, Industrial processes, Agriculture, Land Use Change and Forestry (LUCF), and Waste. The major greenhouse gases reported are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) in accordance with the guidelines annex to decision 10/COP 2 for developing country Parties

The progress on national greenhouse gas inventory work was greatly facilitated by the national inventory seminar/workshop held for the inventory country working group (CWG) within the framework of the Climate Change Capacity Building Project. The Environmental Protection Agency, the country implementing institution (CII) for the project co-ordinated the workshop with technical assistance provided by Environment and Development in the Third World (ENDA-TW). The inventory results were reviewed at the CWG meetings and also at a national seminar involving all relevant institutions, NGOs, and other stakeholders.

Inventory Results

The summary of the results of the national greenhouse gas inventories covering sources and removals by sinks from relevant sectors for the period of 1990-1996 are presented in Figures 1, 2, 3 and 4. The carbon dioxide equivalent (CO_2 eqv.) has been estimated based on global warming potential (GWP) of CO_2 (1), CH_4 (24.5), and N_2O (320). The GWP represents the different capacities of GHGs for absorbing long-wave radiation, thus their radioactive forcing

The IPCC worksheets, given the detailed activity data and emission factors, for the five sectors studied have been put together as a separate volume - Ghana's Initial National Communication, Annex I.

The inventory results indicate that carbon dioxide accounts for the largest share of Ghana's greenhouse gas emissions by sources. However, carbon sinks in forested and afforested lands offset the total CO_2 emissions thus making the country a net CO_2 removal by sinks. During the period 1990-1996, CO_2, CH_4, and N_2O emissions by sources increased by 6.6%, 14.7%, and 12% respectively. The contribution of the reported greenhouse gases to annual national emissions for the period 1990-1996 is depicted in Figures 2.

Although the total methane emissions is lower than CO_2 emissions, the CO_2 equivalent of CH_4 is about 2-3 times higher than CO_2, assuming global warming potential of 24.5 for CH_4 (see Figure 2). Methane emissions are largely due to agriculture and biomass burning for energy. As shown in Figure 5, both sectors account for 91% of the total emissions in 1994. The contribution of solid waste disposal sites is currently very low because they are largely unmanaged shallow sites with very low methane emissions potential.

Nitrous oxide is emitted in much smaller amounts than CO_2 and CH_4 and it contributes 6.8% of the total CO_2 equivalent emissions for 1994 (Figure 6). The main source of N_2O emissions is agriculture which accounts for 65%, while woody biomass combustion contributed 27% of the total nitrous oxide emissions of 3.07Gg (1994).

Overall, Ghana has total net CO_2 removals over the period of 1990 - 1996. However there was a significant decline of about 49% from 1990 to 1996 due principally to diminished of CO_2 removals by woody biomass stocks. The decrease in CO_2 uptake is the result of high increase in fuel wood and charcoal production to meet over 75% of heating and cooking energy demand for a population growing at about 3% over the period. In addition, CO_2 emissions from fuel combustion sources has grown steadily after the drop in 1991.

Figure 1 Total net CO_2 equivalent emissions by sources and removal by sinks for the period 1990-1996

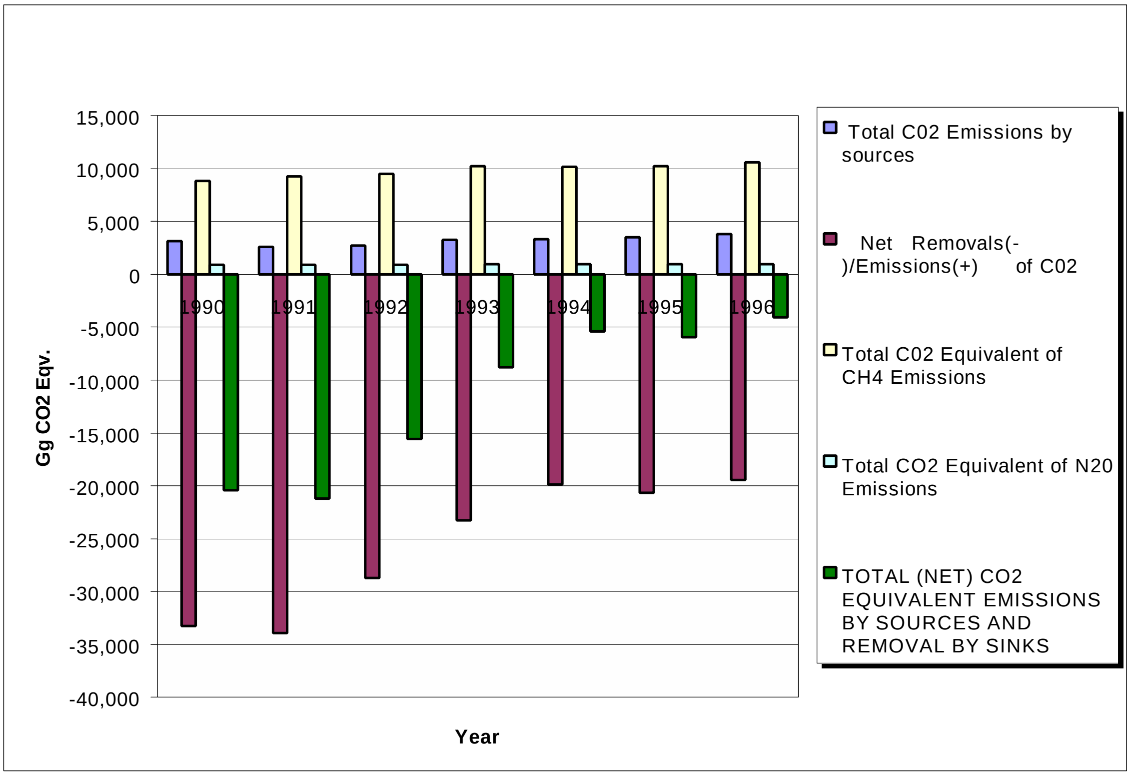


Figure 2 Contribution of various greenhouse gases to annual emissions for the period 1990-1996 (Gg CO_2 Equivalent)

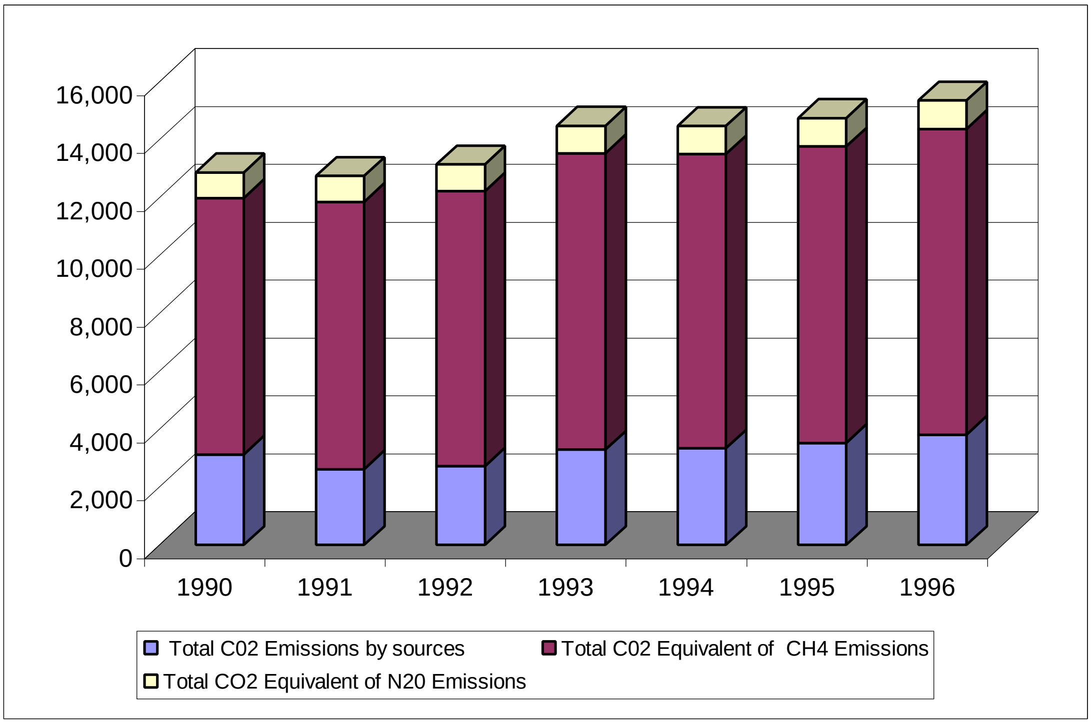


Figure 3 Sectoral Contribution of CO_2 emissions for the base year 1994

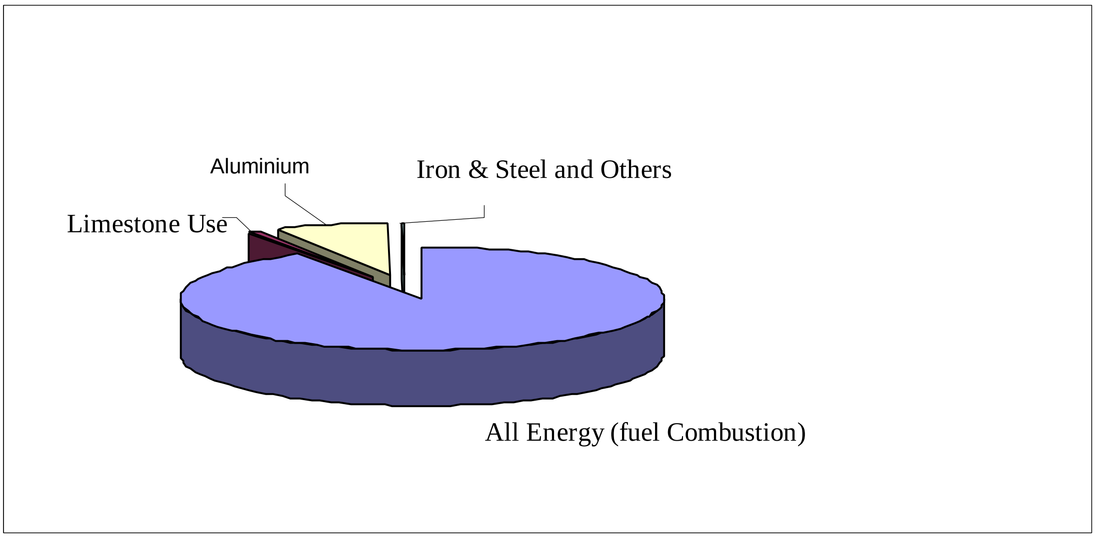


Figure 4 Contribution CO_2, CH_4, and N_2O to Total GHG Emissions by Sources, 1990-1996 (Gg)

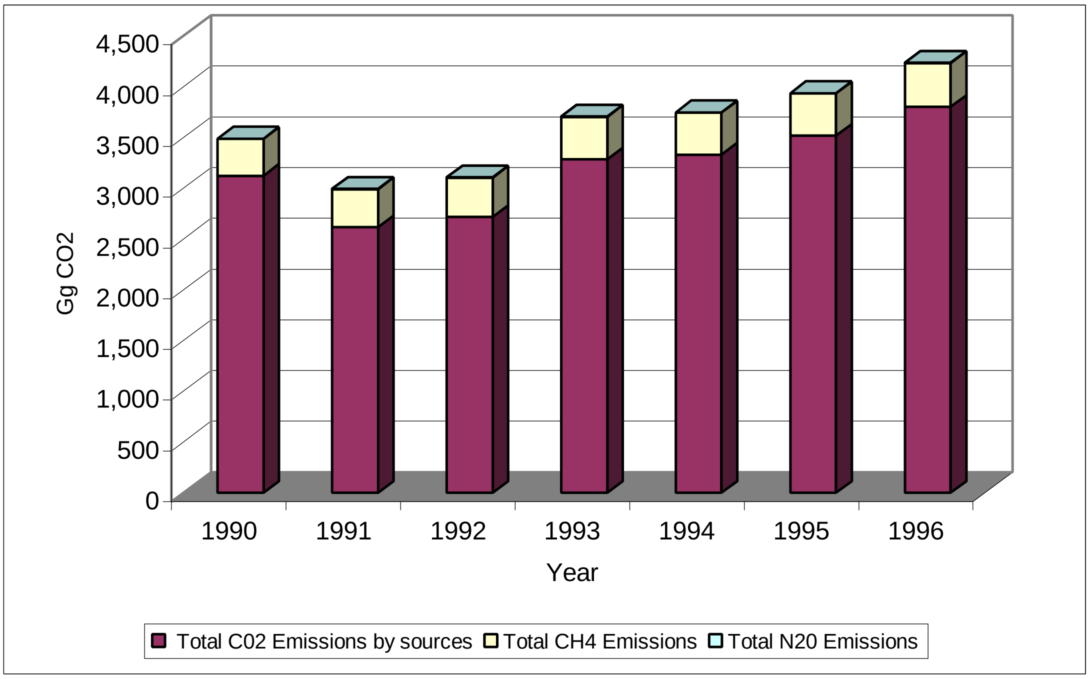


Figure 5 Sectoral contribution of CH_4 emissions for the base year 1994.

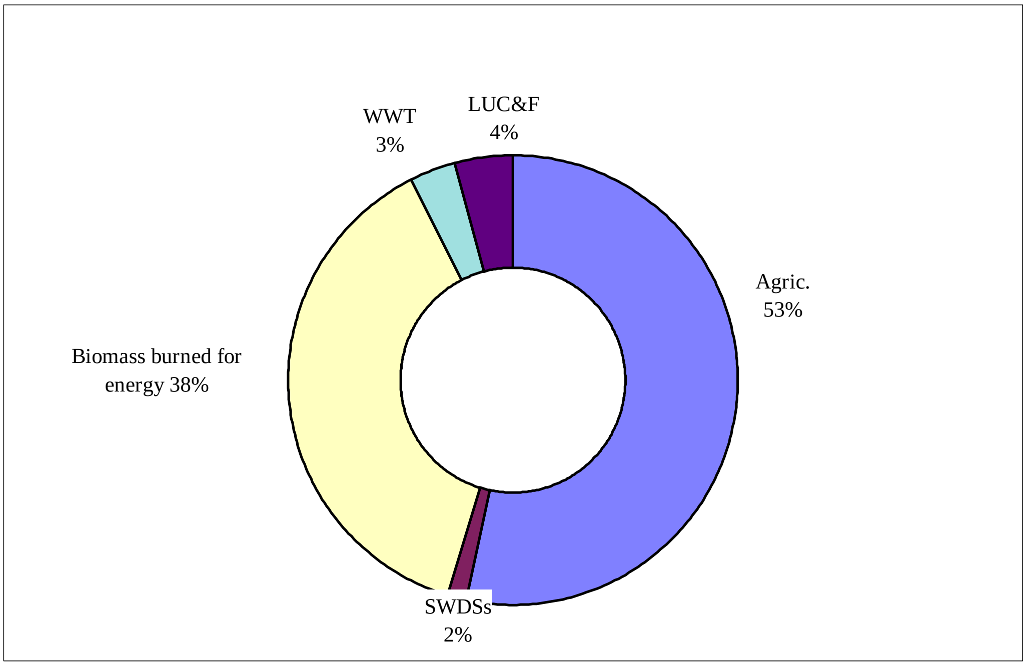
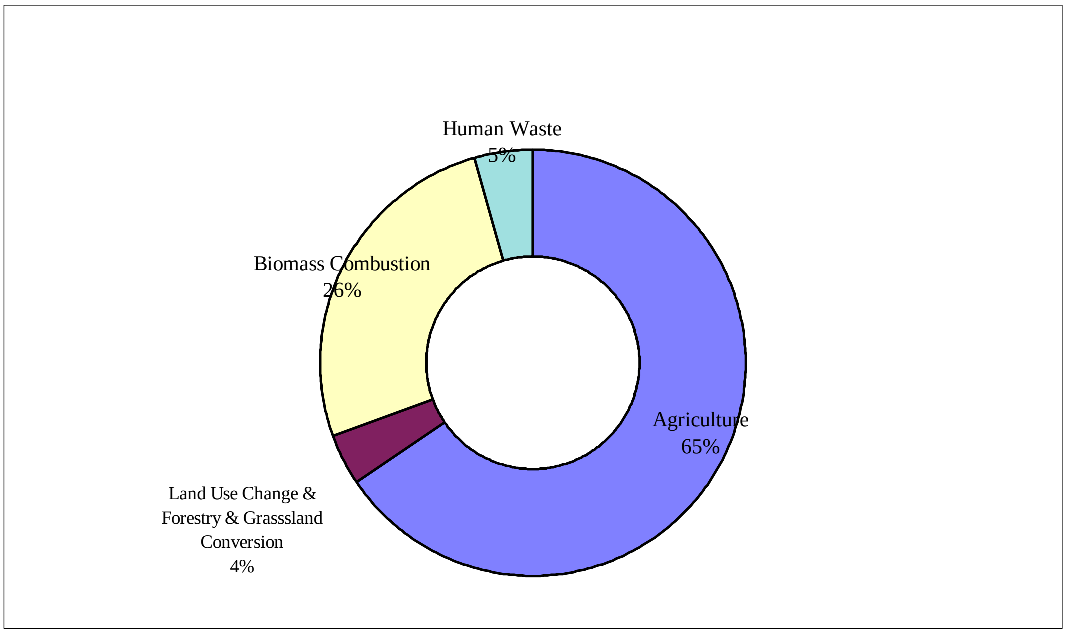


Figure 6 Sectoral contribution of N_2O for the base year (1994)



The sharp decline in the consumption of petroleum products in 1991 and the corresponding drop in CO_2 emissions is due to the sharp increase in prices after the Government decided to remove all subsidies on petroleum products in 1990. The relatively low per capita CO_2 emissions from the energy sector of about 0.18kg CO_2 (1994) is due to the fact that Ghana relies predominantly on hydropower generation for industry, residential and commercial uses. This also explains why industry's share of petroleum products consumption was only 8% in 1994.

Carbon dioxide emissions are projected to increase significantly with the diversification of the country's energy base. Thermal power plants have become absolutely necessary, with the sharp decline in the output of hydropower generation from the Volta Lake as a result of low precipitation/rainfall in the catchment. The overall increase in CO_2 emissions from thermal power plants would however be reduced by the installation of combined cycle utility plants that have higher generation efficiencies of over 60% compared to 34% of conventional thermal plants and adoption of appropriate policy measures for effective transfer of technology for end use energy efficiency enhancement. These measures would offer excellent opportunities of projects within the frameworks of the Activities Implemented Jointly (AIJ) and Clean Development Mechanism (CDM).

▪ IMPACT, VULNERABILITY AND ADAPTATION

The assessment of Ghana's vulnerability to climate change was carried out to evaluate how changes in climate may affect some important sectors of the national economy. These include water resources, coastal resources and some agricultural crops. The assessments consisted essentially of the analysing of the scope and severity of the potential effects of climate change, as a result of probable temperature rise, decreased precipitation and rise in sea level.

Water Resources

Water resources in Ghana is vital for socio-economic development. Impacts of climate change on the water resource can put the country at risk and thus assessment is for planning and management to reduce the effects.

The country's water resources may be classified into two broad categories, namely surface and groundwater resources. The surface water resources depend on the magnitudes of river discharges or runoffs and the groundwater on recharge and capacities of the aquifers.

In assessing the impacts of climate change on water resources, representative basin approach was used. A basin was chosen from each of the three hydroclimatic zones spanning the country. The basins are Pra from the Southwestern basin system, Ayensu from the Coastal basin system and the White Volta from the Volta basin system (Figure 3.1).

Scenarios of potential future climate were developed using three Global Circular Models (GCMs) and a simple climate model. River discharges were simulated by a water balance model using the climate scenarios of temperature and precipitation for the year 2020 and 2050.

Recharges to groundwater storage were computed from the water balance components. The recharges were then used in estimating the groundwater potential. The sum of the available surface and groundwater resources constitutes the total water supply for the basin.

Estimates for domestic, industrial and irrigation water demands based on socio-economic indicators for the year 2020 and 2050 were carried out. Water demands for the same socio-economic conditions under climate change scenario were then computed. Irrigation water demands incorporating changes in evapotranspiration and precipitation were estimated using CROPWAT model. Total water demand was computed by aggregating the various demands. Hydropower generation was simulated from WEAP, a water evaluation and application model.

Impacts and vulnerability assessments in each basin were carried out on water supply and demand. The results were then transferred to the whole hydroclimatic zone on the basis of homogeneity of characteristics within each zone. National impact and vulnerability were then finally inferred.

Major findings of study include the following:

- Temperature rise of about 1°C over a 30 year period and reductions in rainfall and runoff of approximately 20 and 30% respectively were observed from historical data sets.

- Runoffs or discharges in all the representative basins are sensitive to changes in precipitation and temperature. A 10% change in precipitation or a 1°C rise in temperature can cause a reduction in runoff in excess of 10%.

- Simulations using projected climate change scenarios indicated reduction in flows between 15-20% and 30-40% for the year 2020 and 2050 respectively in all the basins.

- Climate change may cause reductions in groundwater recharge of between 5 and 22% by the year 2020. Reductions for the year 2050 are projected to be between 30 and 40%.

- Domestic and industrial water demand may not be affected by climate change.

- Irrigation water demand could be affected considerably by climate change. In the humid part of the country, the projected increase in irrigation water demand due to climate change by 2020 and 2050 will be about 40 and 150% respectively of the base period water demand. However, the relative increases in water demands due to climate change over the scenario without climate change in the same period are 5% and 17% for the year 2020 and 2050 respectively.

  For the dry interior savanna, the corresponding increases in water demand in 2020 and 2050 are projected to be about 150 and 1200% of the base period water demand respectively. Similarly, the relative increases in water demands due to climate change over the scenario without climate change for the same period of 2020 and 2050 are 4% and 12% respectively.

- Hydropower generation could seriously be affected by climate change. The projected reduction by 2020 is about 60% from the base value in the Pra basin modeled by WEAP.

- From the socio-economic point of view, there may be secondary impacts on health, nutrition and energy-based industrial activities, if proper adaptation options are not embarked upon.

- A vulnerability index involving the application of water availability and use criterion indicated that the country, apart from the coastal basin, has water surplus in the base year (1990). The coastal basin has, however, water management problems in the base year. By the year 2020 and 2050 all the basins will be marginally vulnerable. That is, the country will face water management problems.

- The use-availability ratios in the country are very small. The values are 2-10% and 5-31% for 2020 and 2050 respectively. Should this ratio increase to 40% to meet food security and export, the whole country will be vulnerable. It is worth noting that the marginal vulnerability predicted for 2020 and 2050 are due to projected low use-availability ratios based on our current water consumption patterns.

- Adaptation options suggested were in general for water conservation and efficient use of water for projected reduction in water resources.

Agriculture

Analysis of climate change on cereal production in Ghana and adaptation strategies to deal with the potential climate change effects was done. Future climate change scenarios on temperature, solar radiation and rainfall were generated using General Circulation Models.

The impact of climate change on cereal production was assessed using the CERES model. CERES MAIZE and CERES MILLET models were used to generate growth and yield of maize and millet, respectively.

The future climate change scenarios generated indicated that both the maximum and minimum temperatures increased over years in all agroclimatic zones of Ghana (Fig. 3.2), but the increases were higher in the Sudan Savanna Zone where temperatures are normally the highest.

The projections indicate that the average maximum temperature of the Sudan Savanna Zone is expected to increase by 3^{o}C by the year 2100 and 2.5^{o}C in all other agroclimatic zones. The average minimum temperature is expected to increase by 2.5^{o}C in the Sudan Savanna, Guinea Savanna and the Semi-Deciduous Rainforest Zones by the year 2100. For the transition Zone and the High Rainforest Zone, the minimum temperature is projected to increase by 3^{o}C and 2^{o}C, respectively, by the year 2100.

The average solar radiation was projected to increase by 1.95MJ/m^2 in the Transition Zone, and the Semi-Deciduous Rainforest Zone, 1.0MJ/m^2 in the Guinea Savanna Zone, and 0.75MJ/m^2 in the High Rainforest Zone, by the year 2100.

With respect to projected rainfall, the mean annual rainfall would decrease by 170 mm in the Sudan Savanna Zone, 74 mm in the Guinea Savanna Zone and 99 mm in the Semi-Deciduous Rainforest Zone, respectively by the year 2100. In the High Rainforest Zone, however, the mean annual rainfall was projected to increase by 1105mm by the year 2100.

Using the projected climate scenarios and CERES model, it was projected that the yield of maize would decrease in the Transition Zone from 0.5 percent in the year 2000 to 6.9 percent in the year 2020. The yield of millet however was not affected by the projected climate change because millet is more drought tolerant and therefore insensitive to temperature rise.

Coastal Zone

The land area of the coastal zone of Ghana defined as the area below the 30-m contour covers about 7% of the total land area of Ghana. It is home to 25% of the population of the country. Several consequences could be expected for a rise in sea levels in Ghana. In particular low-lying sandy coastal areas such as the Volta delta will be profoundly affected. The expected impacts of sea-level rise are: direct inundation (or submergence) of low-lying wetland and dry-land areas; erosion of soft shores by increasing offshore loss of sediment; increases in salinity of estuaries and aquifers; raised coastal water tables; and exacerbated coastal flooding and storm damage. These impacts will in turn influence coastal habitats, bio-diversity and socio-economic activities.

The length of the coastal zone of Ghana is 565km. The zone comprises the sandy East Coast (149 km) and West Coast (95 km) on the extremities of the zone. The East Coast stretches from Aflao in the east to Prampram while the West Coast stretches from the country's border with La Cote d'Ivoire on the west to the mouth of the Ankobra River west of Axim. Between the two sandy segments of the coastal zone lies the Central Coast stretching from the Ankobra River in the west to Prampram in the east. The Central Coast is 321 km long and comprises mainly rocky beaches interspersed with short sections of sandy beaches between 2 - 10 km long (see Figure 3.4).

The assessment adopted the following procedure:

- one socio-economic scenario (i.e. the case as at 1994);
- future sea-level rise of one meter; and
- a defined response scenario as well as estimates of the associated cost.

The population is concentrated within the main urban centres i.e. Accra-Tema, Sekondi-Takoradi and Cape Coast. Of the 21 administrative districts of the Coastal Zone (Fig. 3.5), Accra Metropolitan Area has the highest population density of 3,388 persons per km^2 and Jomoro District has the lowest, 45 persons per km^2. Apart from the urban centres, the main economic activities of the people living in the coastal zone is fishing and farming. Incomes are low averaging below US$150 per person per year for most districts within the zone.

If current rates of sea-level rise continues to the year 2100, the rise is projected to reach 0.2 m. sea-level rise as a result of global climate change is, however, projected to accelerate attaining 1 m by the year 2100. The assessment here focuses on a rise of 1 m by the year 2100.

A preliminary assessment of the impacts of sea-level rise shows that about two-thirds of the total land area potentially at risk of flooding and shoreline recession in Ghana lies within the East Coast. Other areas that may be impacted adversely are the West Coast and limited sections of sandy beaches within the Central Coast. A total of 1,110 km^2 of land area may be lost as a consequence of a 1 m rise of sea-level. The population at risk is estimated at 132,200. Most of the affected population is within the East Coast.

The loss of land by erosion and inundation will translate into loss of coastal habitats including important wetlands mostly in the Volta Delta. Increasing water depths and salinization of lagoons as a result of sea-level rise will impact adversely on the feeding success of migratory and resident birds. The strand vegetation at risk include, *Canavalia rosea, Ipomea pes-caprae, Sesuvium portulacastrum* and *Phylooxeris vermicularis.* Loss of habitat includes those of marine turtles that lay their eggs on sandy beaches and the habitats associated with coastal lagoons. Salinity levels within the lagoons and water depths will be increased. Some species that are less tolerant to salinity increases will be displaced.

Sea-level rise can be expected to raise the soil moisture content of sandy and silty soils along the coastal zone. These soils when subjected to vibrations will liquefy. The structures founded on these soils could thus be at risk of collapse during earthquakes. The rising water table as a result of sea-level rise will increase the risk of earthquake hazards. The highest risk zone is the Accra area. The risk diminishes eastward and westward.

Estimated cost of protecting all shorelines at risk with populations greater than 10 persons per km^2 with seawalls is US$1,144 million. The protection of important areas only reduces that cost to US$590 million. On account of the high expenditure involved in offering protection, other alternative measures are proposed. These include the controlled abandonment of areas at risk and the use of set backs to control development along sections of the coast that are currently undeveloped.

The values at risk from sea-level rise need better evaluation by the collection of more accurate data. Under the current study this could not be achieved because of the limited available data.

The improvement of the quality of data could also include Aerial Videotape-assisted Vulnerability Assessment (AVVA). Education and Research are considered necessary projects for the adaptation of the larger population to sea level rise.

The current legislative context within which developments are carried out in the coastal zone is fraught with difficulties. A large number of scattered legislation and regulations exist, which are designed to protect the coastal zone. The implementation of the legislative controls, however, has not been very effective.

Several institutions have been identified whose activities border on the management of the coastal zone. However, there is no central co-ordinating body to harmonize the different objectives of the various institutions.

▪ MEASURES CONTRIBUTING TO ADDRESSING CLIMATE CHANGE

Forestry

Detailed studies were carried out on measures to abate climate change through the forestry and land use sector, using the COMAP (Comprehensive Mitigation Analysis Process) model as analytical tool. 1994 was chosen as the base year and 2020, the end of the current National Development Planning Framework, as the end of the analytical period.

Identification and Screening of Abatement Options

Fifteen potential options were initially identified and screened against 12 criteria ranging from impact on GHGs on other pollutants and on other aspects of the environment such as biological diversity; likely direct cost/benefit ratio; consistency with national development goals; to ease of implementation, using an options – criteria matrix. The seven most promising abatement options were then grouped into a Forest Protection Option and a Reforestation/Regeneration Option for further analysis.

Business-as-usual Projections

The base year land use situation (area and biomass pools) was used as a baseline scenario, taking into account the background information on national and sectoral development policies, programs and projects.

The projections indicated that under a business-as-usual scenario, the natural forests in the managed and protected Tropical High Forest Reserves would decrease by 45,000 ha as a result of the conversion of part of the 127,000 ha severely degraded portions (the Conversion Forest) to planted forest. Total closed forests would decrease by 343,000 ha mainly as a result of deforestation. The natural Savanna Woodlands would similarly decrease by about 600,000 ha, again through deforestation. Planted forests would increase from 68,000 ha in 1994 to 154,000 ha by 2020. The biomass pool on all forested lands (excluding the bush fallows, etc) would be reduced from 240,300 tB to 230,485 tB.

The Forest Protection Abatement Scenario

A Forest Protection Scenario to abate climate change developed involved among others:

- increased surveillance of the protected/managed permanent forest and wildlife reserves and involvement of stakeholders in their protection;

- continued enhancement of stumpage for timber trees and of income generation opportunities from unreserved community natural forests, to increase people's appreciation of the value of unreserved forests as against their removal for other land uses;

- provision of alternate livelihoods for communities protecting/conserving currently unreserved ecologically sensitive, culturally significant forests;

- expansion of activities to encourage integrated management of the natural savanna woodlands by communities.

- education and sanctions to reduce the incidence of uncontrolled bush burning.

- continued improvement in agricultural technologies to encourage intensive agriculture.

- effective enforcement of the barn on chain saw operations

As a result of these protection measures:

♦ An additional 42,000 ha of unreserved high forests above the Baseline situation (which would protect 3,000 ha) would be maintained and managed as productive dedicated forests by communities and landowners;

♦ 20,000 ha of unreserved high forests on fragile, ecologically sensitive and culturally significant sites would be protected by communities;

♦ 393,000 ha of unreserved savanna woodland, approximately equal to the area expected to be deforested from 2001 would be protected and managed by communities and individuals.

♦ The rate of deforestation of intact forests outside the forest and wildlife reserves would be progressively reduced from 5% in 2001 to 2.5% in the high forest zone and from 0.34% to 0.3% in the savanna woodlands zone;

♦ Total carbon density would increase from 213 tC/ha in 2001 to 272 tC/ha in 2020 in the high forest zone and in the savanna woodland zone from 55 to 62 tC/ha.

The Reforestation Abatement Scenario

This option will ensure that an additional 112,000 ha is reforested, largely as industrial plantations by private enterprises (small, medium and large scale). This area is equivalent approximately to the unreserved high forests that would be deforested and lost even under the

Protection Option between 2001 – 2020. The incremental carbon that would consequently be sequestered is estimated at 6,060 ktC.

Energy Sector

This section examines the abatement of the increase of greenhouse gases (GHGs) in the energy sector. The energy sector is currently the largest emitter of GHGs. The abatement in the sector was considered over a time horizon of 1994 to 2020.

In estimating the baseline emissions, Vision 2020 which is the government's main development plan and other estimates of energy demand were used. The energy supply situation was also considered. With these as inputs we estimated the emissions of CO_2 equivalent of GHGs to 2020. This is called the baseline emissions in the sense that we considered Ghana's development path with no aim of reducing GHGs. The result showed that the CO_2 equivalent of emissions for the baseline will increase from 7,278 Gg. in 1994 to 118,405 Gg in 2020.

Four abatement scenarios were looked at:

- replacing some biomass with LPG.
- use of biogas and LPG to some biomass from 2010 to 2015 when only LPG and biogas will be used with the largest proportion of cooking being of biogas.
- gradual penetration of solar PVs to the existing mix
- gradual penetration of biogas instead of a huge penetration as in second and third scenarios.

The CO_2 equivalent reductions from the abatement measures of scenarios I, II, III, IV are 495,506 Gg, 700,044 Gg, 712,515 Gg and 543,778 Gg respectively. The cost implications of the reductions are important.

The cost of reduction of a Gg. of CO_2 equivalent of emissions for scenarios I, II, III, IV are $32.22, $2,701.56, $6,932.22 and $9,448.86, respectively.

This abatement assessment has shown that significant amounts of GHG emissions can be reduced in the energy sector through certain abatement options.

SUSTAINABLE DEVELOPMENT AND PLANNING

Vision 2020 recognizes sustainable development as a basic concept for the achievement of a middle income country status by the year 2020. The development objectives in the vision imply that significant increases in human, financial, material and natural resources will be committed to increase production in all the productive sectors, in technological development, in the expansion of services and in growth in the energy sector. In the absence of preventive measures, the likely environmental consequences of the expected increase in economic growth will take the form of industrial and energy related production, deforestation, land degradation and over use of water. A trade-off between the environment and development is virtually inevitable. That is how much loss of environmental quality society is prepared to for go in order to achieve its growth objectives, and vice versa. To ensure sustainable economic growth in which the environment and development will complement each other, sound management of natural resources, proper waste management practices, as well as environmentally friendly technologies will have to be adopted in the process of growth and development.

In addition, Ghana's commitment to the achievement of the goals and targets of international efforts such as Agenda 21, UNFCCC etc., requires that our long-term goals are geared towards reflecting these commitments.

▪ RESEARCH AND SYSTEMATIC OBSERVATION

As part of the Ghana climate change country studies, national climate change scenarios have been developed. Climate Change Scenarios for the climatic variables mean monthly rainfall amount, maximum, minimum and mean daily temperatures have been constructed to cover the whole of Ghana for the years 2000, 2005, 2010, 2015, 2020, 2025, 2050, 2075 and 2100. This was done in accordance with the requirements of the Country Working Groups for Climate Change Vulnerability and Adaptation Assessment on Water Resources, Agriculture and Coastal Zone.

It was observed that there have been increases in temperature over the whole of the country between 1961 and 1990, the period used as the baseline for this scenario development. For the country as a whole rainfall amount also showed a downward trend.

From the projections for temperature, rainfall and sea level rise, the following deductions were made:

a) The mean daily temperatures will increase by about 2.5° C to 3.2°C, if the mid-range atmospheric sensitivity of 2.5°C is assumed, over the 1961 to 1990 baseline temperatures by the year 2100. This is higher than the global average of about 2°C over the same period. These changes could, however, be lower or higher depending on the way the atmosphere will respond to increases in the concentrations of greenhouse gases. The range of uncertainty in these projections is about 1°C to 3.5°C due mainly to oceanic inertia. It should, however, be noted that even if a 1°C rise in temperature is attained by 2100 above current mean temperatures, it would be larger than any century-time-scale trend for the past 10,000 years. The rate of climate warming in Ghana during the baseline period is about 0.2°C per decade which is comparable to the projected decadal rate of increase of about 0.25°C to 0.32°C between the years 2000 and 2100. The differences might be attributed to the increased effect of greenhouse gas concentrations in the past and current periods on global climate between 2000 and 2100.

b) Annual totals of rainfall amount will decrease throughout the country except in regions E1 and E2 (see Figure 3.3) where very slight increases are expected . On monthly basis, however, there will be some slight increases during the dry months, that is from November to March again over the entire country except regions E1 and E2. In the two regions decreases are projected during the months of December to May while June to November show increases causing a net effect of very little increase in annual totals. The predicted trend in rainfall in all regions is similar to the observed trend during the baseline period. For Ghana as a whole, however, the observed rate of decrease in rainfall of about 5.4% per decade during the period 1961 to 1990 is larger than the average predicted rate of decrease of about 4% per decade between 2000 and 2100. Projected changes in rainfall are also subject to uncertainty mainly due to the uncertainty in the way the atmosphere will respond to increased concentrations of greenhouse gases.

c) For sea level rise, the global averages based on the IS92a as amended for the IPCC 1995 report have been used. Using an atmospheric sensitivity of 2.5°C the projected rise in sea level will range from 2cm in the year 2000 to about 48.9cm by 2100. There is a wide range of uncertainty in sea level rise projections due to atmospheric sensitivity. For example under the same emission scenario but with an atmospheric sensitivity of 4.5°C the sea level could change by as much as 85.9cm by 2100.

▪ EDUCATION, TRAINING AND PUBLIC AWARENESS

The successful implementation of Ghana Government Policy on environment including all aspects of Climate Change, is based on the premise that the citizenry understands the functioning of the environment and the problems it presents and contributes meaningfully to its protection, improvement and enhancement.

To achieve this, continuous and detailed environmental education programs have to be implemented at all levels so that every Ghanaian becomes aware of the problems and fully assumes his responsibilities in the protection of the environment.

Environmental Education therefore forms an integral part of the educational system. Sustained effort will be made to promote awareness among policy makers, provide training for resource managers at appropriate levels and promote greater public awareness and motivation for environmental action.

The government believes that economic prosperity of the nation depends on a high quality environment; losses being experienced reduce the living standards of the present generation; and that the prosperity of future generations will be prejudiced by today's excesses.

▪ INTERNATIONAL CO-OPERATION

Realizing that no country on its own can address the climate change problem, but countries have common but differentiated responsibilities towards achieving the ultimate objective of the United Nations Framework Convention on Climate Change, Ghana has worked in close collaboration with international organizations both on bilateral and multilateral basis.

The driving force behind these co-operations has been both technical as well as financial. Technically, there was lack of basic capacity to undertake studies in areas of greenhouse gas inventory, abatement of increase in greenhouse gas emissions and vulnerability/adaptation assessment. Financial assistance was also granted under these co-operations to allow Ghana prepare this initial national communication.

▪ PROPOSED CLIMATE CHANGE PROJECTS

Based on the studies carried out under the UNDP/GEF Capacity Building Project (GHG inventory and Mitigation studies) and the Netherlands Government Change Assistance Project (Vulnerability Studies), the country has developed project concepts or outlines aimed at:

- 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 project to allow Ghana attain sustainable development whilst contributing effectively to global initiatives in addressing climate change.

CHAPTER ONE

1.0 NATIONAL CIRCUMSTANCES

1.1 GEOGRAPHY & DEMOGRAPHY

Ghana lies on the south central coast of West Africa between latitudes 4.5^0N and 11.5^0N and longitude 3.5^oW and 1.3^oE. It shares a common border with the Republic of Togo on the east, Burkina Faso on the north and la Cote d'Ivoire on the west. Ghana covers an average area of 238,539 square kilometers. Extensive water bodies including the Lakes Volta and Bosomtwe occupy 3,275 square kilometers while seasonally flooded lakes occupy another 23,350 square kilometers. The territorial waters extend 200 nautical miles out to sea.

The country's population is estimated at 19.7 million (1999) and is believed to be growing at a rate between 2.8 and 3.0 per cent per annum. The birth rate is estimated at 39 per thousand (1999) while the death rate is estimated at 10 per thousand (1999). The rate of infant mortality is approximately 66 per thousand life births while the overall life expectancy is 59 years (1999). The total fertility rate within the period 1996 to 1999 is estimated as 6.0.

1.2 GEOLOGY

The geological formation of Ghana (Fig. 1.1) comprises the following rock formations:

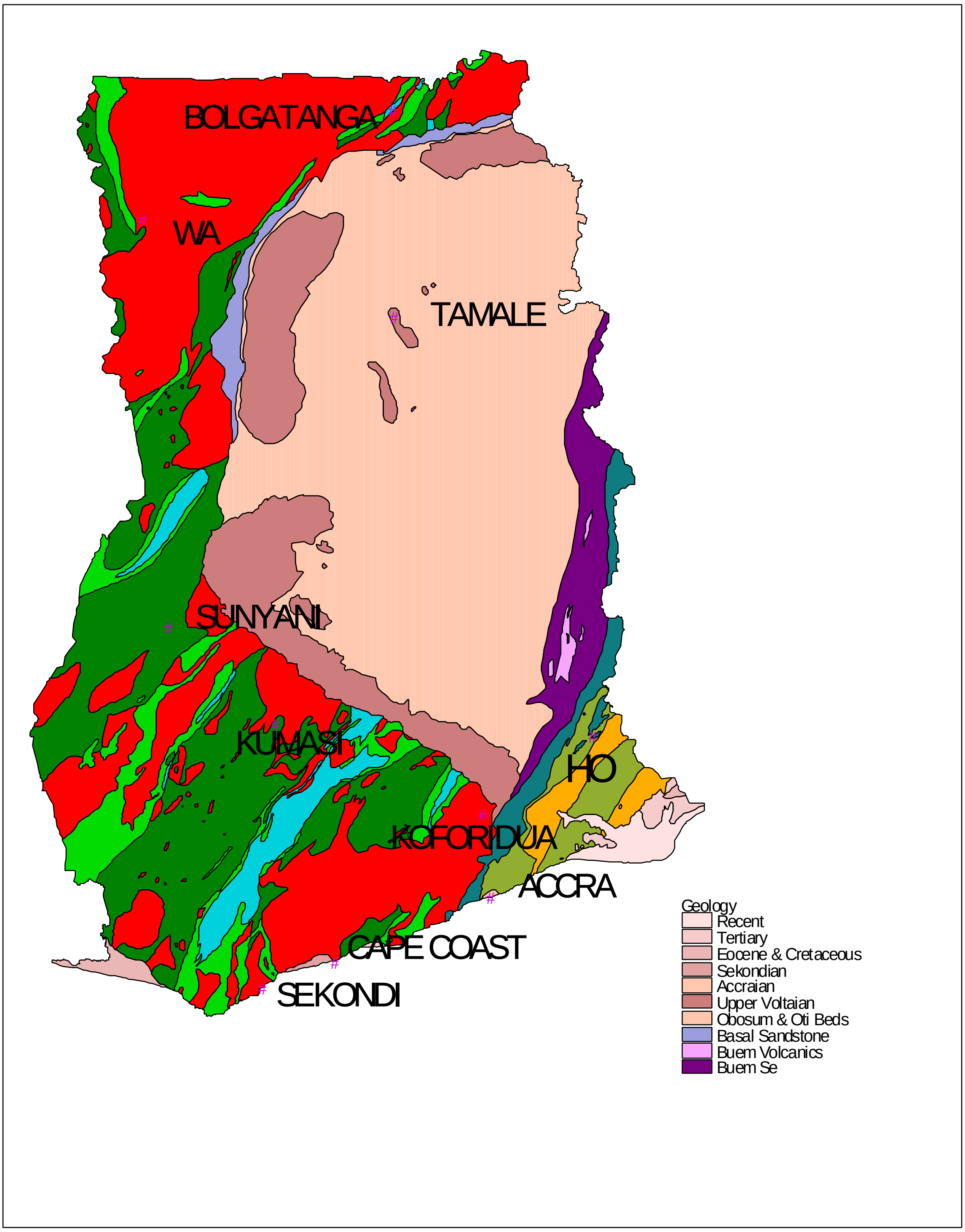
The Dahomean formation is the oldest, and underlines the whole of the south-east coastal plains. It constitutes the floor of the Accra plains and the southern part of the Volta Region. The rocks are mainly metamorphic, consisting of gneisses and schists.

The Birimian formation covers more than three quarters of the closed forest zone and contains all the minerals exported from the country. The formation is divided into the Lower Birimian which consists of such metamorphosed sediments as phyllites and schists, and the Upper Birimian which is the younger of the two and consists of rocks of the Lower Birimian as well as metamorphosed lava. The Birimian formation generally follows a south-west to north-east trend.

The Tarkwaian formation originally consisted of sediments eroded from the Birimian formation and deposited in a shallow narrow basin, and then folded along the same axis as the Birimian formation. This extends from the township of Agogo to the middle section of the Ankobra river and consists of schists, sandstones, quartzite and phyllites. A few patches of this formation consist of plutonic or volcanic rocks.

The Togo series consists of sedimentary rocks and their metamorphosed versions (e.g. quartzite, schists shale, and phyllites) which were strongly folded to form the Akwapim-Togo Ranges.

Figure 1.1 Geological Formation of Ghana



SOURCE: Modified after Bates (1955) by GGMPP (1986)

The Buem formation was formed from material eroded from the Togo series made up of sedimentary rocks together with some volcanic rocks.

The Voltaian formation covers nearly two-fifths of the surface of Ghana and consists principally of sandstones, shales, mudstones and limestones. With the exception of the eastern margins of this formation, where there has been weak folding, the rocks are generally flat-bedded or horizontal.

Upper Cretaceous Rocks are found at the eastern and western extremities of the coast and consist of sandstone, clay shale and limestone.

The Eocene rocks consist of sediments of sand and gravel and are found at the eastern and western extremities of the coast where they cover, either completely or partially, the upper Cretaceous beds.

Recent or Unconsolidated rocks consist of clay, loose sand and gravel deposited by rivers at their mouths. The most extensive of these deposits is to be found at the extreme eastern end of the coast, at the mouth of the River Volta and around the Keta Lagoon.

1.3 RELIEF

The types and arrangements of relief features found in the country depend on the nature and distribution of the different rock formations of which the land is built. It also depends on the intensity and the period of occurrence of earth movements experienced in the country, the nature of the processes of weathering, erosion and deposition, and on how long the land has been exposed to these processes. Figure 1.2 shows the main relief outlines.

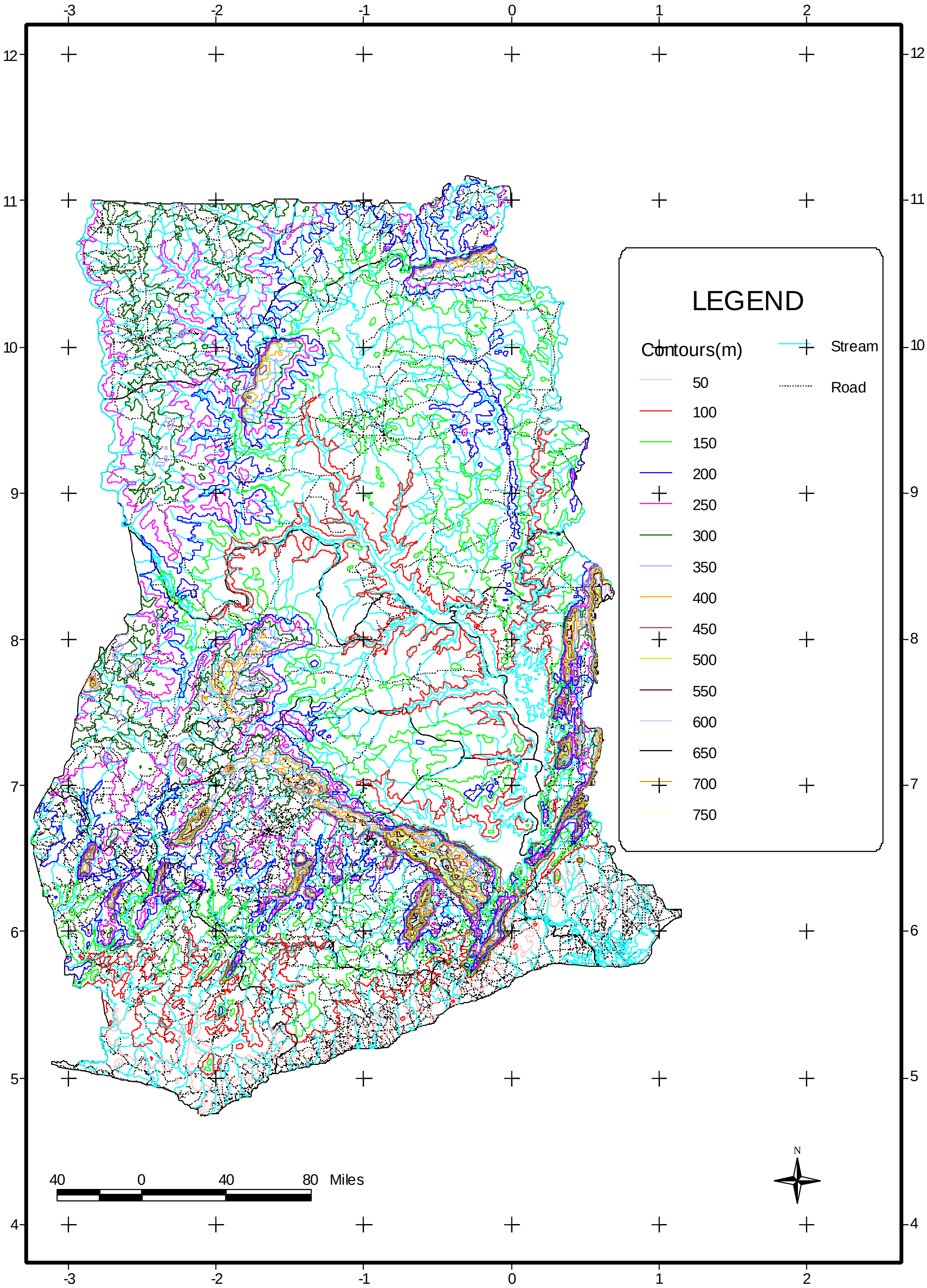
More than half of the country consists of a series of plateau surfaces at different elevations. The remainder is covered by the voltaian sandstone basin. The relief pattern of Ghana is studied in detail through the examination of the physiographic regions. These are distinguished as follows:

- the coastal plain
- the forest dissected plateau,
- the savannah high plains,
- the voltaian sandstone basin, and
- the ridges and escarpments bordering the voltaian sandstone basin.

The coastal plain is broad in the east and west, where it stretches over 80 kilometers inland, and narrow where it does not extend more than 16 kilometers inland from the sea. The coastal plain may be divided into two broad sections: the south-east coastal plains east of Accra and the plains west of Accra.

The south-east coastal plains are very flat and carry only a few isolated hills called inselbergs, e.g. Shai, Krobo, Ningo and Osudoku hills, which rise abruptly from the surrounding plains. The general elevation of the land, except in the case of the inselbergs, is not more than 76.2 meters above sea level, and at some places on the coast, e.g. at Keta, the land is even below sea level and is subject to periodic invasions by the sea.

Figure 1.2 Main Relief Features of Ghana



Between Accra and about the Songor lagoon, the coastline is often cliffed; but further east, the coastline is fairly smooth, without cliffs. It is marked by sandbars, the Volta delta (the only one of its kind in the country) and by numerous lagoons, the largest of which is the Keta lagoon.

West of Accra, the plains show different characteristics. The land is not flat but rather undulating since the land shows deep sides and rises almost abruptly from the surrounding plain. The most widespread rocks found here are granites which also form most of the hills. The coastline forms a series of small bays and headlands and is cliffed in numerous places. However west of Axim, the coastline is smooth, low-lying and marked with sand bars and has neither bays nor cliffs.

The Forest dissected plateau is underlain by Precambrian rocks of the Birimian and Tarkwaian formations and has been reduced by erosion to a uniform low elevation between 244 and 305 meters above sea level. Within the region, different kinds of rocks give rise to different types of relief. A gently rolling landscape is found over the lower Birimian rocks and stands about 61 to 91 meters above the broad flat valley through which flow such rivers as the Bia, Tano and Ankobra. The hills made up of Upper Birimian rocks are steep sided and rise to about 244 meters above broad flat-bottomed valleys and are usually capped with iron-pan and bauxite. Over the Tarkwaian rocks, the topography is rugged and hilly.

The Savanna high plain is composed of granite and is between 105 and 183 meters above sea level. The topography is more gently rolling and characterized by inselbergs of Birimian rocks or granites.

The Voltaian Sandstone basin is made up of flat bedded sandstones, shales and mudstones which are easily eroded. The result is an almost flat and extensive plain which is between 60 and 150 meters in that part of the basin south of the west-east flowing Black Volta, and up to about 180 meters above sea level north of the Black Volta.

The ridges and escarpments bordering the Voltaian sandstone basin comprise of

- the Southern Voltaian Plateau,
- the Gambaga escarpment and
- the Akwapim-Togo ranges.

The Southern Voltaian Plateau, made up of horizontal layers of sandstone, marks the southern boundary of the Volta basin. It runs from south-east to north-west and consists of a series of escarpments. Average elevation is less than 460 meters above sea level

The Gambaga escarpment is also made up of horizontal layers of sandstone and marks the northern limit of the Voltaian sandstone basin. Average elevation does not exceed 460 meters above sea level.

The Akwapim-Togo ranges are fold mountains forming the eastern boundary of the Voltaian sandstone basin. The average height of the ranges is about 460 meters above sea level but heights increase to between 610 and 915 meters near the Ghana-Togo border. The ranges consist mainly of rocks of the Togo series.

1.4 DRAINAGE

All the major rivers in Ghana flow into the sea. The only area of internal drainage is found around Lake Bosomtwe, where only streams flow from the surrounding highlands into the lake. The river valleys show diverse characteristics. The valleys of all the major rivers are bordered by terraces showing the former width and height of the rivers. Some of the valleys are guided in their direction by relief (Morago river for example flows east-west along the foot of the Gambaga escarpment) or by structure.

The two main sources of water supply for the rivers are rainfall and spring. In areas with single rainfall maximum as in the north, the rivers are intermittent. However, in areas with high and well distributed rainfall within the year, the rivers flow throughout the year.

1.4.1 Major Rivers And Their Basins

The Volta River is by far the longest river and within its basin lies nearly three-quarters of the total land surface area of the country. The huge basin can be divided into smaller basins belonging to the Black Volta, the White Volta, the Oti, and the Volta which here refers to the continuation of the Black Volta downstream from the confluence with the White Volta. It is these rivers which together with their numerous tributaries form the Volta river system. Streams of northern Ghana which are all tributaries of the Volta system are not permanent and therefore do not contain enough water during the dry seasons. However during the rainy season, they contain large volume of water that they overflow their banks. Only the main Volta river is permanent and its flow is now regulated to some extent by the artificial Volta lake which has been created behind the Akosombo dam.

1.4.2 The Tano, Ankobra And Pra Rivers

In the closed forest are to be found the following major rivers: the Tano, Ankobra and the Pra all of which have their sources within the forest and flow roughly north-south into the sea. Only the Tano river enters the sea outside Ghana, in la Cote d'Ivoire. All these rivers continue to enlarge their basins by capturing more tributaries. The forest rivers differ from those belonging to the Volta river system in northern Ghana by being permanent. They are also not navigable by large crafts and boats over long stretches, although canoes and smaller boats can be used. This difficulty in using large boats on the rivers is not only due to the seasonal reduction in the volume of water but also to the fact that the courses of the rivers, like those in other wet tropical lands of the world, are interrupted in many places by rapids and water falls.

1.5 CLIMATE

Temperatures throughout the country are typically high. The mean annual temperature is generally above 24ºC, a consequence of the low latitude position of Ghana and the absence of high altitude areas. Average figures range between 24 and 30^0C although temperatures ranging from 18 to 40ºC or more are common in the southern and northern parts respectively. Spatial variability of temperature is experienced in terms of the diurnal and annual ranges as a result of distance from the modifying influence of the sea breeze.

Generally rainfall in Ghana decreases from south to north. The wettest area is the extreme south-west where annual rainfall is about 2000mm. In the extreme north, the annual rainfall is less than 1100mm. The driest area is the wedgelike strip from east of Sekondi-Takoradi, extending eastward up to 40km where the annual rainfall is about 750mm. The dry conditions in the south eastern coastal strip are anomalous and are the cause of important differences in ecology and landuse from the rest of the country.

The seasonal distribution of rainfall is particularly important to the ecology and land use. Two main rainfall regimes are identified:

a) Double maxima regime occurring south of latitude 8º30`N. The two maximum periods are from May to August and from September to October.

b) The single maximum regime found north of latitude $8^0$30`N where there is only one rainy season from May to October, followed by a long dry season from November to May.

1.6 SOCIO-ECONOMIC STRUCTURE

Ghana is classified as a developing country with a per capita income GDP of US$ 390 (1996).

Agriculture and livestock employs 55% of the economically active population. It is predominantly small holder, traditional and rain-fed, with 85% of the country’s 1.8 million farms being smaller than 2 hectares. Only about 12% of Ghana's land area (28, 680km^2) is classified as arable or permanently cropped land. Cocoa is the main cash crop and is grown on 40% of the cropped land. It accounts for about 75% of agricultural exports. Other commercially important tree crops are oil palm, coconut palm, rubber, kola and robusta coffee.

The dominant sectors and their contribution to GDP from 1990 to 1996 are indicated as in Table 1.1

In the early 1970’s, the economy experienced a steady downward trend and was further worsened by policies, which damaged incentives for domestic production and exports. Between 1970 and 1982, per capita income fell by 30%; export earnings were halved while import volumes fell to one-third of their 1970 level.

The formulation and implementation from 1983 of the World Bank/IMF Funded Government Economic Recovery Program (ERP) and a Structural Adjustment Program (SAP) based on market-oriented policies has led to a positive growth performance in the economy. Available statistics indicate a growth of 3% Real Gross Domestic Product in the first decade of implementation.

Table 1.1 Percentage Distribution of GDP by Sector

SECTOR	1990	1991	1992	1993	1994	1995	1996
Agriculture and Livestock	44.6	44.4	42.5	36.9	36.4	36.3	36.1
Agriculture and Livestock	31.1	31.5	29.8	25.7	25.1	25.0	25.4
Cocoa	6.8	6.3	6.2	2.8	3.0	3.2	3.2
Forestry and Logging	5.1	4.9	4.9	2.8	2.7	2.7	2.6
Industry	14.5	14.3	14.6	24.8	24.9	24.9	24.9
Mining and Quarrying	1.3	1.3	1.4	5.5	5.6	5.6	5.6
Manufacturing	9.2	8.8	8.7	9.4	9.2	9.0	8.9
Water and Electricity	1.3	1.4	1.5	2.6	2.6	2.7	2.7
Construction	2.7	2.8	3.0	7.4	7.5	7.6	7.7
Service	43.5	43.9	45.5	27.5	28.0	28.1	28.0
Transport and Communication	5.4	5.6	5.8	4.3	4.4	4.4	4.4
Trade	5.4	5.8	5.4	5.8	5.9	6.1	6.3

The GDP per capita rose consistently over the decade to 192,870 cedis (US$441) in 1992. Agricultural production rose marginally by 1.8% per annum. Investment and savings also rose under the ERP with investment depending heavily on foreign savings. Inflation, which hit an all time record of 123% in 1983, fell to about 10% in 1996. Despite changes in the structure of the economy, Ghana is still dependent on Agriculture (25.4% in 1996). The economy is still heavily dependent on the exports of a few primary products, namely gold, cocoa and timber. Although the export of non-traditional products is growing, the export of these three traditional items accounted for about 85% of total export earnings in 1996.

The strong dependence on agriculture for economic development is of great concern with respect to potential climatic changes. Since almost all the national agricultural production is based on rainfall, the country's agricultural output is directly influenced by weather patterns. During periods of severe drought crop production and livestock herds decline quite significantly. The severe food shortages experienced in the country in the early 1980's is a clear testimony of the dependence of the country's agriculture on climate change.

Mining operations have shifted from underground mining to surface mining as a result of improved technology for processing the low-grade ores. This has however affected land use change and ecology of the country.

The manufacturing industry contributed about half (36%) of the sector's output in 1996, construction (31%) mining and quarrying (22%) water and electricity (11%) respectively.

1.7 TRADE

Ghana’s trade has improved in recent years with respect to GDP. This has increased from ¢968.2 million in 1990 to ¢1.54 billion in 1996. Maintaining this trend is of great interest to Ghana hence the introduction of the Trade and Investment Gateway Project in the country which aims at facilitating industrialization and trade.

The ERP and SAP have been successful in terms of growth in the GDP which has averaged 4% over the years. Of key concern, however, is the potential for environmental issues that must be addressed. The effect of globalization on Ghana's economy is a source of concern since both local and global climate change response strategies may impact negatively on Ghana’s economy.

The national circumstances is as indicated in Table 1.2

Table 1.2: Ghana's Economic Structure and Development Indicators

Criteria	1990	1991	1992	1993	1994	1995	1996
Area (km^2)	238,539	238,539	238,539	238,539	238,539	238,539	238,539
Population (millions) estimated	14.9	15.3	15.9	16.1	16.4	17.2	18.0
GNP (at current prices, billion US$)	6.11	6.88	6.78	6.97	6.42	6.18	
Average rate of growth (GNP) at 1994 prices %	3	5	4	5	3	4	
GDP (at current prices US$)	6.11	7.00	6.88	6.08	6.56	6.31	
Per capita (GDP) US$		452		370		364	
Average rate of growth (GDP) at 1994 prices %	3.1	5.3	3.9	4.7	3.7	4.5	5.2
Average rate of growth (GDP) by sector (at 1994 prices, %)							
Agriculture	-2	5	-1	3	3	4	4
Industry	6.9	3.7	5.8	4.3	1.3	3.3	4.2
Energy	4	4	4	4	4		
Services							
Trade	8.8	6.3	7.7	7.0	5.0	4.7	4.2
Export FOB (US$)	896.7	997.6	986.3	1063.7	1236.4	1431.2	1571
Imports FOB (US$)	1205	1318.7	1450.5	1728	1579.9	1687.8	1937
Annual change in consumer price	37	18	10	25	24.9	74.3	34.0
Annual chance in wholesale price index	28						23
Land Areas of Agriculture (sq. km)	19,000	26000	27000	28000	28000		
Livestock population(million)	6.61	6.61	6.87	7.04	7.04		
Forest area (million ha)	2.0	2.0	2.0	2.0	1.69	1.69	1.69
Population in absolute poverty (%)?			31.4	31.4	31.4	31.4	31.0
Life expectancy at birth (year)	54	55	56	56	56	57	58
Literacy Rate	60.5					71.3	
Urban Population (%of Total)	33.0					36.3	36.4
Rural Population (%of Total)	67.0					63.7	63.6

Sources:
1. World Bank, African Development Indicators 1999
2. Economist Intelligence Unit (EIU) 1999
3. IMF estimates 1999
4. CEPA 1999
5. World Resources : A guide to the Global Environment. 1996-97, 1998-99/
6. Statistical services Report 1998

1.8 ENERGY RESOURCES

The main energy resource is dominated by hydropower generation, which comes from two hydro dams at Akosombo and Kpong with a total production of 912MW and 160MW respectively. Additional investment in the power sector include a diesel generation station at Tema and a thermal generation plant at Aboadze which have installed capacities of 30MW and 300MW respectively. The thermal plant at Aboadze has the potential to generate up to 600MW in the near future. Several sites on some major rivers like Pra and Black Volta have also been identified for further exploitation. These have the potential to generate up to about 1,000MW.

The high-voltage transmission system, which is owned and operated by the Volta River Authority, comprises the following:

- 75 km of 225 kV lines
- 3000 km of 161 kV lines
- 1300 km of 33 kV lines
- 1600 km of 24 kV lines

Energy Demand

Projection made within the sector shows that the electricity demand for Ghana is expected to grow markedly. The supply to existing consumers is estimated to grow as follows: National Electrification Planning Study (Executive Summary, 1991)

- Supplies to VALCO will be maintained at 2,760 Giga Watts hour (GWh) per annum as outlined in the power contract with the Government of Ghana. Power demand will be about 336 MW

- ECG demand from existing supply areas will grow from 1,535 GWh per year in 1990 to 2238, 3129 and 4394 GWh per year by 2000, 2010 and 2020, respectively. Corresponding power demand will grow from 296 to 421, 588 and 827 MW

- Exports to Togo and Benin will grow from 350 GWh to 440 GWh by the year 2000. Peak power demand will remain at about 83 MW.

- Exports to la Cote d'Ivoire are expected to average about 420 GWh per year except in dry years when the export would be reduced.

- The demand from the existing mines will grow from 310GWh per year and 57 MW to 480 GWh per year and 73 MW by the year 2005, and will remain constant thereafter.

- Demand from the existing Northern Electrification Development Project towns will grow from 125 GWh per year and 29 MW to about 354 GWh and 84 MW by the year 2020.

- Aggregate energy demand, including losses, will grow from 5712 GWh per year (1998) to 6736, 7775 and 9206 GWh in the year 2000, 2010 and 2020, respectively. Corresponding power demands will grow from 826 to 971, 1145 and 1394 MW.

The petroleum industry in Ghana is entirely based on imported crude oil, and on imported finished products from established markets.

Table 1.3 depicts, the trend of consumption of petroleum products from 1990 to 1996 and the irregular consumption pattern within the period

Table 1.3 Consumption of Petroleum Products (1990 - 1996) in Tetrajoule (Tj)

Fuel Type/Year	1990	1991	1992	1993	1994	1995	1996
Crude Oil	33,539.2	41,013.9	38,715.3	33,620	44,953.7	33,478.9	42,441.6
Gasoline	5,730.9	669.9	1,000.6	6,933.3	22,227.4	6,649.3	2,943.3
Jet Kerosene	-1,530.3*	-1,189.1	-1,833.8	-1,498.9	-1515.6	-1,603.5	-1,678.9
Other Kerosene	1,922.2	-192.6	628.0	1,222.5	142.4	1,490.5	1,507.2
Gas/Diesel Oil	4,386.9	-757,8	2,047.3	5,321.4	3,889.5	8,436.4	9,152.3
Residual Fuel Oil (RFO)	-4,806.4	-7,456.7	-7251.5	-4,886.0	-8155.9	-6,523.0	-6987.8
LPG	-60.3	-87.9	4.2	422.9	690.8	1,110.8	1,310.5
Lubricants	669.9	711.8	753.6	795.5	699.2	741.1	900.2
Total	52,646	52,080	52,234	54,710	82,275	60,034	66,922

* The negative figures indicate that some of the products were exported.

Table 1.4: Growth in Petroleum Products Demand (1991 - 2000)

Fuel Type	% Per Year
Gasoline	1.6
Kerosene	0.2
Diesel	3.0
Liquefied Petroleum Gas	14.0
Residual Fuel Oil (RFO)	0.6

Source: Ghana Energy Sector Review, 1993, World Bank

Sectoral consumption shows that consumption mainly takes place within the Transportation, Residential, Commercial, Agriculture and Industrial sectors including Mining. The estimated consumption of these products by the various sectors in 1990 is as follows:

- Transportation 60%
- Residential and Commercial 24%
- Agriculture 8%
- Industries and Mines 8%

It is estimated that consumption of petroleum products is expected to grow over the next ten years and beyond. Table1.4 shows the projected percent growth (in 1993) in consumption of petroleum products over the period 1991 to 2000.

This growth is expected to be achieved on condition that the Government pursues its commitment to ensure the availability of petroleum products to all parts of the country through an improved supply and distribution of infrastructure in the country.

Biomass constitutes a major source of energy, particularly to rural population and for the low-income urban group. Of the country's total forest area of about 2.0 million hectares, about 1.63 million hectares are designated as forest reserves. The remaining 0.4 million hectares is given to free access. For energy purposes, only the indigenous (free access forest) can be considered as the major resource. This area is seen to have much lower forest regeneration rate than all the other forest categories. Charcoal production is another form of renewable energy with 80% of the production coming from the ecologically fragile transitional zone between the rainforest and the northern savanna. Any sudden adverse climatic change is bound to have a deleterious effect on the area.

Other forms of renewable energy such as solar energy, (photovoltaic) and biogas are quite insignificant as compared with hydropower and petroleum, as they are mostly in pilot phases.

1.9 ENERGY STRATEGY

The main aim of the Government's Energy Strategy is the sustainable exploitation and use of the efficient use of the country's energy resources and power production in order to improve the quality of life of the people.

In this regard the Government of Ghana aims to pursue only environmentally friendly policies and measures as part of her efforts to meet her obligations under the Climate Change Convention. These include:

- ♦ Encouraging energy efficiency and energy conservation practices. The Government's energy efficiency and conservation program covers:
    - Energy conservation in industry,
    - Energy conservation in residential, commercial and public sectors and
    - Energy conservation in the transport sector.

- ♦ Promoting fuel substitution, particularly the use of less polluting fuels such as natural gas, hydropower and Liquefied Petroleum Gas (LPG). The wide use of LPG as a substitute for charcoal and fuelwood will make it possible to (a) slow down the rate of deforestation caused partly by the production and use of woodfuels and (b) reduce pollution arising from the direct flaring of LPG into the atmosphere.

- ♦ The use of fiscal instruments to reflect the real cost in energy supplied. This serves to promote more efficient energy utilisation

CHAPTER TWO

2.0 INVENTORY OF GREENHOUSE GASES.

2.1 INTRODUCTION

The initial national greenhouse gas (GHG) inventories of emissions by sources and removals by sinks of all greenhouse gases have been carried out to meet Ghana's obligation under Articles 4.1 and 12 paragraph (a) of the United Nations Framework Convention on Climate Change (UNFCCC).

This section of the communication is part of the output of UNDP/GEF Climate Change Capacity Building Project (RAF/GA/93) to develop endogenous capacities in sub-Saharan African countries to respond to the Framework Convention on Climate Change (FCCC).

The methodology used was based on the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories which has been recommended for use by Parties to the UNFCCC in the preparation of their national communications with regard to inventories.

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 1990 - 1996. The greenhouse gases CO_2, CH_4, and N_2O have been reported in accordance with annex to decision 10/CP2

Country activity data were collected to the extent possible. IPCC default factors were employed where country data were not available. Country emission factor for CO_2 emissions for aluminum production under industrial processes, and degradable organic carbon (DOC) under the waste sector have been developed because of the reliability of the activity data. The country's emission factors developed are comparable with the IPCC default factors.

The IPCC worksheets, given the detailed activity data and emission factors, for the five sectors studied have been put together as a separate volume - Ghana’s Initial National Communication, Annex I.

2.2 BASE YEAR INVENTORIES OF GHG EMISSIONS BY SOURCES AND REMOVAL BY SINKS

The results of the initial national greenhouse gas inventories of emissions by sources and removals by sinks are summarized in accordance with the IPCC format in Table 2.1. The results indicate that the significant national sources of CO_2 emissions are petroleum fuel combustion in transportation, residential and commercial activities. Non-CO_2 emissions sources are biomass burned for energy and the burning of savanna in agriculture.

Table 2.1 National greenhouse gas inventories of emissions by sources and removals by sinks of all greenhouse gases, 1994(Gg)

GHG Source and Sink Categories	**CO_2**	**CH_4**	**N_20**
Total (Net) GHG emissions by sources and removal by sinks	***-16,548***	***414.5***	***3.07***
1. All energy (fuel Combustion)	**3,048**	**155.8**	**0.80**
1.1 Fuel Combustion	3,048		
1.2 Biomass burned for energy (Non-CO_2 emissions)		155.8	0.80
2. Industrial Processes	**281.8**		
Mineral Production			
1.1 Cement Production			
2.2 Lime Production	0.16		
2.3 Limestone Use	27.95		
2.4 Soda Ash & Sodium Bicarbonate	0.95		
Chemical Industry			
2.9 Calcium Carbide Use	1.20		
Metal Production			
2.11A Iron and Steel	3.18		
2.11B Aluminum	248.3		
4. Agriculture		**220.6**	**2.01**
4.1 Enteric Fermentation		61.6	
4.2 Rice Cultivation		3.88	
4.3 Prescribed Burning of Savannas		154.0	1.91
4.4 Field Burning of Agricultural Residues		1.03	0.04
4.5 Agricultural Soils			0.06
5. Land Use Change and Forestry	**-19,878**	**17.53**	**0.12**
5.1 Changes in Forest and other Woody Biomass Stock	-22,324		
5.2 Forest and Grassland Conversion	5,738		
5.3 On-site Burning of Forest		17.53	0.12
5.4 Abandonment of Managed Lands	-3,292		
6. Waste		**20.55**	**0.13**
6-1 Solid Waste Disposal Sites (SWDSs)		6.50	
6-2 Domestic & Commercial		13.5	
6-3 Industrial Waste Water Handling		0.55	
6-4 Human Waste (Indirect N_2O)			0.13

Table 2.2 National greenhouse gas inventories by sources and removals by sinks of all greenhouse gases, 1990-1996 (Gg)

GHG Source and Sink Categories	**1990**			**1991**			**1992**			**1993**			**1994**			**1995**			**1996**		
	CO_2	**CH_4**	**N_2O**	**CO_2**	**CH_4**	**N_2O**	**CO_2**	**CH_4**	**N_2O**	**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 (NET) GHG EMISSIONS BY SOURCES AND REMOVAL BY SINKS	**-30,149**	**361.4**	**2.74**	**-31,311**	**376.8**	**2.78**	**-26,308**	**388.0**	**2.87**	**-19,993**	**417.7**	**2.98**	**-16,548**	**414.5**	**3.07**	**-17,187**	**417.6**	**3.07**	**-15,627**	**431.0**	**3.1**
1. All energy (fuel Combustion)	**2,831**	**102.9**	**0.500**	**2,320**	**113.7**	**0.50**	**2,418**	**131.3**	**0.600**	**2,974**	**144.9**	**0.700**	**3,048**	**155.8**	**0.800**	**3,240**	**156.2**	**0.800**	**3,533**	**156.2**	**0.800**
1-1 Fuel Combustion	2,831			2,320			2418			2,974			3,048						3,533		
1-2 Biomass Burned for Energy(Non-CO_2 Emissions)		102.9	0.500		113.7	0.500		131.3	0.600		144.9	0.700		155.8	0.800		156.2	0.800		156.2	0.800
2. Industrial Processes	**293.0**			**295.6**			**298.3**			**311.1**			**281.8**			**277.6**			**268.05**		
Mineral Production																					
1-1 Cement Production																					
2-2 Lime Production							0,005			0.044			0.16			0.22			0.22		
2-3 Limestone Use							0.21			0.45			27.95			28.66			28.82		
2-4 Soda Ash & Sodium Bicarbonate										0.85			0.95			1.33			3.90		
Chemical Industry																					
2-9 Calcium Carbide Use							1.49			1.11			1.20			1.38			0.89		
2-11 *Metal Production*																					
2-11A Iron and Steel				0.022			0.544			1.61			3.18			3.00			3.60		
2-11B Aluminium	293.0			295.6			296.3			307.0			248.3			243.0			230.6		
4. Agriculture		**223.6**	**2.00**		**227.2**	**2.03**		**218.1**	**2.02**		**234.6**	**2.02**		**220.6**	**2.01**		**222.2**	**2.01**		**234.9**	**2.01**
4-1 Enteric Fermentation		64.8			67.84			59.0			75.94			61.61			62.25			62.3	
4-2 Rice Cultivation		4.25			4.57			4.25			3.91			3.88			4.80			5.04	
4-3 Prescribed Burning of Savanas		154.0	1.91		154.0	1.91		154.0	1.91		154.0	1.91		154.0	1.91		154.0	1.91		154.0	1.91
4-4 Field Burning of Agricultural Residues		0.508	0.021		0.77	0.028		0.76	0.03		0.76	0.030		1.03	0.043		1.11	0.042		1.08	0.041
4-5 Agricultural Soils			0.071			0.096			0.085			0.086			0.064			0.063			0.062
5. Land Use Change and Forestry	**-33,273**	**17.53**	**0.120**	**-33,926**	**17.53**	**0.120**	**-28,726**	**17.53**	**0.120**	**-23,278**	**17.53**	**0.120**	**-19878**	**17.53**	**0.120**	**-20,704**	**17.53**	**0.120**	**-19,428**	**17.5**	**0.120**
5-1 Changes in Forest and other Woody Biomass Stock (CO_2 Removals)	-35,719			-36,372			-31,172			-25,724			-22,324			-23,150			-21,874		
5-2 Forest and Grassland Conversion	5,738			5,738			5,738			5,738			5,738			5,738			5,738		
5-3 On-site Burning of Forest		17.53	0.120		17.53	0.120		17.53	0.120		17.53	0.120		17.53	0.120		17.53	0.120		17.53	0.120
5-4 Abandonment of Managed Lands (CO_2-uptake)	-3,292			-3,292			-3,292			-3,292			-3,292			-3,292			-3,292		
6. Waste		**17.36**	**0.123**		**18.34**	**0.127**		**21.05**	**0.130**		**20.7**	**0.134**		**20.55**	**0.134**		**21.70**	**0.143**		**22.38**	**0.147**
6-1 Solid Waste Disposal sites (SWDSs)		4.82			5.80			7.80			7.00			6.50			7.23			7.49	
6-2 Domestic & Commercial Waste		11.99			11.99			12.70			13.10			13.50			13.92			14.34	
6-3 Industrial Waste Water Handling		0.55			0.55			0.55			0.55			0.55			0.55			0.55	
6-4 Human Waste (Indirect N_2O)			0.123			0.127			0.130			0.134			0.134			0.143			0.147

Table 2.3 Summary of GHG emissions by sources and removals by sinks, 1990-1996 (Gg)

Greenhouse Gas	1990	1991	1992	1993	1994	1995	1996
1.1 CO_2-Emissions by sources							
All energy (Fuel consumption)	2,831	2,320	2,418	2,974	3,048	3,240	3,533
Industrial Processes:	293.0	295.6	298.3	311.1	281.8	277.6	268.1
Total $C0_2$ Emissions by sources	***3,124***	***2,615***	***2,717***	***3,285***	***3,330***	***3,517***	***3,801***
1.2 CO_2 Emissions and Removal by Sinks Categories							
Land use change and forestry							
Changes in forest and woody biomass stocks	-35,719	-36,372	-31,172	-25,724	-22,324	-23,150	-21,874
Forest and grassland conversion	5,738	5,738	5,738	5,738	5,738	5,738	5,738
Abandonment of managed and (Total CO_2 Uptake)	-3,292	-3,292	-3,292	-3,292	-3,292	-3,292	-3,292
Net Removals(-)/Emissions(+) of CO_2	**-33,273**	**-33,926**	**-28,726**	**-23,278**	**-19,878**	**-20,704**	**-19,428**
Total net CO_2 removals	**-30,149**	**-31,311**	**-26,009**	**-19,993**	**-16,548**	**-17,187**	**-15,627**
2.0 Methane emissions (CH_4)							
Biomass burned for energy	102.9	113.7	131.3	144.9	155.8	156.2	156.2
Agriculture	223.6	227.2	218.1	234.64	220.6	222.2	234.9
Land Use Change & Forestry	17.53	17.53	17.53	17.53	17.53	17.53	17.53
Waste	17.35	18.34	21.05	20.65	20.55	21.65	22.38
Total CH_4 Emissions	**361.4**	**376.8**	**388.0**	**417.7**	**414.5**	**417.6**	**431.0**
Total CO2 equivalent of CH4 emissions	***8,854***	***9,231***	***9,506***	***10,234***	***10,155***	***10,231***	***10,560***
3.0 Nitrous Oxide emissions(N2O)							
Biomass burned for energy	0.500	0.500	0.600	0.700	0.800	0.800	0.800
Agriculture	2.00	2.03	2.02	2.02	2.01	2.01	2.01
Land Use Change and Forestry (Grassland Conversion)	0.120	0.120	0.120	0.120	0.120	0.120	0.120
Human waste	0.123	0.127	0.130	0.134	0.134	0.143	0.147
Total N20 emissions	**2.74**	**2.78**	**2.87**	**2.97**	**3.06**	**3.07**	**3.08**
Total CO2 Equivalent of N20 emissions	**877.8**	**888.6**	**918.4**	**951.7**	**980.5**	**983.4**	**984.6**
Total CO2 Equivalent emissions by sources	***12,855***	***12,735***	***13,141***	***14,471***	***14,465***	***14,731***	***15,345***
4.0 TOTAL (NET) CO2 EQUIVALENT EMISSIONS BY SOURCES AND REMOVAL BY SINKS	**-20,418**	**-21,191**	**-15,586**	**-8,807**	**-5,411**	**-5,971**	**-4,082**

Table 2.4 Summary of Sectoral Contributions to the Total CO_2 Equivalent Emissions of GHG By Sources and Removals by Sinks, 1990-1996 (Gg)

TOTAL (NET) GHG EQUIVALENT EMISSIONS BY SOURCES AND REMOVAL BY SINKS	***-20,417***	***-21,191***	***-15,586***	***-8,807***	***-5,411***	***-5,971***	***-4,082***
1. All Energy	**5,512**	**5,265**	**5,827**	**6,748**	**7,122**	**7,323**	**7,616**
1.1 Fuel Combustion(CO2)	2,831	2,320	2,418	2,974	3,048	3,240	3,533
1.2 Biomass Burned for Energy(Non-CO2)	2,681	2,945	3,409	3,774	4,073	4,083	4,083
2. Industrial Processes (CO2)	**293.0**	**295.6**	**298.3**	**311.1**	**281.8**	**277.6**	**268.1**
Mineral Production							
2.1 Cement Production							
2-2 Lime Production			0.005	0.040	0.16	0.22	0.22
2-3 Limestone Use			0.210	0.450	27.95	28.66	28.82
2-4 Soda Ash & Sodium Bicarbonate				0.85	0.95	1.33	3.9
Chemical Industry			1.49				
2-9 Calcium Carbide Use					1.2	1.38	0.89
2.11 *Metal Production*							
2-11A Iron and Steel		0.022	0.544	1.61	3.18	3.00	3.60
2-11B Aluminium	293.0	295.6	296.3	307.0	248.3	243.0	230.6
4. Agriculture(CH4 and N2O)	**6,118**	**6,216**	**5,990**	**6,396**	**6,049**	**6,087**	**6,398**
4.1 Enteric Fermentation	1,588	1,662	1,446	1,860	1,509	1,525	1,525
4.2 Rice Cultivation	104.1	112.0	104.1	95.8	95.1	117.6	123.5
4.3 Prescribed Burning of Savanas	4,384	4,384	4,384	4,384	4,384	4,384	4,384
4.4 Field Burning of Agricultural Residues	19.17	27.78	28.32	28.32	39.10	40.60	39.63
4.5 Agricultural Soils	22.72	30.72	27.20	27.52	20.50	20.20	19.84
5. Land Use Change and Forestry	**-32,805**	**-33,458**	**-28,258**	**-22,810**	**-19,410**	**-20,236**	**-18,960**
5.1 Changes in forest and other woody biomass stock (CO_2 removals)	-35,719	-36,372	-31,172	-25,724	-22,324	-23,150	-21,874
5.2 Forest and grassland conversion (CO_2 emissions from biomass)	5,738	5,738	5,738	5,738	5,738	5,738	5,738
5.3 On-site Burning of Forest (CH4 & N2O Emissions from Biomass Burning)	467.9	467.9	468	467.9	467.9	467.9	467.9
5.4 Abandonment of Managed Lands (Total CO2-uptake)	-3,292	-3,292	-3,292	-3,292	-3,292	-3,292	-3,292
						0	
6. Waste (CH4 & N2O)	**464.7**	**490.0**	**557.4**	**548.9**	**546.5**	**577.4**	**596.3**
6-1 Solid Waste Disposa Sites (SWDSs)	118.1	142.1	191.1	171.5	159.3	177.1	183.5
6-2 Domestic & Commercial	293.8	293.8	311.2	321	330.8	341	351.3
6-3 Industrial Waste Water Handling	13.48	13.48	13.48	13.48	13.48	13.48	13.48
6-4 Human Waste (Indirect N20)	39.36	40.64	41.60	42.88	42.90	45.80	47.00

2.3 TOTAL GHG EMISSIONS BY SOURCES

The total CO_2, CH_4 and N_2O emissions by sources for the base year 1994 are 3,330, 414.6 and 3.07 Gg respectively. CO_2 emissions thus constitute 89% of the total GHG emissions by sources while CH_4 and N_2O contribute 11.1% and 0.1% respectively in absolute terms. However, considering the global warming potentials of CH_4 (24.5) and N_2O (320), the percentage share of CO_2 equivalent emissions changes very significantly to CO_2 (23%), CH_4 (70%), and N_2O (7%).

Figure 2.1 Share of CO_2 Equivalent Emissions by Gases, 1994.

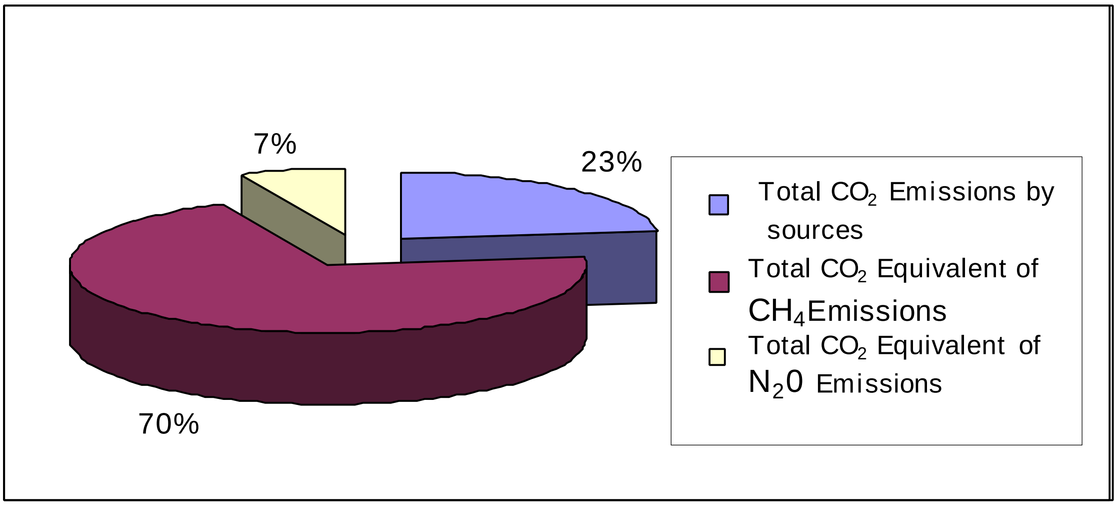
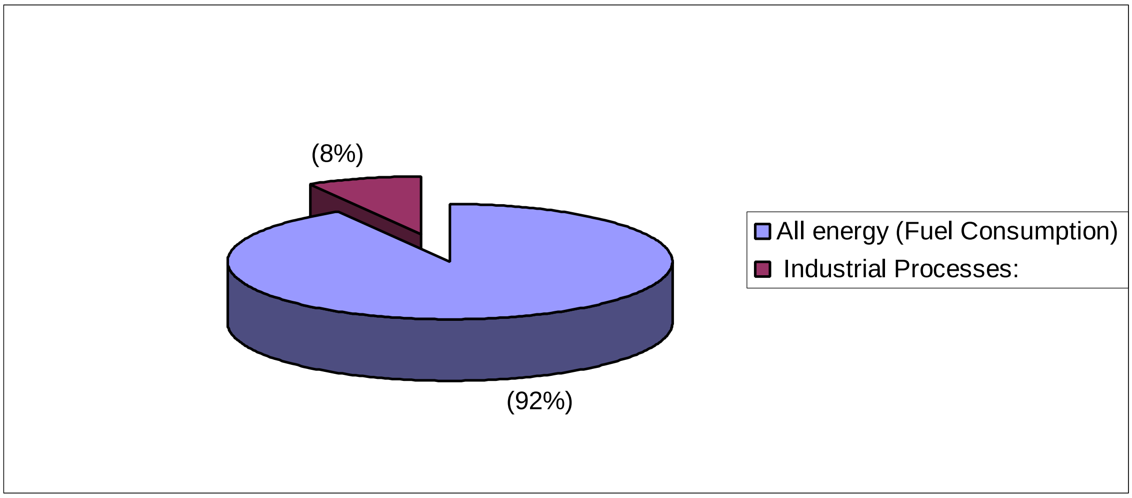


Figure 2.2 Share of CO_2 Emissions by Source Categories, 1994



2.4 CO_2 EMISSIONS BY SOURCES AND REMOVALS BY SINKS

The significant sources of CO_2 emissions are fuel combustion in the energy sector and industrial processes. The other sources are biomass burned for energy and burning of savanna in agriculture. However, the net emissions from these sources are considered zero because CO_2 is absorbed during re-growth period. Of the 3330 Gg emissions by source categories, in 1994, fuel combustion contributes 92% (3048 Gg), while industrial processes account for 8% (282 Gg) (Figure 2.2).

2.5 Total CO_2 Equivalent Emissions by Sources and Removals

The significant source categories of the total CO_2 equivalent emissions are energy (49%) and agriculture (42%), constituting 91% of the total CO_2 equivalent emissions. The total CO_2 equivalent emissions by sources of all GHGs (i.e. CO_2, CH_4, N_2O) for the base year is 1,4465 Gg CO_2 equivalent (Table 2.3) and the corresponding total net CO_2 removals by sinks is -19,878 Gg CO_2.

Thus, the carbon sinks in the forested and the reforested lands offset the total CO_2 equivalent emissions giving total net CO_2 equivalent removals by sinks as -5,411 Gg CO_2 equivalent in 1994. This made the country a net sink in 1994. The total CO_2 equivalent removals by sinks over the period, however, decreased drastically from -20,418 Gg (1990) to -4,082 Gg (1996) representing about 80% reduction during the inventory period. The sharp decline was due to the increase in the total CO_2 equivalent emissions (CO_2, CH_4 and N_2O increased by 6.6%, 14.7% and 12% respectively) and the decrease in total CO_2 removals by sinks which decreased by over 40% during the same period as a result of high rate of deforestation and correspondingly low reforestation (Table 2.3). Ghana was CO_2 equivalent remover from 1990 to 1996 (Table 2.4). The trend of the total CO_2 equivalent removals (Fig. 2.6), however, shows a significant decline of about 49% from 1990 to 1996. This was due principally to the reduction of CO_2 sequestration as a result of deforestation and other land use changes. These changes included expansion of agricultural lands and high increase in fuelwood and charcoal production.

Figure 2.3 CO_2 equivalent emissions by sources, 1994

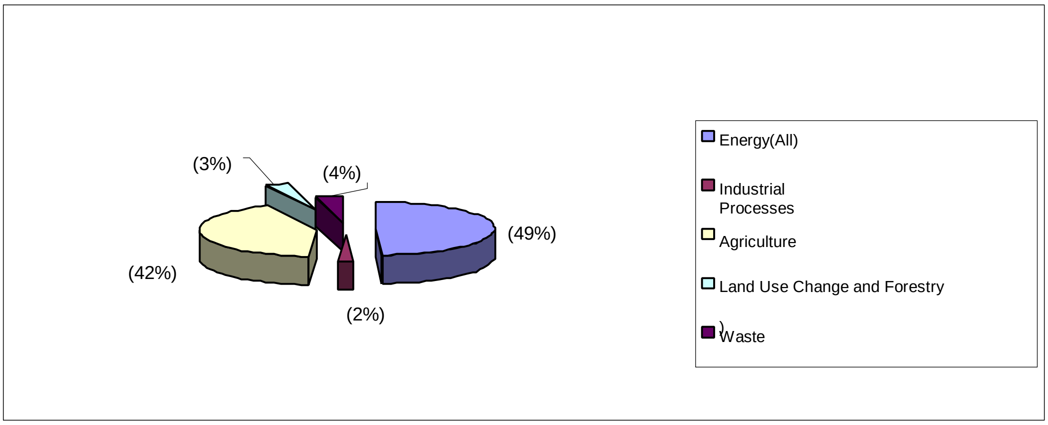


Figure 2.4 Total Net CO_2 equivalent emissions by sources and removal by sinks, 1994

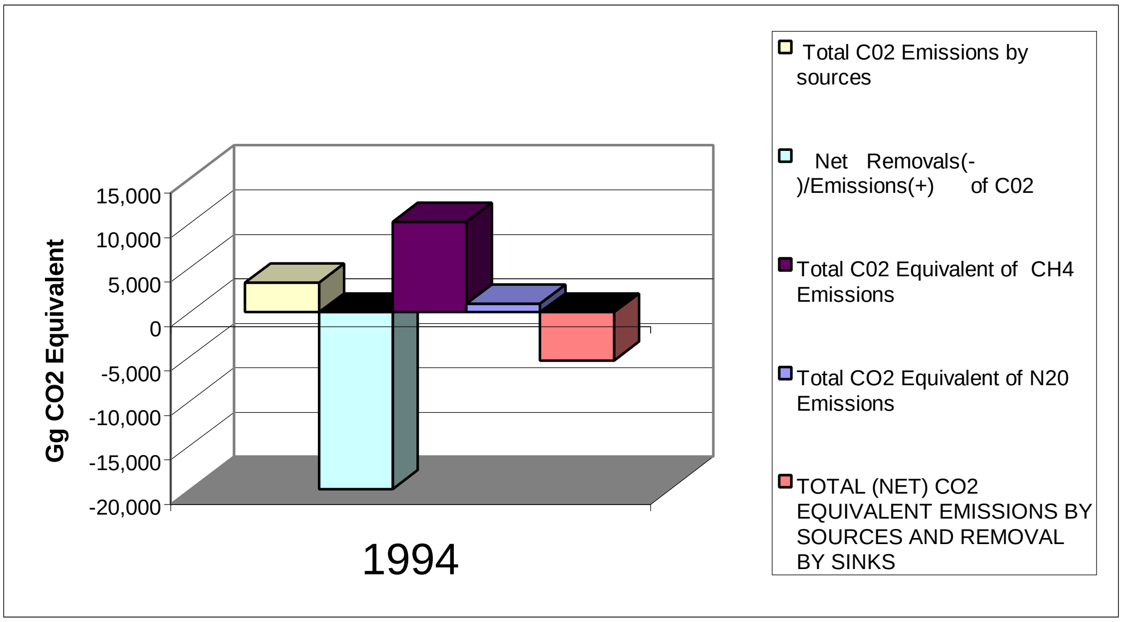
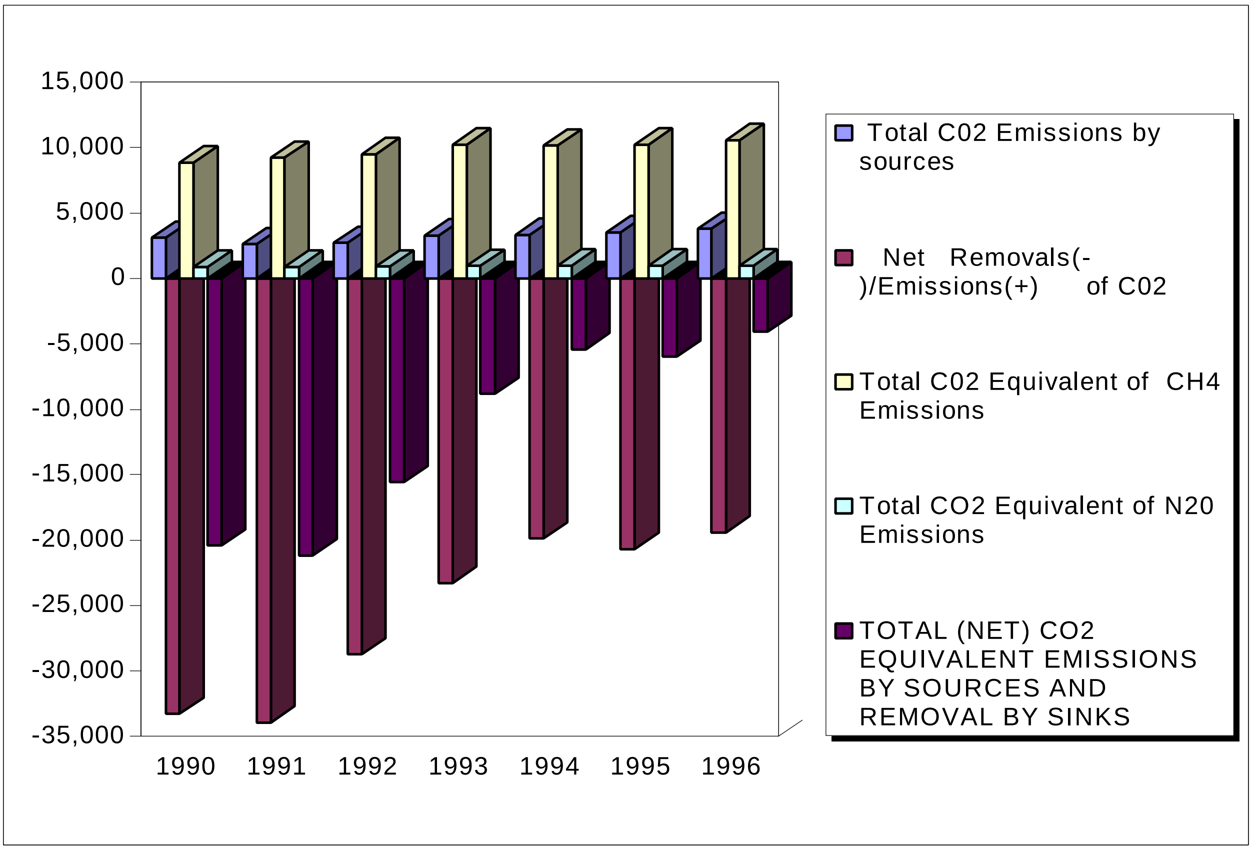


Figure 2.5 Trends in Total CO_2 equivalent emissions by sources and removals by sink 1990-1996



2.6 METHANE EMISSIONS BY SOURCES

Methane is predominantly emitted from biomass burned for energy and agricultural activities namely rice cultivation and prescribed burning of savanna. Both sectors accounted for 91% of the total CH_4 emissions in 1994. The contribution from solid waste disposal sites was very low because they were largely unmanaged shallow sites with very low methane emission potentials (Figure 2.6)

2.7 NITROUS OXIDE EMISSIONS BY SOURCES

Nitrous oxide is also emitted in much smaller amounts than CO_2 and CH_4. The total emissions for 1994 amounted to 3.1 Gg. as compared to CO_2 (3,048 Gg) and CH_4 (155.8 Gg). Regardless of the low emission levels N_2O like methane has much higher GWP of 320 and contributed to 6.8% of the total CO_2 equivalent emissions for 1994. (Fig. 2.7) The main sources of N_2O emissions are burning of savanna in the agriculture sector and biomass burned for energy. N_2O emissions from human waste is presently not significant because of the small population size and also the present low level of protein consumption per capita.

2.8 SECTORAL GHG INVENTORIES

The report of the sectoral inventories identifies the significant sub-sources and sinks categories of the respective economic sectors. The sectoral GHG emissions by sources and removals by sinks and the sectoral contributions to the CO_2 equivalent by all the GHGs are summarized in Table 2.3 and Table 2.4 respectively.

Energy

The emissions from the sector grew by 6.6% during the period 1990 - 1996. The sector contributed about 57, 122 Gg to the total CO_2 equivalent emissions in 1994. The share of fuel combustion was 3,048 Gg from the sector, while biomass burned for energy accounted for 4,073 Gg. The country's per capita CO_2 emission from commercial energy was relatively low for the inventory period. This was due to the fact that only 20% of the national energy consumption was as a result of fuel combustion, which leads to CO_2 emissions. Thus 80% of the national energy consumption (10% hydropower, and 70% biomass energy) do not contribute to the net CO_2 emissions from the sector. Non-CO_2 emissions from fuel combustion have not been estimated.

Figure 2.6 Share of CH_4 Emissions by Source Categories, 1994 (Gg)

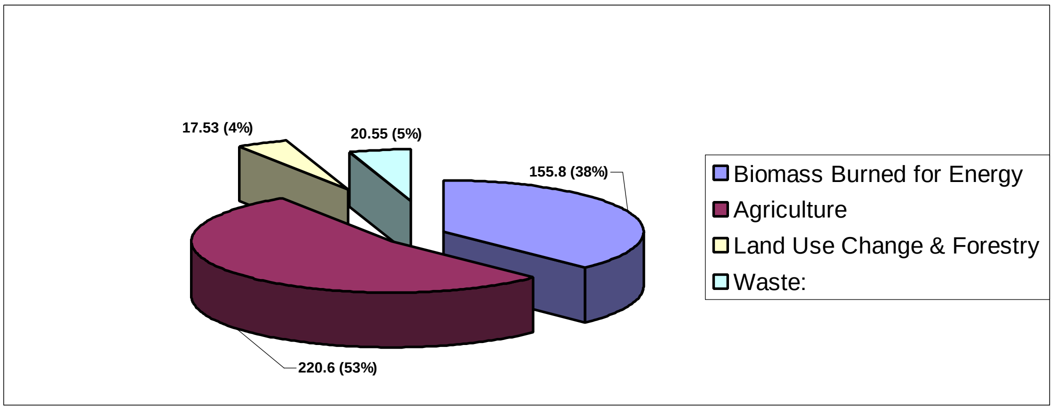


Figure 2.7 ***Share of N_2O Emissions by Source Categories, 1994 (Gg)***

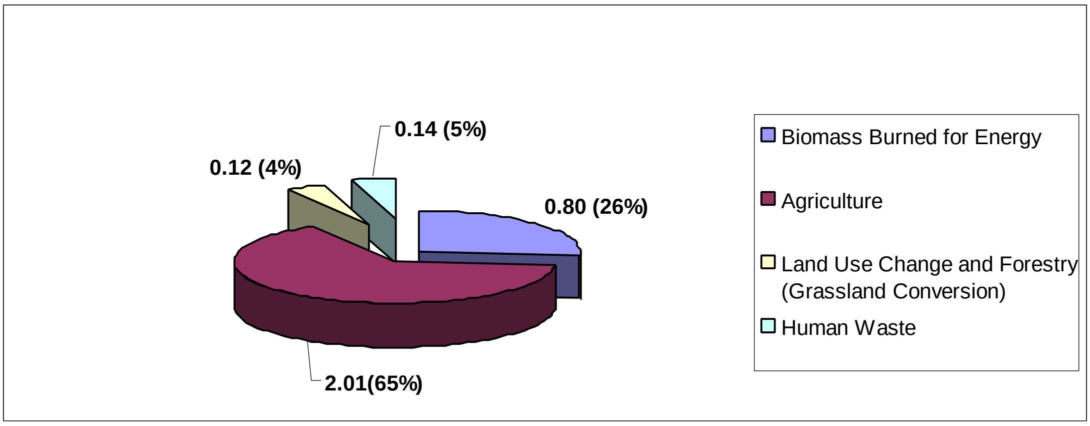


Figure 2.8 ***GHG Emission from Energy Sector, 1990-1996***

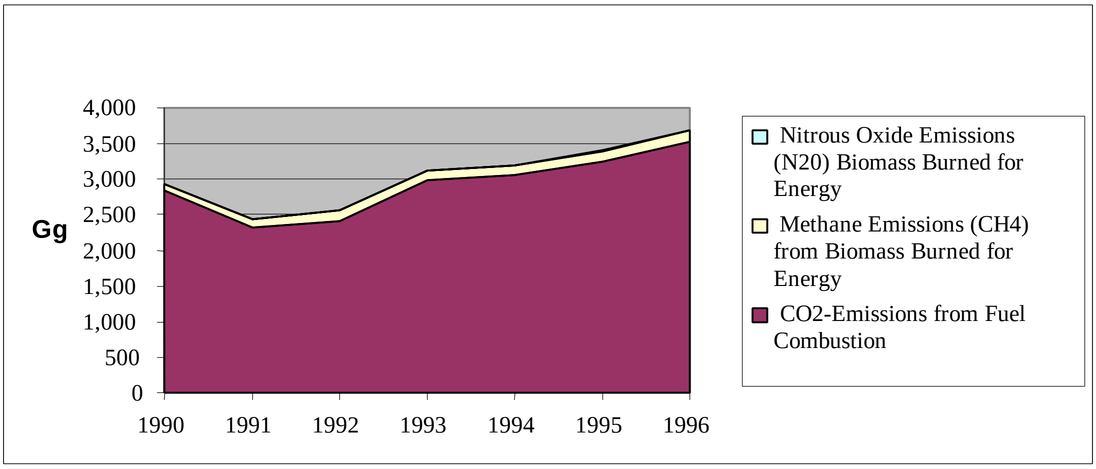
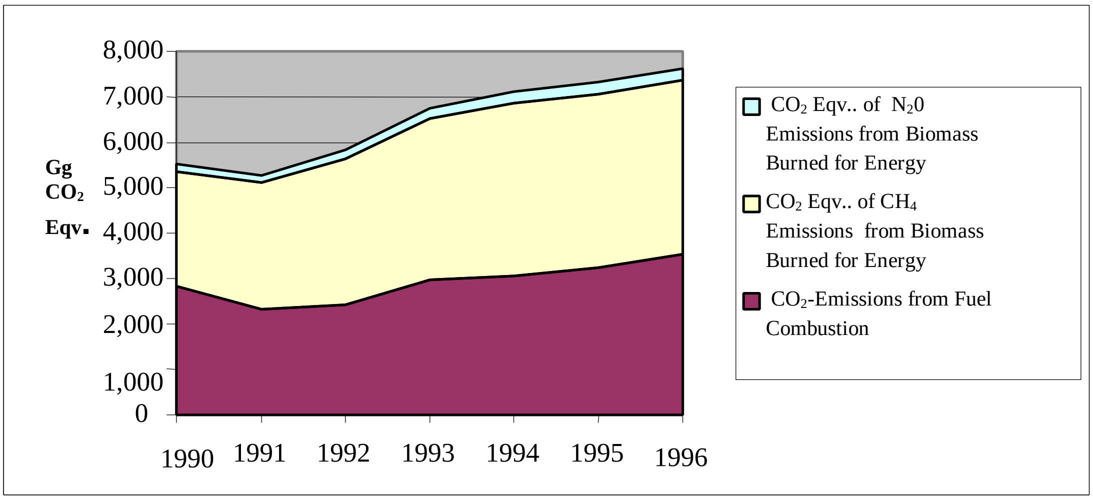


Figure 2.9 *Share of CO_2 Equivalent Emissions from Energy Sector, 1990 - 1996*



Industrial Processes

The contribution of the sector to total CO_2 equivalent in 1994 was 2%. The significant CO_2 source categories in the sector were aluminum smelting, limestone use, and iron and steel scrap melting plants. The CO_2 emissions from the sub-sectors in 1994 are aluminum (248.3 Gg), limestone use (28.0 Gg) iron and steel (3.18 Gg). Thus aluminum and limestone use contributed over 98% of total sectoral CO_2 emissions. Cement is currently produced from clinker processing and therefore does not contribute to CO_2 emissions. The emissions from the aluminum sector decreased from 1994 due to reduction in hydropower production, which supplies power to the aluminum plant. This was also due to low water levels arising from the low precipitation in the Volta catchment, which suggests the vulnerability of the water resources to climate variations.

Agriculture

The non-CO_2 emissions from the sector for 1994 are CH_4 (220.6 Gg) and N_2O (2.01 Gg). The total CO_2 equivalent emissions thus amounted to 6,049 Gg, which is quite close to energy sector emissions of 7,122 Gg. The significant source categories in the sector were burning of savanna and enteric fermentation. .The CO_2 emissions from burning of savanna and agricultural residue were considered zero since there is re-absorption during re-growth. Burning of savanna in the agriculture sector contributed to 68% whilst enteric fermentation accounted for 28.4% of CH_4 emissions in 1994. About 95% of the total N_2O emission in 1994 in this sector was due to savanna burning.

Land Use Change and Forestry

In 1994 the estimated CO_2 emissions by forest and grassland conversion amounted to 5738 Gg while the total CO_2 removals by the country's sinks was estimated at -25,618 Gg. This gives the net CO_2 removal by sinks in the land use change and forestry sector as -19,878 Gg for 1994. The sector is therefore very important in providing the country's sinks for CO_2 sequestration. The total non-CO_2 equivalent emissions of CH_4 and N_2O from on-site burning of forest were very low, estimated at 467 Gg, CO_2 equivalent representing only 3% of the total emissions.

The CO_2 removals by the country's sinks however reduced drastically from -40275 Gg. (1973) to as low as -5411 Gg (1994) within about two decades. The sharp decline is attributed to the following national circumstances.

- Seasonal biomass clearings annually for farming, grazing lands, mining and settlements.
- Charcoal and fuelwood use has been increasing over the years (approximately 2.3 times of wood harvested for timber in 1973).
- Restoration of deforested lands was minimal.
- High population growth led to shortening of fallow periods.
- Stocking levels of timber in the high forest area has fallen.

Waste Sector

The methane emissions from the various sub-categories were very low due to absence of waste management practices. The methane emissions from Solid Waste Disposal Sites

(SWDSs), based on the recommended IPCC methane correction factor of 0.40 for shallow unmanaged SWDS (<5-m depth), ranged from 4.8 Gg in 1990 to 7.50 Gg in 1996. The increase may be the result of increased population and increase in the volume of solid waste disposal to SWDSs.

The total estimated methane emissions from domestic and industrial wastewater handling source categories increased slowly from 17.35 Gg in 1990 to 22.35 Gg in 1996. The increase was attributable to increased urban population using septic tank sewage treatment that approximates to anaerobic system.

The estimated nitrous oxide (N_2O) emissions from human sewage increased from 0.12 Gg/yr. in 1990 to 0.15 Gg/yr. in 1996 as a result of increased population. The relatively low N_2O is accounted for by the low protein intake per person per year, estimated at approximately 10% of WHO level of 25.55 kg/person/year.

Figure 2.10 CO_2 equivalent emissions from agriculture, 1990 - 1996 (Gg)

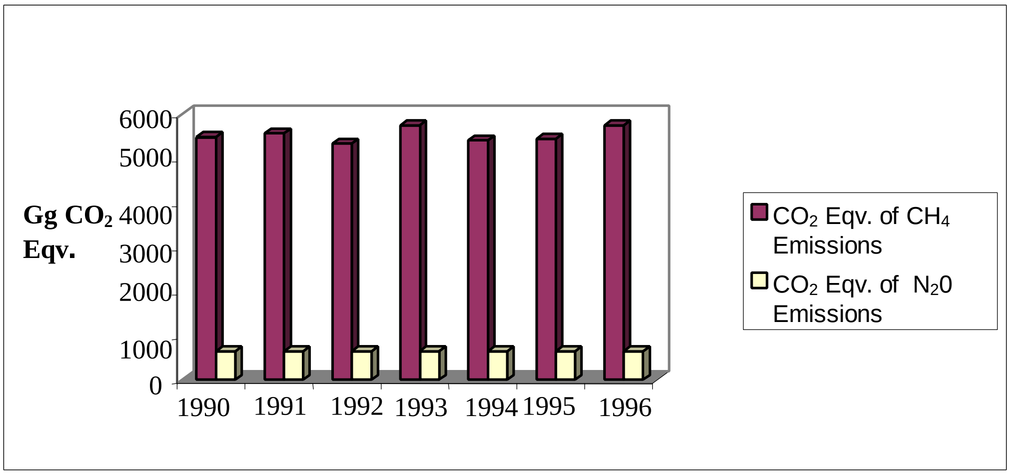
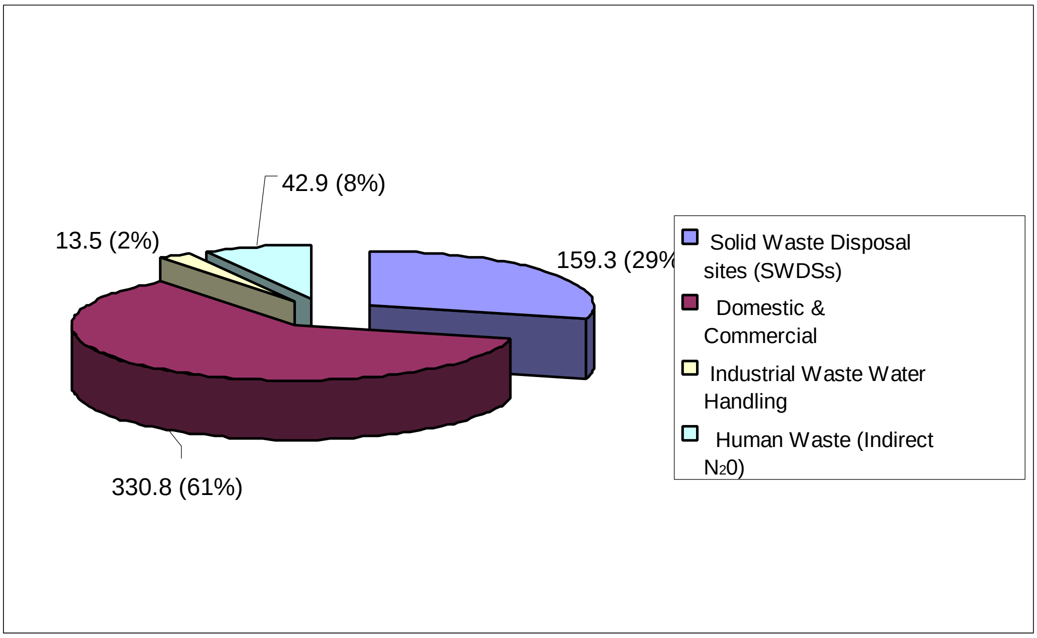


Figure 2.11 Share of CO_2 Equivalent Emissions by Sources from Waste Sector (Gg)



CHAPTER THREE

3.0 IMPACTS, VULNERABILITY AND ADAPTATION

INTRODUCTION

The assessment of Ghana's vulnerability to Climate Change was carried out to evaluate how changes in climate may affect segments of the national environment, elements of the national economy, human health and welfare. Three key national resources that might be susceptible to climate change were studied. These included; water resources, coastal resources and agricultural crops. The vulnerability assessment consisted of analysis of the scope and severity of the potential effects of climate change, looking at possible temperature rise, decreased precipitation and rise in sea level.

The vulnerability studies further assessed possible adaptation and policy options that can be taken to prepare for climate change.

3.1 WATER RESOURCES

3.1.1 Introduction

Water resource in Ghana is vital for socio-economic development. Impacts of climate change on the water resource can put the country at risk and thus assessment is for planning and management to reduce the effects.

The country's water resources can be put into two broad divisions: surface and groundwater resources. The surface water resources depend on the magnitudes of river discharges or runoffs and the groundwater on recharge and capacities of the aquifers.

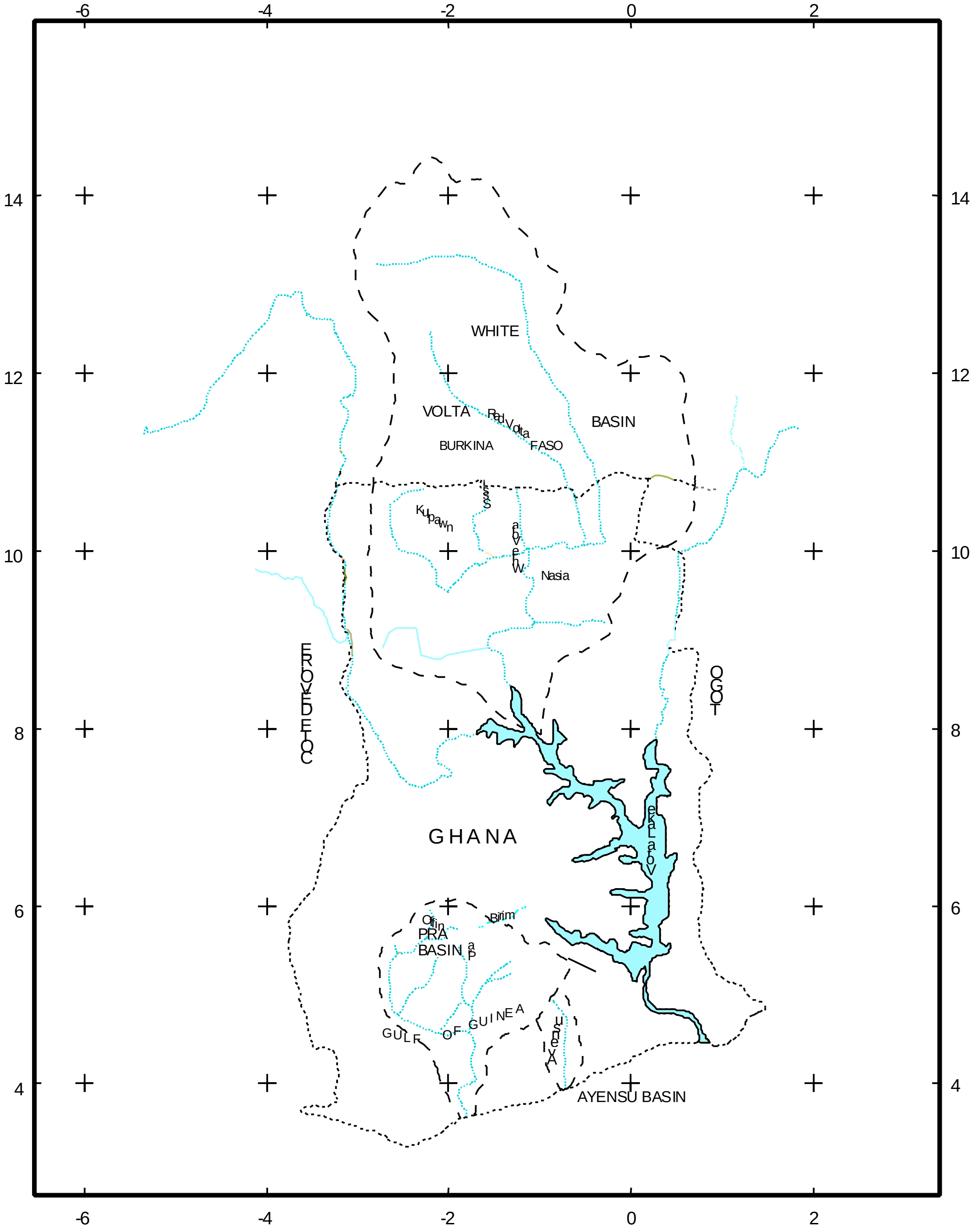
In assessing the impacts of climate change on water resources, representative basin approach was used. A basin was chosen from each of the three hydroclimatic zones spanning the country. The basins are Pra from the South-Western basin system, Ayensu from the Coastal basin system and the White Volta from the Volta basin system (Fig. 3.1)

Scenarios of potential future climate were developed using three Global Circular Models (GCMs) and a simple climate model. River discharges were simulated by a water balance model using the climate scenarios of temperature and precipitation for the year 2020 and 2050.

Recharges to groundwater storage were computed from the water balance components. The recharges were then used in estimating the groundwater potential. The sum of the available surface and groundwater resources constitutes the total water supply for the basin.

Estimates for domestic, industrial and irrigation water demands based on socio-economic indicators for the year 2020 and 2050 were carried out. Water demands for the same socio-economic conditions under climate change scenario were then computed. Irrigation water demands incorporating changes in evapotranspiration and precipitation were estimated using CROPWAT model. Total water demand was computed by aggregating the various demands.

Fig. 3.1 A Map showing the Representative Basins



Hydropower generation was simulated from WEAP, a water evaluation and application model.

Impacts and vulnerability assessments in each basin were carried out on water supply and demand. The results were then transferred to the whole hydroclimatic zone on the basis of homogeneity of characteristics within each zone. National impact and vulnerability were then finally inferred.

The following were the findings of the study:-

1. There was observed increase in temperatures of about 1^oC over a 30 year period and reductions in rainfall and runoff of about 20 and 30% respectively in the historical data sets.

2. Runoffs or discharges in all the representative basins are sensitive to changes in precipitation and temperature and thus to climate change. A 10% change in precipitation or a 1^oC rise in temperature can cause a reduction in runoff of not less 10%.

3. Simulations using projected climate change scenarios indicated reduction in flows between 15-20% and 30-40% for the year 2020 and 2050 respectively in all the basins.

4. Climate change can cause reduction in groundwater recharge between 5 and 22% by the year 2020. Reductions for the year 2050 are projected to be between 30 and 40%.

5. Domestic and industrial water demand may not be affected by climate change.

6. Irrigation water demand could be affected considerably by climate change. In the humid part of the country, the projected increase in irrigation water demand due to climate change by 2020 and 2050 will be about 40 and 150% respectively of the base period water demand. However, the relative increases in water demand due to climate change over the scenario without climate change in the same period are 5% and 17% for the year 2020 and 2050 respectively. For the dry interior Savanna, the corresponding increases in water demand in 2020 and 2050 are projected to be about 150 and 1200% of the base period water demand respectively. Similarly, the relative increases in water demand due to climate change over the scenario without climate change for the same period of 2020 and 2050 are 4% and 12% respectively.

7. Hydropower generation could seriously be affected by climate change. The projected reduction by 2020 is about 60% from the base value in the Pra basin modeled by WEAP.

8. From the socio-economic point of view, there may be secondary impacts on health, nutrition and energy-based industrial activities, if proper adaptation options are not embarked upon.

9. A vulnerability index involving the application of water availability and use criterion indicated that the country, apart from the coastal basin, has water surplus in the base year (1990). The coastal basin has, however, water management problems in the base year. By the year 2020 and 2050 all the basins will be marginally vulnerable. That is, the country will face water management problems.

10. The use-availability ratios in the country are very small. The values are 2-10% and 5-31% for 2020 and 2050 respectively. Should this ratio increase to 40% to meet food security and export, the whole country will be vulnerable. It is worth noting that the marginal

vulnerability predicted for 2020 and 2050 are due to projected low use-availability ratios based on our current water consumption patterns.

11. Adaptation options suggested were in general for water conservation and efficient use of water for projected reduction in water resources.

3.1.2 The Climate and climate change scenarios

3.1.2.1 Climate

Ghana is located in the tropical region of West Africa between latitudes 11.5^{o}N and 4.5^{o} S and longitude 3.5^{o} W and 1.3^{o} E. The climate is dominated by two major air masses: the dry and warm North-East Trade Winds and the moist South-Westerlies or the monsoons. The moist maritime monsoons are associated with rainfall while the dry Trade Winds bring dry conditions. Thus the country has distinct dry and wet seasons depending on the dominant wind in the area.

The country is spanned by three hydroclimatic zones and these are the Volta basin system, the South-Western basin system and the Coastal basin system. The South-Western system is the most humid part of the country with mean annual rainfall between 1500mm and 2000mm. The Volta basin system covering the northern part of the country has mean annual rainfall of about 1000mm in the Savanna area and about 1500mm to 2000mm in the forest area. The Coastal basin system is the driest with mean annual rainfall of about 900mm.

3.1.2.2 Climate Scenarios

Two sets of climate change scenarios were used in the study and these were synthetic scenarios and scenarios based on global climate system. The climatic parameters represented in the scenarios for climate change were temperature and rainfall.

The synthetic scenarios were developed from the temperature and precipitation of the base period. The temperature was uniformly incremented by 1^{o}C and 2^{o}C and the precipitation by reduction and increase of 10% and 20%. The synthetic climate change scenarios were used in testing the sensitivities of the hydrologic model to potential climate change.

The second set of climate change scenarios used was derived by a process-based method involving three General Circulation Models (GCM). The average of the three GCM experimental results was used in the calculations.

The simple climate model used is known as MAGICC (Model for the Assessment of Greenhouse Gas Induced Climate Change). The results of the MAGICC experiments were linked to the average results of the three GCM experiments by computer software known as SCENGEN (Scenario Generator) to construct a range of climate change scenarios. Observed global and regional climatic data were also used during the scenario development. The climate change scenarios were projected for different time horizons under this procedure.

The results of the scenarios indicated that mean daily temperatures will increase by 2.5^{o}C to 3.2^{o}C over the 1961-1990 baseline by the year 2100. Further, it was projected that annual rainfall totals, using medium sensitivities, will decrease by about 9 to 27% throughout the country by the year 2100. The reductions vary spatially.

3.1.2.3. Impacts of Potential Climate Change on Water Resources

Impacts of potential climate change on surface water resources were assessed via impacts on river discharges. The groundwater resources were assessed on the basis of recharge under climate change scenarios.

3.1.2.4. River Discharge

Impact assessment on stream flow, and thus the surface water resources, was carried out through model simulations. The model used, WATBAL, is a water balance model. It has precipitation and temperature as basic inputs for simulating stream flow or runoff.

The calibration and validation of the model in the basins (Fig. 3.1) were all satisfactory with correlation coefficients between observed and simulated values in the range of 0.74 to 0.92.

Also, changes in runoff from the model prediction compared favourably with the changes observed in the historical data sets, thus demonstrating the goodness of fit of the model and its veracity for assessing impacts on runoffs. Increases in temperatures of about $1^{o}C$ over a 30-year period and reductions in rainfall and runoff were observed in the historical data sets.

The impacts of climate change on the runoffs were assessed by comparing the simulated runoffs under the future climate change scenarios and the base scenario. The future climate change scenarios used in the simulations were those derived from General Circulation Models and Regional Atmospheric Models.

Results indicated that runoffs are sensitive to changes in precipitation and temperature in all the representative basins. The magnitudes of the changes are approximately similar in all the basins. However, these changes were not uniform. A 10% change in precipitation at constant temperature produced between 10% to 25% changes in runoff depending on the magnitudes of precipitation and temperature at which the changes occurred. Similarly, for a $1^{o}C$ rise in temperature, there was a reduction of about 10% to 23% in runoff.

Simulations using GCM-based scenarios indicated reductions in flows for the future. Reductions in flows for the year 2020 are 17%, 20% and 16% for Pra, Ayensu and the White Volta basins respectively. Similarly, for the year 2050, the reductions are 33%, 37% and 37% for the corresponding basins. These results obtained for the representative basins can be applied to the corresponding river basin system in the country.

3.1.2.5. Groundwater Recharge

Groundwater resources are the main sources of domestic water supply in villages and some small towns. Thus recharge of groundwater from the supply point of view is important.

Impacts of potential climate change on groundwater recharge in the representative basins were evaluated from the subsurface and baseflow components generated from the WATBAL model. The recharge was estimated as the sum of subsurface flow and base flow.

In the base period, the mean annual recharge for Pra, Ayensu and White Volta basins are 3.83, 0.13, and 3.78×10^9 m^3/year respectively. In terms of depth, the corresponding annual recharges are 0.456, 0.207 and 0.224mm. Thus the recharges in the relatively dry Ayensu and White Volta basins are about half of the humid Pra basin.

Concerning the impacts, there were reductions in recharges in all the representative basins for the climate change scenarios in the year 2020 and 2050. For the year 2020, the reductions are 17%, 5% and 22% for Pra, Ayensu and the White Volta basins, respectively. The reduction in the Ayensu basin is unduly low. The reductions for the year 2050 are even greater and are 29%, 36% and 40% for Pra, Ayensu and the White Volta basins, respectively.

Comparing the reductions in recharges of the groundwater to reduction in streamflows, it could be seen that the percentage reductions are similar. This implies that climate change will equally impact on streamflow and groundwater resources.

3.1.3. Impacts of Potential Climate Change on Water Demand

3.1.3.1 Domestic And Industrial Water Demand

Domestic water demand is driven to a large extent by the population growth and the industrial water demand by expansion of industries for socio-economic development.

The direct impact of climate change, in terms of temperature and precipitation changes, on water demand by most industries is envisaged to be very small. The climate change impacts, with rise in temperatures, may be on cooling processes.

Available scanty literature indicates that residential water demand is inversely correlated with precipitation and positively correlated with average temperature. Due to lack of data, the impacts of climate change on domestic water demand from this point of view could not be investigated. However, from expert judgement, the impact of climate change on domestic and industrial water demand may not be significant.

3.1.3.2 Irrigation

Irrigation of crops in the country is traditionally on a low scale due to the country's dependence on rainfed agriculture. Irrigation of crops is, however, bound to increase because of the need to crop all year round to feed the rapidly growing population.

In assessing the impacts of climate change on irrigation water demand, the CROPWAT model was employed to determine the net irrigation water requirements using the temperature and precipitation scenarios for the base period, 2020 and 2050 period as inputs. The net irrigation water demand was converted to the gross water demand by dividing by the local efficiency factor of 0.54.

The gross water demands in the representative basins were determined for the year 2020 based on planned area to be put under irrigation by Ghana Irrigation Development Authority (GIDA), without consideration to climate change and then with climate change. For the year 2050, the areas to be irrigated were estimated based on population increase from 2020 to 2050. The water demands were computed with and without climate change as a factor.

The results in the Pra basin indicated that the water demand for the year 2020 will increase by 551% and 510% from the base period's magnitude with and without climate change respectively. Thus the change due to climate change alone will be 41% of the base value. Similarly, for the year 2050 in the Pra basin, the changes with respect to the base values are 922% and 771% with and without climate change respectively. Thus the change due to climate change alone in 2050 is 151% of the base value. The water demand for the base period is about 4,200,416m^3 and thus the water demand under climate change can be substantial.

In a similar analysis, water demand for the years 2020 and 2050 in the Ayensu basin for climate change alone are 141% and 652% respectively of the base value of 48,128m^3.

The water demand in the White Volta basin for the years 2020 and 2050 for climate change alone are 278% and 1,206% respectively of the base value of 6,056,400m^3.

It is interesting to note that the changes in area put under cultivation from the years 2020 to 2050 in all cases were slightly less than 50%. However, the changes in the water demand due to climate change were about four (4) times.

3.1.3.3 Hydropower Generation Impacts

Hydropower generation is determined by the head of water behind a dam on a river. The head is also related to the amount of water behind the dam.

In assessing the impacts of climate change on hydropower generation, the WEAP model was used in routing the flows through the dams for hydropower generation. The WATBAL was first used in simulating the flows under different climate change scenarios. The output was then expressed as hydrological fluctuations and used as input for the WEAP model.

The WEAP model was run for only Pra basin for the 1990 (the base year) and 2020. The inflows in 2020 showed a reduction of about 45% from the base value. The energy generated for the base case was about 108 and 160 GWh for Awisam and Hemang potential sites respectively. However, for the altered climate scenarios, the energy generated was about 41% of the base values, i.e. 59% reduction.

3.1.4 Potential Impacts Climate Change on Socio-Economic Activities and Floods

3.1.4.1 Socio-economic Impacts

The climate change impacts to be experienced under socio-economic conditions are second - order impacts; the first order impacts being on the supply and demand of the water resource. The findings indicate that both surface and groundwater resources will decrease across the country in the year 2020 and 2050. Water demand will in general, increase due to increase in population and the need for improvement in socio-economic conditions. Climate change will increase irrigation water demand in the country.

Simulation of hydropower, which forms 77% of current-electric energy in the country, indicated considerable reduction in hydropower output of order of 59%.

From the foregoing, there may be impacts on health, nutrition, employment and energy-based industrial activities, if proper adaptation options are not embarked upon.

3.1.4.2 Floods

In assessing the impact of potential climate change on flood, it was found that the present resolution of the General Circulation Models (GCM) is insufficient to simulate rainfall intensities for individual storms adequately.

The products of streamflows simulated from the climate scenarios were monthly totals and averages and could not be related to floods. This is because floods are usually associated with rainfall intensities with short duration of order of few hours or days.

Floods can be associated with the magnitudes of 24-hr maximum rainfalls. Since scenario monthly rainfall totals for the future were available, relationships between historic 24-hr maximum rainfalls and monthly rainfall totals were investigated. The relationships observed were inconsistent. Thus, the monthly rainfall totals developed under the climate scenarios were not useful for assessing flood potential under climate change.

Available literature indicates that, in some parts of the country, the last decade (1986-1995) had the most devastating rainfall events and a relatively high number of 24-hour maximum rainfall events. Increases in temperatures have also been observed in this study for all the basins and this tends to suggest that the observed increases in flood frequency in recent times may not be mere natural variability as stated in literature. This is due to the reason that increase in air temperature and evapotranspiration should result in larger thunderstorms and a greater risk from flash flooding. Further studies will be needed on this observation whereby it can be used as a historical analogue for climate change impacts on floods.

3.1.5. Vulnerability

In assessing vulnerability, the total potential water resources available from surface and groundwater resources were computed for the various scenarios as the supply component. The supply per capita was then estimated. The supply term used here is independent of infrastructure. The constraint imposed by infrastructure was removed because at the country's level of development, water supply based on infrastructure cannot meet domestic and industrial water demand. Thus the systems can be described as vulnerable under the present circumstances.

Total water demand based on domestic, industrial and irrigation water requirements were estimated for the base year, 2020 and 2050 and then used in computing per capita water demand.

A joint availability and use level criterion was developed and used in assessing the basins' vulnerability to climate change. A summary result is presented in Table 3.1. From the results in the Table and the criteria set in Kulshreshtha (1993), it can be concluded that Ghana will be marginally vulnerable under climate change by 2020 and 2050 if assumptions on our water use patterns do not change drastically from the projected values for accelerated development. The other assumption is that infrastructure will not be a limiting factor for water supply to meet demand in the country.

Table 3.1 Combined availability-use criterion of Vulnerability

		Supply per capita (m^3)	Use/ Availability (%)	Type of Vulnerability
1990	Pra	3,679	0.7	*
	Ayensu	1,587	3.6	**
	White Volta	4,917	0.3	*
2020	Pra	1,349	2.0	**
	Ayensu	523	10.3	**
	White Volta	1,606	5.7	**
2050	Pra	488	5.6	**
	Ayensu	166	31	**
	White Volta	538	13	**

* Not vulnerable or water surplus
** Marginally vulnerable (water management problems)

Hydropower generation could be judged to be extremely vulnerable by the year 2020 due to over-dependence on this relatively cheap source of electricity in the country. The reduction in power generation of the order of 50% simulated for the Pra basin in 2020 underlines the fact that existing supply cannot meet future demand.

3.1.6. Adaptation Options

The adaptation options in this sector could be viewed from two perspectives: the supply and demand options. Under each option, we have adaptations which could be spontaneous and referred to as autonomous adaptation and the other which involves deliberate policy decisions also known as adaptation strategy or option.

3.1.6.1 Supply Adaptation Options

Autonomous adaptation options which could be embarked upon by stakeholders in the face of stream flow reduction under climate change involve the use of groundwater resources from shallow and hand-dug wells to supplement the shortfalls especially during the dry seasons. Water conservation practices such as rainfall harvesting at domestic level may be increased. Those who can afford paying for water tanks may acquire such facilities for water storage during the rainy season.

There may also be a natural migration of people from water-stressed areas to areas with relatively good amounts of water supply. People may also move from rural areas to the cities and urban areas which are served with pipe-borne water supply. This will lead to rural to urban drift in population with its attendant problems such as sanitation and poor housing facilities. There may also be rural unrest and confrontation of the rural communities with

those entities degrading the water resources. It is recommended that sound environmental management policies be fully formulated and pursued.
The adaptation options to be embarked upon from the supply perspective include shifts in spatial and temporal distribution of river flows. It was found out that the Volta basin is less vulnerable among the river systems in the country. It may, therefore, be necessary in the long-term to transfer water from the Volta basin to the Coastal basin system which is more vulnerable.

Currently, water is transported from the Volta basin at Kpong, down the Akosombo hydropower generating site, to Accra for domestic and industrial water supply. This transfer of water will have to be increased to meet rising urban population and the impact envisaged on the Densu river flows in the Coastal basin system since the Densu basin is more vulnerable than the Volta basin.

Poor land-use practices including uncontrolled deforestation have the effect of exposing the land surfaces to erosion and sedimentation of reservoirs for water supply and hydropower generation. Reservoirs will be needed to store more water from reduced flows for dry season demand of water and for hydropower generation. Thus, the existing reservoirs must be kept free from sedimentation either by prevention through proper land use practices or by routine removal of the sediments. Farming, for example, should be done, at least, 50m from the river courses.

Reservoirs may also have to be built on rivers which have run-of-the-river-intake points without storage because of reduction inflows. Afforestation should be encouraged to enhance dry season flows in the basins. The process could enhance infiltration and groundwater recharge. The water quality could also be improved or maintained under afforestation. Care should, however, be taken in the choice of tree crops to plant as some species of exotic plants could deplete the water resources through increased evapotranspiration. Artificial recharge may also be employed to reduce evaporation and improve groundwater recharge.

Other measures to improve water supply include changing location or height of water intakes by using floating intake structures, installing canal linings and using closed conduits instead of open channels in transporting water, to say, irrigation fields.

Towns and villages which are sited near river courses should be prevented from polluting the rivers. An example is Nsawam near river Densu in the Coastal basin system. The waters of the Densu river serve the eastern part of Accra and the resource needs to be protected, especially under climate change where projected water resources indicate reduced quantities.

3.1.6.2 Demand Adaptation Options

Autonomous adaptation in water demand where resources become limiting in quantity involves reduction in the amount of water use for various activities. Activities may also be reduced or curtailed, e.g. in industrial activities. These, however, may not be the best option.

The principle of planned adaptation in demand is to use water in the most efficient manner and this includes reduction in water losses.

There will be the need to educate the population on the economic use of water by the introduction of the concepts of demand management. There will also be the need to install or build very efficient infrastructure capable of maintaining the right water pressure and water heads. These will reduce water losses through pipe bursts and losses encountered at the service points due to excessive high head or pressure. Pipe bursts should be repaired promptly with urgency than what is hitherto the practice.

There should also be the use of efficient domestic appliances. Dual supply system for potable and non-potable water may be put in place. There may also be the need to recycle domestic water for non-potable uses.

Reduction in industrial water use could be done through reuse of acceptable quality of water, recycling and dry cleaning technologies.

With reduced flows, there will be the need for efficient water use for energy generation. This could be achieved by keeping reservoirs at lower head to reduce evaporation. Further, in constructing new hydropower schemes, low head run of the river should be considered as appropriate measures for adaptation. More efficient hydropower turbines should also be introduced. In the country as at now, additional hydropower schemes will be required to meet the energy needs of the increasing population and its associated demand.

3.2. AGRICULTURE

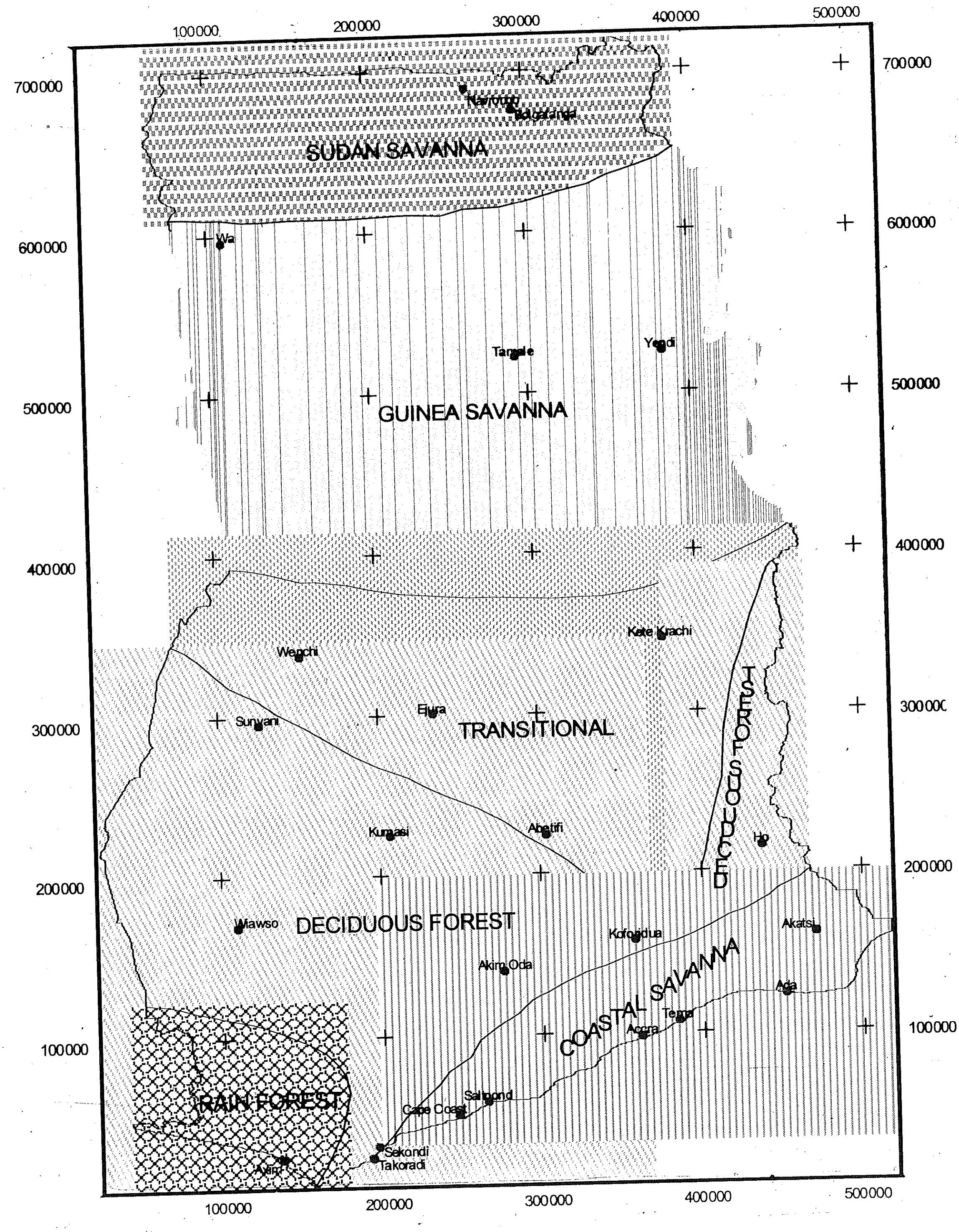
3.2.1 Introduction

Analysis of climate change on cereal production in Ghana and adaptation strategies to deal with the potential climate change effects was done. Future climate change scenarios on temperature, solar radiation and rainfall were generated using General Circulation Models. The impact of climate change on cereal production was assessed using the CERES model. CERES MAIZE and CERES MILLET models were used to generate growth and yield of maize and millet, respectively.

The future climate change scenarios generated indicated that both the maximum and minimum temperatures increased over years in all agroclimatic zones of Ghana (Fig 3.2), but the increases were higher in the Sudan Savanna Zone where temperatures are normally the highest.

The projections indicate that the average maximum temperature of the Sudan Savanna Zone is expected to increase by $3^{o}C$ by the year 2100 and $2.5^{o}C$ in all other agroclimatic zones. The average minimum temperature is expected to increase by $2.5^{o}C$ in the Sudan Savanna, Guinea Savanna and the Semi-Deciduous Rainforest Zones by the year 2100. For the Transition and the High Rainforest zones, the minimum temperature is projected to increase by $3^{o}C$ and $2^{o}C$, respectively, by the year 2100.

Figure 3.2 Agroclimatic Zones of Ghana



The average solar radiation was projected to increase by 1.95MJ/m^2 in the Transition and the Semi-Deciduous Rainforest zones, 1.0MJ/m^2 in the Guinea Savanna Zone, and 0.75MJ/m^2 in the High Rainforest Zone, by the year 2100.

With respect to projected rainfall, the mean annual rainfall would decrease by 170 mm in the Sudan Savanna Zone, 74 mm in the Guinea Savanna Zone and 99 mm in the Semi-Deciduous Rainforest Zone, respectively by the year 2100. In the High Rainforest Zone, however, the mean annual rainfall was projected to increase by 1105mm by the year 2100.

Using the projected climate scenarios and CERES model, it was projected that the yield of maize would decrease in the Transition Zone from 0.5 percent in the year 2000 to 6.9 percent in the year 2020. The yield of millet however was not affected by the projected climate change because millet is more drought tolerant and also insensitive to temperature rise.

3.2.2 Climate Change and Cereal Production in Ghana.

The important cereals grown in Ghana are maize, millet, sorghum and rice. Cereals as crop group were chosen because of their importance to the national economy and food security and other vulnerability to climate change.

The production of these cereals in Ghana is influenced by soil and climatic factors. The poor fertility status of soils of Ghana and irregular climatic conditions such as untimely onset of rainfall and abrupt cessation of rainfall during the growing season, adversely affect the production of cereals in Ghana.

In recent times, the recurrence of droughts and floods in the Northern Savannas is common. Drought conditions in the Northern Savannas are often associated with high temperatures and intense heat. The yields of cereals are typically low in Ghana and high temperatures are among the causative factors for low yields. Physiologically, high temperatures induce higher rate of growth but the overall growing period becomes shorter. The shortened reproductive stages due to high temperatures limit carbohydrate accumulation resulting in overall yield reduction. High temperatures also lead to high evapotranspiration rates which induce water stress and yield reduction in cereals.

Because of high temperatures in Ghana, it is projected that any increased drought conditions will be greatly manifested in the northern sector where the highest temperatures are recorded. In the northern sector, the people depend mostly on agriculture for their livelihood. In this area, the production of millet, sorghum, rice and to some extent maize, is very popular. Therefore, in Ghana, it is the driest northern sector that would be most vulnerable to any negative impact of climate change.

Climate change may also manifest itself in changes in the rainfall pattern. Extreme rainfall intensities may result in serious soil erosion and overall land degradation. Prolonged drought conditions will adversely affect the entire hydrological regimes of the northern savannas, which will result in a threat of desertification.

Providing food in sufficient quantities for the growing population of Ghana in future would be difficult in as much as the land and the forest resources continue to be degraded and water availability for agriculture becomes unreliable. This problem will be exacerbated by the process of global warming and its attendant effects on climate change.

Cereals are the major food crops consumed in Ghana. Millet is the staple food crop for most people in the Sudan Savanna zone, whereas maize and rice are virtually consumed across the whole country. Sorghum is mostly used in brewing a local drink called “pito”. At present the bulk of rice consumed in Ghana is imported. The total maize produced in Ghana is mainly consumed by human and the poultry industry.

3.2.3 Climate Change Impact Analysis

3.2.3.1 Construction of Climate Change Scenarios:

The climate change scenarios were assessed using process-based methods that rely on the use of General Circulation Models (GCMs) in conjunction with Simple Climate Models (SCMs). Specifically, the “Linked Model” approach was adapted. This model made use of the Hardly Centre Model 2 ($HADCM_2$), the UK Meteorological Office Transient Model (UKTR) and the UK Meteorological Office High Resolution Model (UKHI) to generate future climate change scenarios on temperature, solar radiation and rainfall.

The country was divided to correspond with the various agro-climatic zones, namely the Sudan Savanna zone, the Guinea Savanna zone, the Transition Zone, the semi-Deciduous Rainforest zone and the High Rainforest Zone. These zones are represented geo-climatically by Navrongo, Tamale, Wenchi, Kumasi and Axim, respectively (Figure 3.3).

Daily values of the climatic variables from the Meteorological Services Department of Ghana were used to compute their monthly means for a 30-year period (1961-1990). This was used to define the baseline climatic variables from which the projected values of temperature, solar radiation and rainfall were estimated from years 2000 to 2020.

The impact of climate change on cereal production was assessed using the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) crop simulation models. Specifically, the DSSSAT V.3.1 software package was used. This package is a collection of computer programs that enables the user to match the biological requirements of crops to the physical characteristics of the land so that the objectives specified by the user may be obtained. For this study the CERES models were used.

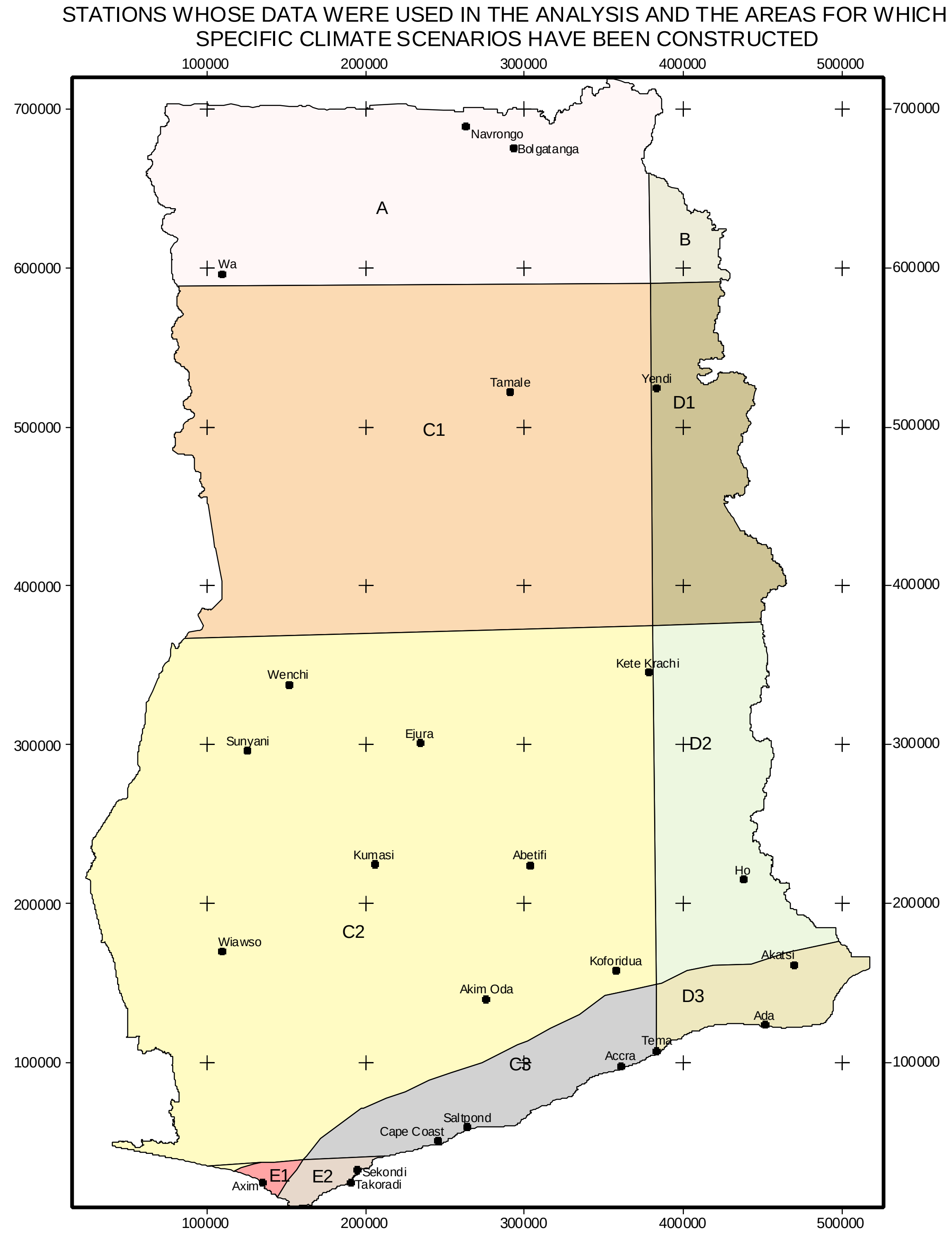
These models are process-oriented computer models, which simulate growth, development and yield as a function of plant genetics, weather, soil conditions and crop management selections. The CERES MAIZE and CERES MILLET models were used to quantitatively determine the growth and yield of maize and millet respectively.

3.2.3.2 Projected Average Maximum and Minimum Temperatures

The projected average maximum and minimum temperatures adapted are given in Tables 3.2 and 3.3 respectively. Table 3.4 also gives the projected daily mean temperatures. The projected changes in maximum and minimum temperatures for the different agro-climatic zones between the years 2000 and 2020 are given in Tables 3.5 and 3.6, respectively.

The analysis of the maximum and minimum temperatures indicates that there are consistent increases in both the maximum and the minimum temperatures over the years in all the agro-climatic zones. However the increases are higher in the Sudan Savanna zone where temperatures are highest. The temperature rise decreases towards the forest zones.

Figure. 3.3


STATIONS WHOSE DATA WERE USED IN THE ANALYSIS AND THE AREAS FOR WHICH SPECIFIC CLIMATE SCENARIOS HAVE BEEN CONSTRUCTED
100000
200000
300000
400000
500000
700000
600000
500000
400000
300000
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100000
A
B
C1
C2
C3
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D2
D3
E1
E2
Navrongo
Bolgatanga
Wa
Tamale
Yendi
Wenchi
Kete Krachi
Sunyani
Ejura
Kumasi
Abetifi
Ho
Wiawso
Koforidua
Akatsi
Akim Oda
Ada
Tema
Accra
Saltpond
Cape Coast
Sekondi
Takoradi
Axim

A critical look at the maximum temperature changes indicates that the average maximum temperature of the Sudan Savanna zone is expected to increase by 3^{o}C and by 2.5^{o}C in the other ecological zones by 2100. For the same time span, the minimum temperatures are expected to increase by 2.5^{o}C in the Sudan and Guinea Savannas and the Semi-Deciduous Rainforest Zones. In the Transition and the High Rainforest Zones the minimum temperatures are expected to increase by 3^{o}C and 2^{o}C respectively by the year 2100.

3.2.3.3 Projected Solar Radiation

The projected values of daily average solar radiation adapted from Yelifari (1998) up to the year 2020 are presented in Table 3.7 The changes in the projected solar radiation in the different agro-climatic zones are also presented in Table 3.8. The rise in solar radiation is significantly highest in the Sudan Savanna Zone but decreases consistently towards the High Rainforest Zone. The average solar radiation is expected to increase by 1.95 MJ/m^2 in the Sudan Savanna Zone, 1.0 MJ/m^2 in the Guinea Savanna Zone, 1.15 MJ/m^2 in the Transition and the Semi-Deciduous Rainforest Zones, and 0.75 MJ/m^2 in the High Rainforest Zone, by the year 2100.

Table 3.2 Projected daily average maximum temperature (^{o}C)

Year	**Navrongo**	**Tamale**	**Wenchi**	**Kumasi**	**Axim**
1961-1990	34.8	33.8	30.8	30.7	29.3
2000	35.2	34.2	31.2	31.0	29.5
2005	35.3	34.3	31.3	31.1	29.6
2010	35.5	34.4	31.4	31.3	29.8
2015	35.6	34.6	31.6	31.4	29.9
2020	35.8	34.7	31.7	31.5	30.0

Table 3.3 Projected daily average minimum temperature (^{o}C)

Year	**Navrongo**	**Tamale**	**Wenchi**	**Kumasi**	**Axim**
1961 - 1990	22.4	22.3	21.2	21.5	23.5
2000	22.9	22.7	21.5	21.9	23.8
2005	23.0	22.8	21.5	22.0	23.8
2010	23.2	22.9	21.7	22.1	23.9
2015	23.3	23.0	21.9	22.3	24.1
2020	23.4	23.2	22.1	22.4	24.2

Table 3.4 Projected daily mean temperature (^oC)

Year	Navrongo	Tamale	Wenchi	Kumasi	Axim
1961 - 1990	28.6	28.1	26.0	26.1	26.2
2000	29.0	28.4	26.3	26.5	26.4
2005	29.2	28.6	26.5	26.7	26.6
2010	29.3	28.7	26.7	26.8	26.7
2015	29.5	28.8	26.8	27.0	26.8
2020	29.6	29.0	26.9	27.1	26.9

Table 3.5 Projected changes in maximum temperature for the different agro-climatic zones relative to the baseline

Year	Projected changes in maximum temperature (^oC)				
	Navrongo	Tamale	Wenchi	Kumasi	Axim
2000	0.4	0.4	0.4	0.3	0.2
2005	0.5	0.5	0.5	0.4	0.3
2010	0.7	0.6	0.6	0.6	0.5
2015	0.8	0.8	0.8	0.7	0.6
2020	0.9	0.9	0.9	0.8	0.7

Table 3.6 Projected changes in minimum temperature for the different agro-climatic zones relative to the baseline

Year	Projected changes in minimum temperature (^oC)				
	Navrongo	Tamale	Wenchi	Kumasi	Axim
2000	0.5	0.4	0.3	0.4	0.3
2005	0.6	0.5	0.3	0.5	0.3
2010	0.8	0.6	0.5	0.6	0.4
2015	0.9	0.7	0.7	0.8	0.6
2020	1.0	0.9	0.9	0.9	0.7

Table 3.7 Projected daily average solar radiation $(MJ/m)^2$

Year	Navrongo	Tamale	Wenchi	Kumasi	Axim
1961 - 1990	21.84	19.24	16.23	15.68	16.33
2000	22.14	19.44	16.40	15.83	16.43
2005	22.23	19.50	16.38	15.88	16.47
2010	22.32	19.55	16.49	15.93	16.47
2015	22.42	19.65	16.55	15.99	16.53
2020	22.53	19.69	16.63	16.06	16.58

Table 3.8 Changes in projected daily average solar radiation relative to the baseline

Year	Projected changes in MJ/m^2 solar radiation				
	Navrongo	Tamale	Wenchi	Kumasi	Axim
2000	0.30	0.25	0.17	0.15	0.10
2005	0.39	0.26	0.15	0.20	0.14
2010	0.48	0.31	0.26	0.25	0.18
2015	0.58	0.39	0.32	0.31	0.20
2020	0.69	0.45	0.40	0.38	0.25

Table 3.9 Projected total annual rainfall (mm)

Year	Navrongo	Tamale	Wenchi	Kumasi	Axim
Average of (19961 - 1990)	986.1	1100.2	1252.9	1402.1	1985.5
2000	957.6	1089.2	1241.6	1388.6	2002.1
2005	948.9	1086.2	1238.1	1384.2	2006.9
2010	939.5	1082.8	1234.7	1379.7	2012.0
2015	930.1	1078.7	1230.5	1374.5	2018.0
2020	919.6	1074.8	1226.1	1368.8	2024.2

Table 3.10 Changes in projected total annual rainfall relative to the baseline

Year	Projected changes in (mm) annual rainfall				
	Navrongo	Tamale	Wenchi	Kumasi	Axim
2000	- 28.5	- 10.6	- 11.3	- 13.5	+ 16.6
2005	- 37.2	- 14.0	- 14.8	- 17.9	+ 21.4
2010	- 46.6	- 17.4	- 18.2	- 22.4	+ 26.5
2015	- 56.0	- 21.5	- 22.4	- 27.6	+ 32.5
2020	- 66.5	- 25.4	- 26.8	- 33.3	+ 38.7

Table 3.11 Average yields of cereals in temperate and tropical regions

Crop	Temperate Regions (Mt/ha)	Tropical Regions (Mt/ha)
Maize	3.99	1.35
Sorghum	2.27	1.25
Rice	4.11	1.96

Source: Haws et al., (1983)

Table 3.12 Average yields of cereals from traditional farmers' fields in Ghana (1987-1990) and (1993-1997).

Crop	Yield (Mt/ha)	
	(1987-1990)	(1993-1997)
Maize	1.18	1.53
Sorghum	0.75	1.08
Millet	0.70	0.95
Rice	1.45	2.02

Source: ISSER (1992, 1998).

Table 3.13 Measured and predicted yields of maize and millet in the Transition Zone and Sudan Savanna Zone using the CERES model.

Zone	**Crop**	**Measured yield (Kg/ha)**	**Predicted Kg/ha**
Transit	Maize	3,380	3,456
Sudan Savanna	Millet	766	719

Source: Bonsu et al. (1998).

Table 3.14 Projected yields of maize in the Transition Zone of Ghana for 2000 to 2020

Year	Projected yield of maize (Kg/ha)
1996 (Baseline)	3,456
2000	3,439
2005	3,436
2010	3,436
2015	3,434
2020	3,432

3.2.4 Projected Total Annual Rainfall

The projected values of total annual rainfall estimated for the different agro-climatic zones are given in Table 3.9. The changes in the projected total annual rainfall in the different agro-climatic zones between the years 2000 and 2020 are presented in Table 3.10.

The estimated rainfall decreases consistently in all the agro-climatic zones with the exception of the High Rainforest Zone where the rainfall consistently increases with time. The highest decrease in rainfall is in the Sudan Savanna Zone where the increases in temperature and solar radiation are highest. In the Sudan Savanna Zone, the projected annual rainfall is estimated to decrease by a total of 190 mm in the year 2100. In the Guinea Savanna Zone the annual rainfall is estimated to decrease by 74 mm in the year 2100. The expected decreases in the annual rainfall in the transition and the Semi-Deciduous Rainforest Zones in the year 2100 are

78 mm and 99 mm, respectively. In the High Rainforest Zone, however, the annual rainfall is expected to increase by 110.5 mm in the year 2100.

3.2.5 Analysis of Impact of Climate Change on Cereal Production

The yields of cereals in the tropics are generally low compared to those in the temperate regions. Table 3.11 gives the average yield of some cereals in the temperate regions compared to the tropical regions. The average yield of maize in the tropics is about 3 times lower than in the temperate regions. The average yield of sorghum is about 1.8 times lower in the tropics compared to what is obtained in the temperate regions. The yield of rice is about two times lower in the tropics than in the temperate regions.

The average yields of some cereals in Ghana for the periods 1987 to 1990 and 1993 to 1997 are presented in Table 3.12. The average yields of cereals in Ghana are comparable to the averages in the tropics. A variety of factors such as inherent poor soil fertility, insufficient application of fertilizers, poor land husbandry, and possibly unreliable climate may contribute to the low yields of cereals.

Using the CERES model the yields of maize were estimated for the Transition Zone and yields of millet for the Sudan Savanna Zone. Table 3.13 gives the measured and predicted yields of maize and millet in the Transition and the Sudan Savanna zones, respectively. In the transition zone, the CERES model after calibration overestimated the measured yield of maize by 2.2 percent. In the Sudan Savanna Zone, the CERES model underestimated the measured value of millet by 6.1 percent. These differences in yield are so small that it could be said that CERES model is quite reliable to give good estimates of cereal yields using climate, crops and soil factors.

3.2.6 Projected Yield of Cereals Due to Climate Change

The General Circulation Model (GCM) predicted increases in maximum and minimum temperatures and solar radiation but predicted decreases in rainfall with the exception of the High Rainforest Zone. These values in conjunction with the relevant soil and crop factors were effected in the CERES model to estimate the yields of maize and millet in the Transition and Sudan Savanna Zones, respectively.

Table 3.14 gives the projected yields of maize for the years 2000 to 2020. The model output showed that there was a consistent decrease in the yield of maize in the Transition Zone due to an increase in temperature and solar radiation and a decrease in rainfall. However, the decreases in the projected yields were not significantly different from the baseline yields. The percentage decrease in the projected maize yield ranged from 0.5 percent in the year 2000 to 6.9 percent in the year 2020. With respect to millet, however, the changes in the climatic variables did not effect any change in the projected yield of millet. This could be ascribed to the drought tolerant nature of millet.

3.2.7 Discussion on Climate Change and Cereal Production in Ghana.

Invariably, drought conditions are often associated with high temperatures. In such situations, the relatively drier areas of the Sudan Savanna Zone would be more vulnerable to adverse climate change. In this area, land degradation, threat of desertification, poverty and rapid population growth could accentuate the problem of climate change.

Low incomes and high unemployment rates would impact negatively on any adverse changes in climate. In addition, huge national debts and stringent government micro-economic policies may combine with any adverse extremes of climate change to put serious stress on government and threaten the national economy through huge importation of cereals. Most farmers cannot afford expensive inputs to address any adverse impacts of climate change since majority of farmers practice subsistence agriculture. There is, therefore, the need to institute effective adaptation strategies, both short term and long term, to forestall any future adverse climate change.

3.2.8 Adaptation Strategies to Climate Change in Cereal Production

Adaptation to climate change involves taking action to reduce either the negative effects or to capitalize on the positive effects of climate change. Adaptive actions may be taken in anticipation of potential climate change. However, some adaptive actions may have to be taken to deal with situations when actual impacts on climate change do occur.

3.2.8.1 Anticipatory adaptive strategies

Anticipatory adaptive strategies are taken to deal with the effect of climate change on cereal production when there is an indication that climate change may negatively impact on future cereal production. In this case all indications must show that climate change is evident. If the change is going to be a negative one, the following strategies may be adapted:

- Development of drought tolerant varieties.
- Breeding of early or extra early maturing genotypes.
- Educating farmers on effective low input soil and water competition practices such as conservation tillage.
- Educating farmers to plant in low population densities so as to reduce competition for scarce or limited soil moisture.
- Farm level adaptations such as shift in planting dates and modifying the amount and timing of fertilizer application may be adopted. Changing cropping sequences may be useful.
- Economic adaptive measures such as plans to change national production of rice and other cereals. If higher prices of cereals are anticipated, measures should be taken to increase investment in infrastructure for cereal production. For instance, reallocation of more land and water to cereal production because of anticipated higher economic returns from cereals due to expected scarcity in the commodity as a result of negative impact of climate change.

- Shifts in national production centres for cereal production. Production of cereals may be shifted to areas where comparative advantage in production can be obtained. For example, under extreme drought conditions, millet production may be shifted from the Sudan Savanna Zone to the Guinea Savanna Zone, whilst sorghum may be shifted from the Guinea Savanna Zone to the Transition Zone and maize production may be concentrated in the Semi-Deciduous Rainforest Zone. Production of heat tolerant crops such as cowpea may be concentrated in the Sudan Savanna Zone.

- Adopting food security measures by storing cereals in national food banks. In extreme climate changes situation, such as abrupt drought or flood conditions that destroy all farms, food should be released from the national food bank to the affected areas.

3.2.8.2 Reactive Adaptive Strategies:

Reactive adaptive measures are taken if actual impacts of climate change do occur unexpectedly. In this instance, no preparatory steps have been put in place and therefore an ad hoc and urgent decision is taken to deal with the problem. If the change is a negative one such as drought, then the following steps may be taken:

- Release of reservoir water for supplemental irrigation. In this instance, a balance between the need of water for domestic use and water for supplemental irrigation should be established and a firm decision taken on the issue.
- Cutting the cereals for use as fodder or silage for livestock instead of waiting for no seed to develop in the cereal. This reactive adaptive measure is pertinent in mixed farming systems.

3.2.8.3 Caution for Adaptation Strategies

When studies have predicted future climate change, the projects designed should have the ability to bring improvements in cereal production whether climate changes do really occur or not.

In proposing adaptive strategies for cereal production, the technology proposed must go with availability of resources. For example, the use of improved seeds may go with fertilizer application that may be either too expensive or incompatible with the indigenous systems of production. In the context of the indigenous systems of production, steps must be taken to ensure that adaptive technology brings about sustainable production.

Care must be taken so that adaptive measures do not bring about negative or unwanted consequences on the farmers in the rural areas. For instance, if the adaptive changes involve shifting from cereal production to vegetable production, farmers may be exposed to marketing and credit problems brought about by higher capital and operating costs for vegetable production. Also, shifts from cereals to other crop varieties may bring about reduced nutritional quality and profits for the rural farmers. Local farmers are quite conservative and it, therefore, requires a very effective extension system to assist farmers to accept innovations.

3.2.9 Land Use Change for Cereal Production Due To Climate Change

3.2.9.1 Land Use Change for Millet and Sorghum Production

The texture of the major soils for growing millet and sorghum in Ghana are predominantly sand, loamy sand or sandy loam. The soils are highly permeable and very low in nitrogen and organic carbon content as well as low in cation exchange capacity. The production of these crops is concentrated in the Guinea and Sudan Savannas. These crops are normally grown on ridges made either by bullocks or by hand using the local hoe. The crops are grown under rain-fed conditions using family labour. The local farmers hardly apply mineral fertilizer to the crops. The dominant cropping system is growing early millet interplanted with late millet, sorghum and cowpea or groundnut.

A notable effect of climate change is insufficient rainfall during the major cropping season between August and November. However, in certain years, rainfall can become excessive leading to floods as was the case in 1999. The following adaptive landuse change are proposed for these areas:

- The production of early millet and cowpea using the early rains should increase. This implies that early millet, groundnut or cowpea, which do not require too much water, should be grown as monocrop to increase their level of production. Late millet should also be grown as a monocrop. If the major rainy season fails, the farmer would have harvested sufficient early millet, cowpea or groundnut.
- Mixed farming involving ruminants and cereal production could be intensified. The farmers should, therefore, consider ruminant production as a commercial venture. Whenever there is an indication that climate change is going to impact negatively the farmers should not wait for the millet or sorghum to set seeds but cut the crops in their green stage and convert them to either hay or sillage to feed the livestock which would serve as a source of income for the farmers to purchase food and other needs.
- As rainfall becomes uncertain and low in quantity, millet production could be shifted to the Guinea Savanna Zone where rainfall is always better than the Sudan Savanna Zone. The production of cowpea and groundnut could be concentrated in the Sudan Savanna Zone for the farmers in this area to be able to generate sufficient income to purchase millet from the market. Efficient groundnut oil extraction plants could be established in the area to process groundnut oil of low cholesterol content for the international market.

3.2.9.2 Land Use Change for Maize Production

The texture of the soils for growing maize varies from predominantly sand to loamy sand in the Forest-Savanna Transition Zone and either sandy clay loam, sandy loam or loam in the moist Semi-Deciduous Forest Zone. Maize is also now being grown in the Guinea Savanna Zone on loamy sand soils.

In the Transition Zone land preparation for maize production is by the use of tractors. In the Semi-Deciduous Forest Zone, land preparation for maize production is by slash-and-burn. In the Transition Zone the farmers normally apply mineral fertilizer to the maize crop, while in the Semi-Deciduous Forest Zone they do not apply mineral fertilizer.

The soils in the Transition Zone have low organic carbon and nitrogen content. The cation exchange capacity is also low. In the Semi-Deciduous Forest Zone, organic carbon and nitrogen content are moderately high. In the Forest Zone the cation exchange capacity is 30% higher than in the Transition Zone. In these maize-growing areas the common climate change is unreliable rainfall. The problem is more pronounced in the minor season (September - November) than in the major season (April - July).

The following land use change may be adapted to offset climate change in the maize growing areas:

- ♦ In the Transition Zone, where rainfall is becoming more unreliable than in the Forest Zone, sorghum or cowpea should replace maize, especially during the minor season, since these crops can withstand drought conditions better than maize.
- ♦ Cashew production as a cash crop should be intensified in the Forest-Savanna Transition Zone to serve as the major export crop of this zone.
- ♦ In the Forest-Savanna Transition Zone, mixed farming involving ruminants and cereals should be encouraged. The cereals would benefit from the manure produced by the livestock. In a year when climate change impacts negatively on maize or sorghum, the crops could be cut when green and used to feed the animals in the form of hay or silage.
- ♦ Vegetable production, especially tomatoes during the minor season, is very popular in the Forest-Savanna Transition Zone. Over-production of tomatoes tends to force the price of the commodity down. Farmers should be encouraged to produce other vegetables such as watermelon and pepper, which can be exported to generate foreign exchange and more income for the farmers in the minor season.
- ♦ In the Semi-Deciduous Forest Zone, maize production should be encouraged in the major season (April - July) as monocrop under no-tillage system with chemical weed control. The application of mineral fertilizer should go with this system to improve yields.

- ♦ In the Semi-Deciduous Forest Zone maize should be rotated with cowpea in the minor season (September - November) when the rainfall tends to be more erratic, since cowpea is more drought tolerant.
- ♦ In the Semi-Deciduous Forest Zone, farmers should desist from using abandoned cocoa farms to produce maize. The abandoned cocoa farms should be reverted to the production of plantation-crops such as oil palm or citrus. The plantation crops would ensure regular income for the farmers whilst glut in maize production would be reduced to increase the producer price of maize.

3.2.9.3 Land Use Change for Rice Production

The two major rainfed rice producing zones are

- ♦ The Guinea Savanna Zone where the texture of rice soils varies from loam to silty loam. The soils are located on relatively flat areas. It is the high silt content that makes the soil poorly drained since the clay content ranges from 11% to 19%. The soils dry fast and have low plant extractable water content. The soils require more frequent rainfall to sustain rice production since their water retention capacity is not appreciably high. The soils are low in organic carbon and nitrogen. They also have low cation exchange capacity. In the Guinea Savanna Zone, farmers usually apply fertilizers because of the high economic value of rice.
- ♦ The High Rainforest Zone, where the soils for growing rice are located in valley bottoms. The texture of the soil is predominantly sandy loam. In this zone, the soils are acidic and low in organic carbon and nitrogen content.

Whilst the projected climate change in the Guinea Savanna involves a decrease in rainfall over time, in the High Rainforest Zone, it is rather an increase of rainfall over time.

The following land use changes may be adapted to offset any climate change in rice production.

- In the Guinea Savanna Zone, broadcasting seed rice over large areas by farmers should be discouraged. Farmers should rather construct basins to harvest water, puddle the soils and transplant rice seedlings on to the puddled soils in the basins. This would reduce percolation losses of water and conserve water to carry the rice to maturity in case rainfall stops abruptly.
- Rice production should be more concentrated in the High Rainforest Zone where the rainfall is projected to increase over years. The rainwater should also be harvested into basins, the soils puddled and rice transplanted.

3.2.10 Policies for Adaptation Responses

Adaptation to climate change aims at setting up human responses to climate changes before or after such changes have actually begun.

All the current evidence is that climate change is real and cannot be averted completely. Therefore, policies may be put in place to minimize the potential damages that may arise as a result of climate change. Government policies must be set in place to moderate future impacts, alleviate damages and institute adaptation strategies to deal with future climate change.

In formulating policies, it must be realized that there are physical and social factors that influence any agricultural development process. Also, climate changes are not the only deleterious factors that influence climate-crop relationships. It must be realized that the so-called El-Nino/Southern Oscillation (ENSO) events that recur every 2 to 9 years are now perturbing the current climate and may interact with global climate change.

In assessing adaptation policies, the following factors must be taken into consideration:

- The effectiveness as well as the shortcomings of current government policies in coping with climate change.
- The costs and benefits of alternative policies to deal with climate change impacts.
- Identifying policies with highest priorities for immediate implementation.

Policy options for adaptation of cereal production to climate change

The following policies, though not exhaustive, may be set in place to deal with adaptation of cereals to climate change:

1. Policies to produce heat-tolerant and drought-tolerant crops to enable farmers to produce profitably under adverse conditions
2. Policies to collect germplasms for future screening to obtain cultivars that are tolerant to heat and water stress.
3. Policy measures to improve social systems (health, education etc) and to open up the rural areas to modernization.
4. Policies on environmental protection to deal with bush fires and rampant vegetation removal that encourage the adverse impact of climate change.

5. Policcies to encourage farmers to adopt efficient farming practices. For instance, relatively easy acquisition of credit, stabilization of food supplies and farm incomes through effective pricing policies, effective land tenure systems, etc.
6. Drought management policy through information systems about changing climate conditions and patterns, preparatory practices and options to deal with the eventuality of drought, and farm insurance programs, must be set in place.
7. Policy to set up more efficient irrigation systems such as drip and micro-spray techniques in drought-prone areas to make efficient use of limited water available for irrigation of cereals.
8. Policy to promote soil and water conservation technologies, such as conservation tillage, through education and training.
9. Macro-economic policies involving fiscal and monetary arrangements to encourage private sector engagement in rural enterprise establishment. For example, establishing efficient groundnut extraction plants to produce cholesterol free groundnut oil for international market in the Sudan Savanna Zone will create employment as well as boost agricultural activities in the area.

3.2.11 Barriers for adaptation responses

The following factors may serve as barriers for adaptation response to cereal production by farmers:

1. Social and economic barriers may not allow farmers to adapt to climate change responses. For example, increased fertilizer application and improved seeds may be too expensive costly for the Ghanaian local farmer.
2. Sometimes an adaptive measure may not lead to sustainable production. For example, using irrigation as an adaptive measure may lead to soil salinization
3. Increased demand for water by competing sectors may limit the viability of using irrigation as a sustainable adaptation to climate change.

4. Inadequate technical know-how, and scarcity of resources may not favour the scientists to research into adaptive options.
5. The adaptive measures may involve a change that is capital intensive. In such circumstances, the farmers may be exposed to credit and marketing problems and, therefore, may be unwilling to accept the technology.
6. If the changes in climate are offset by changing planting schedule or crop varieties, such measures may lead to decreased nutritional quality or food production as well as profit for farmers.
7. Farmers' failure to pay back credit offered them to deal with climate change adaptations may be inimical to government policies on adaptation to climate change. This situation is likely to arise when farmers are poor and, therefore, view credits given them as grants.

3.3 COASTAL ZONE

3.3.1 Introduction

The coast of Ghana, faces south into the Atlantic Ocean. It comprises 565 km of shoreline and is relatively low, fairly straight only slightly indented. The most southerly point is Cape Three Points. The coast trends east-north-east on the east of Cape Three Points and west-north-west on the west (Fig. 3.4). The coastal area consists of entirely sandy beaches on the western and eastern extremities with a central section that is abundant in rock exposures. The sandy West

Coast covers 95 km of shorelines and runs from Ghana's international border with Côte d'Ivoire to the Ankobra River. The Central Coast, 321 km in length, stretches from the Ankobra River to the Laloi Lagoon west of Prampram and the 149-km East Coast is made up of the delta of the Volta River from Prampram to the international border with the Republic of Togo.

According to the last census in Ghana, 25% of the population reside in the coastal zone, which makes up about 7% of the total land area of Ghana. The estimated population living within the coastal zone in 1994 is 4 million (Fig. 3.5). The land area of the coastal zone comprises all the area below the 30-m contour. Sea-level rise is predicted to increase flood frequency probabilities, inundate low-lying coastal areas, cause shoreline recession on sandy shores, increase the salinity of estuaries and aquifers and raise coastal water tables. These physical changes will in turn impact on socio-economic activities within the coastal zone. Coastal habitats will be lost and bio-diversity could be adversely affected.

The aim of this study is to determine the land area that is potentially vulnerable to a sea-level rise of 1 m by the year 2100. An estimate of the population at risk can then be determined as well as potential impacts on bio-diversity, socio-economic activities and the effects on structures built within the coastal areas prone to earthquake. Measures for adapting to sea-level rise are explored together with estimates of the cost for each adaptation measure.

3.3.2 Climate Change Scenarios

The vulnerability assessment of sea-level rise considered a rise of 100cm by the year 2000. This limitation was dictated by the limited topographic data available. Locally, tidal measurements at the Port of Takoradi over a 32-year period indicate a rise of 2.1 mm per year. This rate of rise is consistent with global trends of eustasy.

Population estimates carried out for the year 1994 showed that over four million people lived within the zone, which make up about 25% of the national population. The area within the coastal zone potentially vulnerable to sea-level rise is referred to as the Risk Zone. It comprises all the land area within the coastal zone below the 3-m contour. Over 60% of this area within Ghana fall within the East Coast. The affected areas have population densities of about 120 persons per km^2. Annual incomes within these areas are relatively low often below US$150 per person.

The main occupation of the people in this area is farming and fishing.

The response scenarios selected have been similar to that utilized in the vulnerability assessment of other studies. These are:

- total protection of all areas with a population density of more than 10 persons per km^2;
- limited protection involving important areas only;
- the use of set backs in development planning for all undeveloped areas; and
- do nothing.

The costs associated with these options are assessed with existing available information. The important areas referred to in the second response strategy are defined as all sections of the coast with medium to highly developed areas (e.g. cities, tourist beaches etc.).

3.3.3 Potential Impacts of Climate Change

The expected impacts of sea-level rise were assessed using:

- limited data from aerial photography obtained from the years 1974 and 1986 for some sections of the coastal area;
- satellite imagery;
- town sheets, which are maps with a scale of 1:2,500 for some urban centres along the coast; and
- limited ground truth data.

3.3.3.1 Flooding and Inundation

A large proportion of the low-lying coastal plains within the East Coast are expected to be inundated by a sea-level rise of 1 m. This area has wetlands of international importance. These wetlands would be lost and the migratory birds that visit the area may be adversely affected because of the increased water depths, which will make difficult their ability to feed. All the human settlements surrounding the coastal lagoons will potentially come under increased threats of flooding and inundation.

The estimates of the land area and population at risk of inundation were carried out utilizing a simple inundation model. All areas below the high water mark by the year 2100 are considered at risk. Flood frequency probabilities were obtained from a plot of the probability of exceedance versus water levels. It shows that the Risk Zone is defined by all land below the 3-m contour (i.e. the contour line with the probability that the area below it will be flooded once in a 1,000 years).

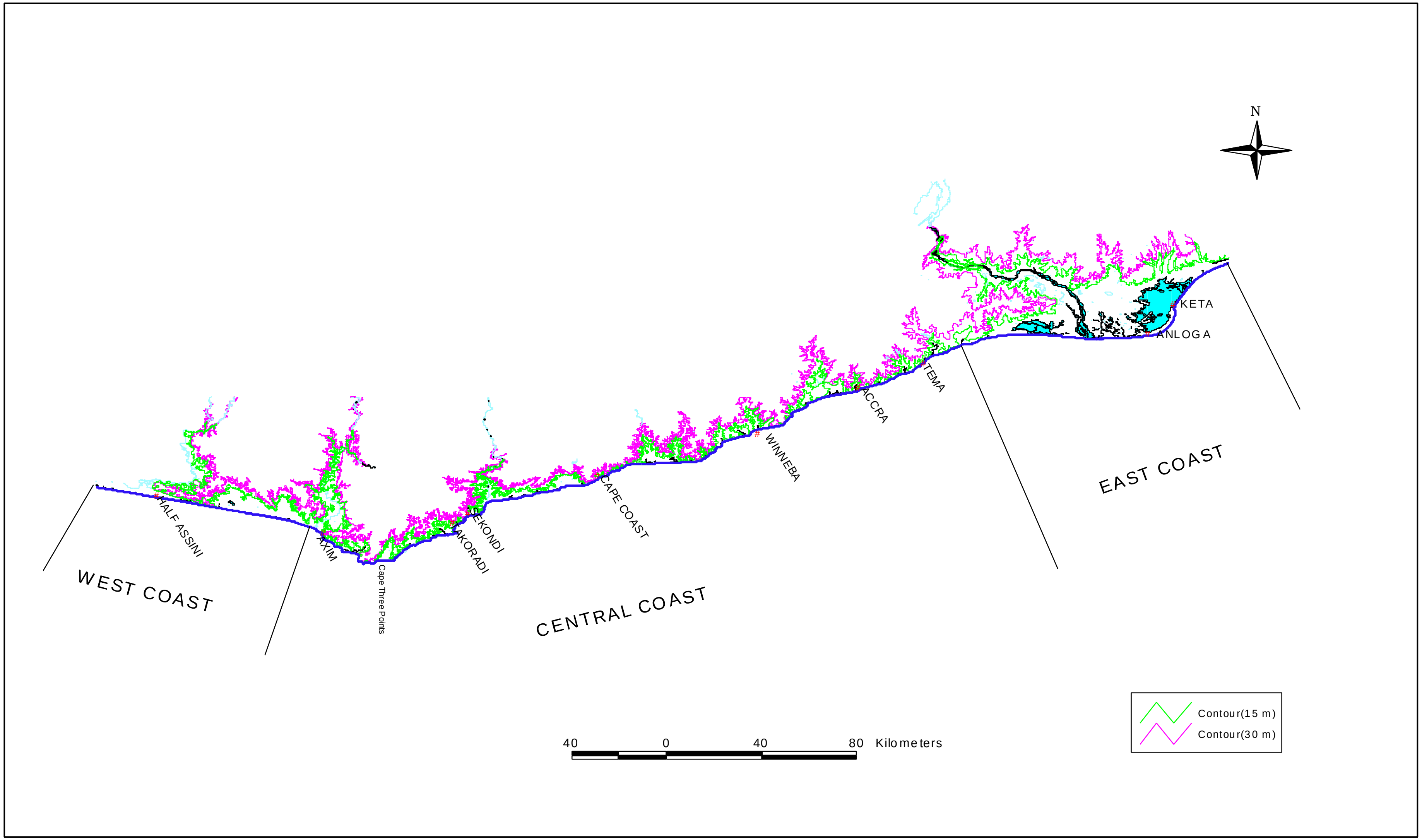

Figure 3.4 Coastal Zone of Ghana

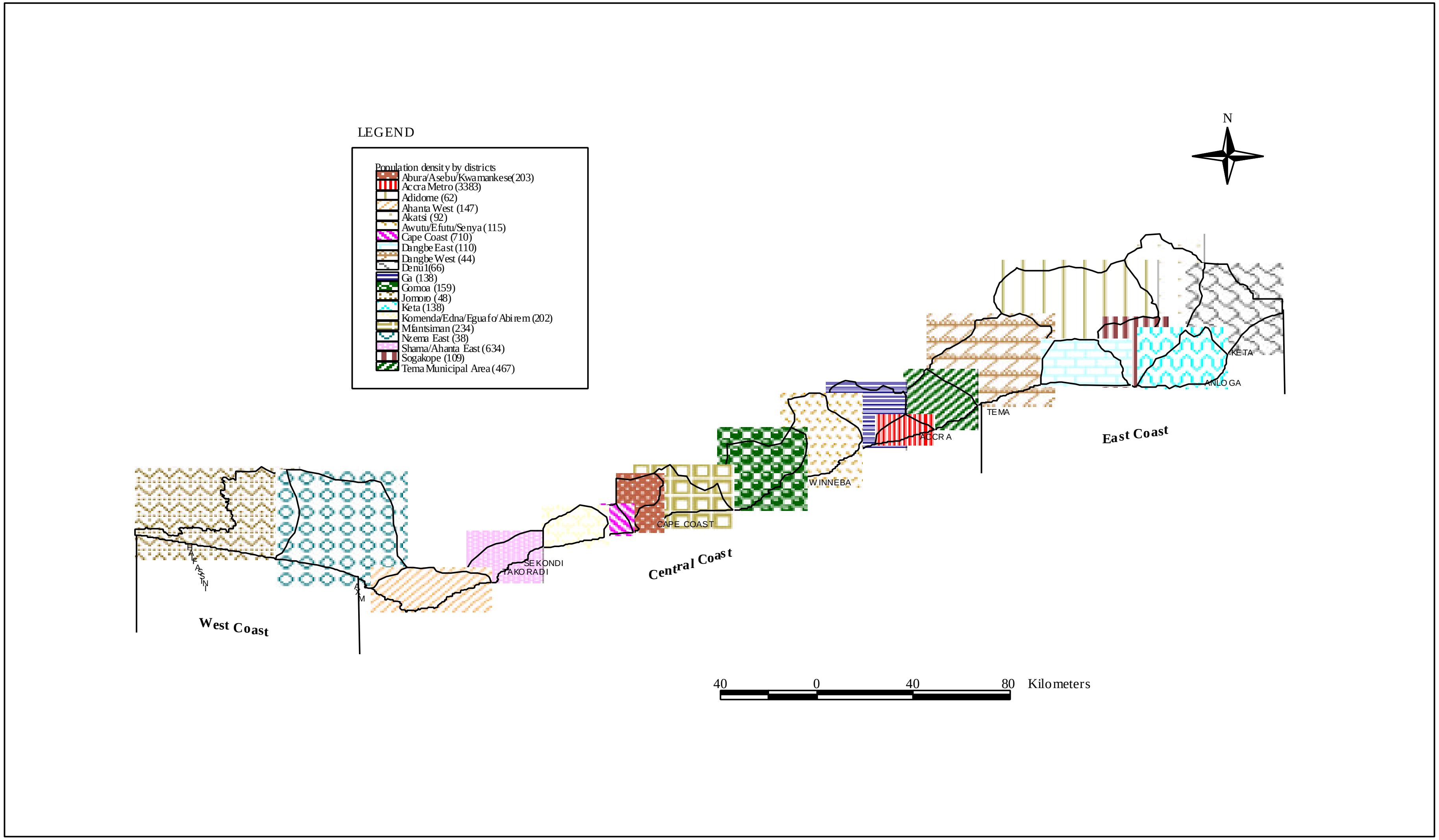

Figure 3.5 Population density by Districts within the Coastal Zone

3.3.3.2 Shoreline Recession

Shoreline recession for the sandy coasts has been analyzed using the Bruun Rule. This rule, which has now become popular for estimating the land at risk from shoreline recession as a result of sea-level rise, is applicable only for straight sandy shores. For the other coastal segment within the Central and Rocky Coasts, a simple inundation model was applied. The Bruun Rule requires the following input parameters: the amount of sea-level rise, active profile width; coastal land height; and the depth of closure.

3.3.3.3 Saltwater Intrusion

Saltwater intrusion can be expected from both surface waters and ground waters. The rural communities in Ghana are often dependent on groundwater for water supply. The urban centres are served from surface water sources. The salinization of coastal aquifers is expected from sea-level rise. It will, however, be exacerbated by the over-exploitation of the groundwater resource as a result of growing populations within rural communities in the coastal zone. Currently, this rate of population increase in the rural areas is of the order of 3% per annum.

The various factors, which influence saltwater intrusion in surface waters, are density difference between freshwater and saltwater; tidal range; river discharge; cross-sectional area; and vertical mixing of water. Water supplies for some urban settlements within the coastal zone could be adversely affected as a consequence of salinization. A qualitative assessment is provided.

3.3.3.4 Rising Water Tables and its Impact on Earthquake Hazards

In areas of soft, wet soils, liquefaction intensifies earthquake damage. Liquefaction occurs when strong ground shaking causes wet soils to behave temporarily like liquids rather than solids. Anything, including buildings may sink into the soft liquefied ground, and liquefied soil may also flow toward lower ground burying anything in its path. Thus under conditions where sea level rise results in the increase of pore fluid content of soft soils, soil liquefaction will be greatly enhanced even during low magnitude earthquakes.

Within the western margins of the capital city, Accra, and the West Coast, lie active geologic faults that could potentially create problems during an earthquake. Ground movements caused by earthquakes have the most devastating consequence on structures founded on sand, and silt saturated with moisture.

An elevation of water tables as a result of sea-level rise will increase the extent of areas within the Risk Zone that are saturated with moisture. Areas with sand and silt subjected to vibrations may liquefy. As a result, foundations of the affected structures will seriously be undermined during earthquakes. This poses risks to the structure, life and property.

3.3.3.5 Coastal Habitats and Bio-diversity

The effect of sea-level rise on coastal habitats and bio-diversity can be expected from the inundation, erosion and salinization of habitats. Inundation of coastal wetlands will, for instance, affect the feeding grounds of migratory birds that feed in shallow waters. Erosion of coastal areas will cause the loss of the habitat of several species including marine turtles. Saltwater intrusion will alter the composition of the ecosystem by driving away freshwater or brackish species in favour of species that are more tolerant to increased salinity.

3.3.4 Assessment of Vulnerability

Already all the characteristics of sea-level rise are evident on sandy beaches in Ghana. Many sections of the coastal area, particularly within the East Coast, are already eroding at a phenomenal rate of about 8 m per year. Westward, the rate of erosion generally reduces. Flooding has been reported from coastal communities. This usually occur during spring tide.

Besides flooding from the sea, the closed lagoons on the coast are prone to flooding from discharges they receive from the rivers that flow into them. Rising water levels within the lagoons often flood many communities along their shores until a cut is made artificially or naturally by overtopping of the narrow sand bar that separates the lagoon from the sea. The resulting tidal inlet maintains water exchange between the ocean and lagoon until the inlet is closed again by the littoral drift.

3.3.4.1 Land at Risk

The total land area at risk to flooding and inundation as a result of a sea-level rise of 1 m is estimated at 1,110 km^2 (Table 3.15). Out of this, 18% is distributed along the 321 km of shorelines of the Central Coast on sandy beaches occurring between rocky shores within the Central Coast. The West Coast (95-km) is estimated to have about 15% of the total land at risk distributed uniformly along its shores.

By far the largest land at risk lies within the delta of the Volta River. This area referred to as the East Coast has about 67% of the total land at risk. The land area at risk covers all the settlements along the shores east of the Volta River and including Ada Azizanya. In the Central Coast, the area includes settlements bordering coastal lagoons such as the two Sakumo Lagoons on the east and west of Accra, the Pra River estuary and the numerous estuaries of the rivulets occurring within this coastal segment.

Table 3.15 Land at Risk

Coastal Segment	**Land at Risk (km^2)**
East Coast	740
Central Coast	200
West Coast	170
Total	1,110

3.3.4.2 Population to be Displaced

Estimates of the population to be displaced were obtained from population densities of the coastal districts with the assumption that these are uniformly distributed within all the land areas at risk. The East Coast again has the highest population of 88,800 at risk out of a total of 132,200 (Table 3.16) followed by the Central Coast with 36,3000% of the total population at risk.

The relatively low population densities along the West Coast give a low population at risk of 7,100. The main settlements that could be impacted by flooding, inundation and shoreline recession are the communities along the shores from Aflao to Ada including Aflao, Adina, Blekusu, Keta, Anloga, Srogboe, Dzita, Atiteti and Ada-Azizanya. Settlements surrounding the Keta Lagoon are also potentially at risk of flooding and inundation. These include, Anyako and Alakple and surrounding towns and villages.

Table 3.16 Population Displaced

Coastal Segment	Population at Risk
East Coast	88,800
Central Coast	36,300
West Coast	7,100
Total	132,200

East of Ada, the settlements potentially at risk include Pute, Totope, Lolonya, Anyamam, Akplabanya and Wekumagbe. Along the Central Coast areas that could be impacted are the Takoradi Harbour, Tema Harbour, settlements surrounding the two Sakumo Lagoons one in Tema and the other west of Accra.

3.3.4.3 Salinization of Surface and Ground Water

Water resources within the coastal zone comprising coastal aquifers and surface waters will be contaminated by the intrusion of saltwater. It is estimated that the salinization of groundwaters will take a longer time compared with surface waters, which are relied upon for the supply of water to urban centres. Communities that could potentially be affected are the settlements that rely on water supply from the Pra River intake point. These include all the settlements from Dixcove in the west through Sekondi-Takoradi to Shama. Those communities within the East Coast that are dependent on the southeastern district water supply scheme could also be affected adversely. The southeastern district water supply scheme comprises the communities of Ada and those on the eastern side of the River Volta including Keta-Anloga and its environs. All the other urban communities within the coastal zone may not be impacted by salinization of their water supplies.

Some farming could be affected by the salinization of coastal aquifers and surface water. The shallot (*Allium Ascalonicum*) industry that thrives in the Anloga area of the Volta Region for instance could be lost. Water sources for farming in these areas are mainly from groundwater occurring in sandy formations within the Volta Delta.

3.3.4.4 Coastal Habitats and Bio-diversity

Over 80% of the wetlands in the coastal zone are found within the East Coast. Significant wetlands of over 10 km^2 in surface area are presented in Table 3.17. It shows that apart from the Volta Delta, the West Coast also has a sizeable proportion of wetlands estimated at 50 km^2. In the West Coast, coastal habitats at risk include mangrove stands, lagoons and wetland areas, sheltered bays and rocky outcrops. Threatened key bio-diversity are shorebirds, mangroves and lagoon flora and fauna.

The main physical changes that are expected to cause the loss of habitat are salinization of estuaries and aquifers. Along the Central Coast, mangrove stands, sandy and rocky shores the Densu wetland and Sakumo II Ramsar sites, lagoons, productive tidal flats are the habitats at risk to sea-level rise. Biodiversity under threat includes water birds, marine turtles, mangroves and lagoon fauna and flora.

Along the East Coast can be found the largest concentration of shorebirds, turtle nesting sites, extensive stands of mangrove, lagoons, wetlands and productive tidal flats. These are all potentially at risk. The biodiversity under threat includes shorebirds, marine turtles, shallots, mangrove and lagoon fauna and flora.

Table 3.17 Main wetlands along the Coastal Zone (size > 10 km^2)

Name	Size (km^2)
Volta Delta (East Coast)	702
Amunsure (Nzulezo) (West Coast)	50
Pra (Central Coast)	16
Songaw (Central Coast)	15
Sakumo (Central Coast)	14
Laloi (Central Coast)	10

3.3.5 Adaptation Options

Various adaptation options have been proposed. The 'do nothing' option presents the case where no intervention is involved and nature is allowed to take its own course. Protection of important area involves the construction of sea walls urban centres and areas with medium to high investments within the coastal zone that could potentially be at risk. The cost of full protection of important areas is considered for all land areas at risk with a population density of more than 10 persons per km^2. Since the entire coastal area has population densities greater than this value all sections of the coastal zone at risk are considered under the option of providing full protection.

3.3.5.1 "Do nothing"

The option of "do-nothing" results in an estimated loss of 1,110 km^2 of land and a displaced population of 132,200. The estimated areas at risk include wetlands and human settlements. A larger population of about one million will be impacted by the intrusion of saltwater in surface waters. The hazard of earthquakes within the coastal zone will mainly impact on the capital city, Accra, where unconsolidated sedimentary formations occur.

3.3.5.2 Important Areas Protection

The protection of important areas is expected to cost US$590 million in all. The East Coast is expected to take US$300 million and the Central Coast US$128 million. The relatively less populated West Coast will require US$162 million. The estimates of the protection works include the cost of construction and maintenance of the structures.

3.3.5.3 Full Protection of Areas at Risk

The entire protection of vulnerable areas covers the whole of the East and West Coasts where all the shorelines are at risk of erosion, flooding and inundation. Some sections of the Central Coast are also estimated to require protection. A total of US$1,140 million will be required for the protection of all vulnerable areas. Out of this total, 52% will go to the protection of the East Coast, 23% to the Central Coast, and 25% will be required for the West Coast.

3.3.5.4 Set Backs and Controlled Abandonment

The huge sums required for the protection of the shores may not be available and hence other adaptation options need to be considered and planned for. The use of set backs for all undeveloped areas within the coastal zone is highly favoured. This measure attempts to prevent the construction of immovable structures within hazard areas. It requires the delineation of all the potentially hazardous zones as well as historical records of shoreline recession to aid the planning process. It is advocated that areas prone to earthquake hazards and occurring mainly in Accra have to be regulated by the control of development activities. Areas within the coastal zone that potentially can be subjected to liquefaction during earthquakes can then be avoided.

3.3.5.5 Coastal Management Board

National Coastal Management Board is proposed to be established for the co-ordination of all developmental activities within the Coastal Zone. Each coastal district Assembly should also establish its own District Coastal Management Board which shall undertake the management of the section of coastline within the district with technical support from the National Coastal Management Board.

3.3.6 Legal and Institutional Framework

The main existing legislative context that impacts adversely on the rational management of coastal hazards are:

1. The large number of scattered legislation and regulations in Ghana, dealing with protection the coastal zone.
2. The inadequacy of existing legislation and regulation.
3. The ineffective implementation of existing legislation and republications

A community-based approach backed by appropriate legislation is deemed to be more appropriate for the management of the coastal zone. The current interprets Coastal Zone Management strategy supports this approach. Existing legislation will have to be diverse to ensure that they promote this community based and interprets approach to the management of coastal zones In line with all national development activities, all structures in the coastal zone should be subject to environmental impact assessment.

A community-based approach in conjunction with a legislative approach is supported for the management of the coastal zone. The current draft of the Coastal Zone Management Laws is consistent with this approach. Additional laws will be required to determine set backs for the developments within the coastal zone. All structures to be constructed within the set backs should be required to show proof that such construction will not be inimical to adjoining shores and that shoreline recession will not impact it within its design life.

The nucleus of the proposed Coastal Management Board may come from the following existing institutions:

1. Hydro Division of the Ministry of Works and Housing,
2. Ghana Ports and Harbours Authority,

3. Water Research Institute (CSIR),
4. Environmental Protection Agency,
5. Volta River Authority,
6. Department of Town and Country Planning,
7. Wildlife Department,
8. Ghana Tourist Board,
9. Navy, and
10. National Disaster Management Organization (NADMO).

The Coastal Zone Management Board is proposed to have three task groups namely:

- Legal and administrative group
- Measurement and study group
- Construction and Maintenance group.

CHAPTER FOUR

4.0 MEASURES CONTRIBUTING TO ADDRESSING CLIMATE CHANGE

ABATEMENT MEASURES

The Climate Change abatement study principally focused on the two major sectors that were potential sources for greenhouse gas emissions and/or reductions. It was realized from the greenhouse gas inventory studies that the highest source of carbon dioxide emissions was from the energy sector. Consequently, abatement of CO_2 in the energy sector was assessed. Land use change and forestry activities were the main areas identified as leading to carbon segrestration. In this regard, the forestry sector was studied as a possible area to increase the nation's carbon sink base

4.1 ABATEMENT OF GHGs IN THE FORESTRY SECTOR

4.1.1 Introduction

Detailed studies were carried out on measures to abate climate change through the forestry and land use sector, using the COMAP (Comprehensive Mitigation Analysis Process) model as analytical tool. 1994 was chosen as the base year and 2020, the end of the current National Development Planning Framework, as the end of the analytical period.

4.1.2 Identification and Screening of Abatement Options

Fifteen potential options were initially identified and screened against 12 criteria ranging from impact of GHGs, on other pollutants and on other aspects of the environment such as biological diversity; likely direct cost/benefit ratio and consistency with national development goal; to ease of implementation, using an options – criteria matrix. The seven most promising abatement options were then grouped into a Forest Protection Option and a Reforestation/Regeneration Option for further analysis.

4.1.3 Business-as-usual Projections

The base year (1994) landuse situation (area and biomass pools) was used as a baseline (Business – As – Usual) scenario, taking into account the background information on national and sectoral development policies, programs and projects.

The projections indicated that under a business-as-usual scenario, the natural forests in the managed and protected Tropical High Forest Reserves would decrease by 45,000 has (in 2020) as a result of the conversion of part of the 127,000 ha severely degraded portions (the Conversion Forest) to planted forest. Total closed forests would decrease by 343,000 ha mainly as a result of deforestation. The natural Savanna Woodlands would similarly decrease by about 600,000 ha, again through deforestation. Planted forests would increase from 68,000 ha in 1994 to 154,000 ha by 2020. The biomass pool on all forested lands (excluding the bush fallows, etc) would be reduced from 240,300 tB to 230,485 tB.

4.1.4 The Forest Protection Abatement Scenarios

Forest Protection Scenarios to abate climate change developed include:

- increased surveillance of the protected/managed permanent forest and wildlife reserves and involvement of stakeholders, especially local communities in their protection;

- continued enhancement of stumpage for timber trees and of income generation opportunities from unreserved community natural forests, to increase public appreciation of the value of unreserved forests as against their removal for other land uses;

- provision of alternate livelihoods for communities protecting/conserving currently unreserved ecologically sensitive, culturally significant forests;

- expansion of activities to encourage integrated management of the natural savanna woodlands by communities.

- education and sanctions to reduce the incidence of bush burning.

- continued improvement in agricultural technologies to encourage intensive agriculture.

- effective enforcement of the ban on chain saw operations

As a result of these protection measures:

♦ An additional 42,000 ha of unreserved high forests above the Baseline situation (which would protect 3,000 ha) would be maintained and managed as productive dedicated forests by communities and landowners;

♦ 20,000 ha of unreserved high forests on fragile, ecologically sensitive and culturally significant sites would be protected by communities;

♦ 393,000 ha of unreserved savanna woodland, approximately equal to the area expected to be deforested from 2001 would be protected and managed by communities and individuals.

♦ The rate of deforestation of intact forests outside the forest and wildlife reserves would be progressively reduced from 5% in 2001 to 2.5% in the high forest zone and from 0.34% to 0.3% in the savanna woodlands zone;

♦ Total carbon density would increase from 213 tC/ha in 2001 to 272 tC/ha in 2020 in the high forest zone and in the savanna woodland zone from 55 to 62 tC/ha.

4.1.5 The Reforestation Abatement Scenario

This option will ensure that an additional 112,000 ha is reforested, largely as industrial plantations by private enterprise (small, medium and large scale). This area is equivalent approximately to the unreserved high forests that would be deforested and lost even under the forest Protection Option between 2001 – 2020. The incremental carbon that would consequently be sequestered is estimated at 6,060 ktC.

4.1.6 Abatement Assessment

4.1.6.1 Importance of the Forest Sector

The national inventories of GHG emissions were carried out in the agricultural, non-energy industrial processes, waste management, conventional energy supply and the land use change and forestry sectors. Results obtained indicated that about 85% of total carbon dioxide emissions from anthropogenic sources originated from changes in forest and woody biomass stocks, and from forest and grassland conversion 55 – 60% of methane emissions are derived from uncontrolled burning of savanna woodlands.

On the other hand, of all the sectors, the forestry sector provides a reliable sink for the removal of carbon dioxide and its sequestration and storage for some reasonable time in woody biomass or in long term durable wood products. The studies thus showed that while abatement measures in terms of technologies as well as policies might be taken in all sectors, the greatest potential for reducing anthropogenic GHG emissions and expanding carbon sinks would appear to lie in the forestry and land use change sector.

Furthermore, the forestry abatement options have other potential benefits, which thus make them attractive for adoption, namely;

- In the maintenance of climatic resources, the regulation of surface water flows (protection of water-catchment areas); the protection of soils and the conservation of biological diversity;
- In meeting energy needs and
- in the supply of timber and non-timber forest products.

4.1.6.2 ***Methodology***

The Comprehensive Mitigation Analysis Process (COMAP) model was used and is summarized below:

- ♦ description of the baseline situation in terms of the general economic situation, relevant social indicators, the forestry and land use situation and the general climatic indicators
- ♦ analysis of the national and sectoral development policies and measures to provide a basis for projecting the base year situation into a'business – as – usual' scenario;
- ♦ identification of fifteen potential abatement options, out of which seven options were selected and grouped into a Protection Option (to maintain existing sinks) and a Reforestation/Regeneration Option (to expand sinks)
- ♦ projection on the basis of "business-as-usual" land use scenario and of an abatement scenario for land use over the analytical period 1994 – 2020;

- estimation of carbon sequestration under the Protection Option in terms of biomass density, biomass carbon density for both the business-as-usual and the abatement scenarios;

- estimation of carbon pools and sequestration under the reforestation/Regeneration Option

- estimation of costs and benefits associated with the Reforestation/Regeneration Option, using indicator figures derived from other studies for growing *Obeche* (*Triplochiton scleroxylon*) on a 20-year (2001 – 2020) rotation,

- identification of implementation strategies for the two options.

4.1.6.3 Results

The Identification and Screening of Potential Abatement Options

The seven most promising outcomes identified after the screening exercise were:

- better protection of the protected/managed permanent forests through improved monitoring particularly through the application of remote sensing

- improved technical efficiency in the management of the protected forests;

- reduction in bush fires, especially savanna woodland burning, through public education and integrated management for productive use;

- utilization of forest and mill residues for long duration wood products e.g. Flooring strips, reconstituted fibre panels and furniture.

- promotion of agroforestry/farm forestry for joint production of food and wood

- promotion of long rotation commercial forest plantations; and

- promotion of short rotation energy plantations

4.1.7 Projection of Land Use Scenarios

These will include:

The base year land use situation and its projection under both a business-as-usual and the Mitigation Scenarios are summarized in Tables 4.1a and 4.1b. The assumptions are explained under each scenario.

Changes in forest land use will arise from dedication of unreserved community forests in the closed forest zone to permanent protection and production, deforestation, conversion of degraded forest reserves to planted forests and integrated management of savanna woodlands under the mitigation scenario. Total forested land area and corresponding biomass pools will still decline even under the mitigation scenario but by about 231,000 ha less under the abatement scenario than under a business – as – usual scenario.

4.1.8 Projection of Forest Protection Abatement Scenario

Activities under the Forest Protection Option

- increased surveillance of the reserved/permanent forests;
- involvement of stakeholders in protection of reserved forests;
- provision of alternate livelihoods for local communities protecting/conserving currently unreserved forested lands rather than deforesting them for other uses;
- continued enhancement of stumpage for timber trees and development of forest based tourism and of markets for non-timber forest products, leading to increased appreciation of the value of keeping lands under forests
- expansion of activities to encourage integrated management of unreserved savanna woodlands for food, wood, wildlife and environmental protection;
- education and sanctions through bye-laws of district assemblies to reduce the incidence of uncontrolled bush burning and chain-saw operations;
- improvement in agricultural technologies to encourage intensive agriculture.

4.1.9 Major Assumption under the Business-as-usual Scenario

- policies and programs initiated from about 1994 will not begin to have significant effect on forested land use till about 2000.
- deforestation rate (15,000 to 22,000 ha per annum in 1994) will continue at about 20,000 ha per annum in the Closed Forest Zone to 2000 which will be equivalent to about 6.6% of remaining unreserved closed forests by 2000. Increases in stumpage fees for timber under the Timber Resource Management Act (3 to 10 times 1994 rates) will raise the value of unreserved forest lands in the eyes of landowning communities, resulting in a slowing down of deforestation to 5% p.a from 2001.
- private plantation development targeted at 10,000 ha p.a. will be realized gradually under incentives provided under the Natural Resource Management Project and the compulsory requirement for planting under the Timber Resource Management Act. New planting will therefore continue to grow at the 1994 rate of 3% p.a. Thereafter planting rates are projected at 5,000 ha p.a. from 2001 – 2005, 7,500 ha p.a. from 2006 – 2010 and 10,000 ha p.a. from 2011 – 2020.
- 60% of new commercial tree planting will be in the Conversion Forests, i.e. degraded portions of the closed Forest Reserves
- in the Savanna Woodlands, a deforestation rate of 24,000 ha p.a. (pre 1994 rates) is assumed to year 2000 and subsequently converted to its equivalent of 0.34% of remaining unreserved savanna woodland.

4.1.10 Quantitative Results of Forest Protection Option

The expected results I the Forest Protection Option will include:

- ♦ progressive reduction in deforestation of unreserved forested lands from 5% in 2001 to 2.5% by 2005 in the High Forest Zone and from 0.34% to 0.3% p.a. in the case of the savanna woodlands;

- ♦ additional 42,000 ha above business-as-usual scenario of unreserved high forests maintained by communities and owners and managed for production;

- ♦ 20,000 ha of unreserved high forests on fragile, ecologically sensitive and culturally significant sites protected by communities.

- ♦ carbon density and stocking of the severely degraded reserved forests improved by converting additional 69,000 ha beyond business-as-usual projections to planted forests;

- ♦ 393,000 ha of unreserved savanna woodland (approximately equal to the area estimated to be deforested from 2001) put under integrated management for wood, food, etc, thus partially maintaining sinks;

- ♦ increase in total carbon density from 213 tC/ha in 2001 to 272 tC/ha in 2020 in the high forest zone and in the savanna woodland zone from 55 to 62 tC/ha (Table 4.2)

4.1.11 Projections under the Reforestation/Regeneration Abatement Scenario

The abatement option aims at ensuring that an area approximately equivalent to the area deforested between 2001 – 2020 is reforested. By 2020, therefore, if this option is implemented, industrial plantations will amount to 266,000 ha, compared with 68,000 ha in the base year and 154,000 ha under the business-as-usual scenario, the incremental 112,000 ha above the baseline scenario representing the mitigating reforestation option.

Current policies are towards encouraging planting by the private sector. For the larger scale entrepreneur, it will be easier to acquire within the reserved forests than outside. It is assumed that 60% of new planting will be within the Conversion Forest and 40% in the degraded fallow lands.

The incremental carbon to be sequestered by the 112,000 ha plantation established under this option between years 2001 – 2020 will amount to 6,060.5 ktC.

4.1.12 Cost Effectiveness of the Reforestation Option

On the basis of indicative costs and benefits developed for private sector industrial forest plantation programs in Ghana, the initial establishment cost, inclusive of first year weeding and maintenance, is estimated at US $836 per ha. This would amount to US $93.6 million for the 112,000 ha business-as-usual option or about US $15.45 per ktC sequestered. Net present benefit at 10% discount rate over 20-year rotation is estimated at US $330 per ha and US $6.10 per ktC. Such a program would therefore eventually pay for itself from timber harvests. For mitigating climate change, rotations longer than 20 years could be adopted and lower net discounted benefit from timber sales accepted.

4.1.13 Implementation Strategies

The National Forest and Wildlife Policy (NFWP) was adopted in 1994. Derivatory policies and development plans including a Forestry Development Master Plan (1996 – 2020) under Ghana Vision 2020, have come out from the NFWP.

Many of the policy measures required to remove barriers to the implementation of the NFWP have been adopted.

Three broad groups of action are required to implement these strategies:

- a wider sensitization of policy makers and the public to the issue of climate change so that specific requirements for mitigating and adapting to climate change may be considered, identified and included when developmental and other issues are being considered;

- further capacity building and resources to acquire better or more appropriate country/regional related data for GHG inventories and mitigation assessments, especially in the forestry and land use change sector;

- providing/accessing the resources required and implementing the projects identified.

The abatement studies could also be continued, in particular to test the biomass energy production option and to develop the streams of costs and benefits associated with the Protection Option.

Table 4.1a Ghana Land Use (Area: kha)

Land Use	1994 (Baseline)	2020			
		Business -as-usual Scenario	Abatement Scenario	Difference Business-as-usual 1994	Difference Abatement & Business-as usual
High Forest Zone					
Timber Production Area – Forest Reserve	885	888	930	+ 3 (a)	+ 42 (a)
Permanent Protection Area – Forest Reserve	352	352	372	0	+ 20 (b)
Conversion Forest – Forest Reserve	397	352	283	- 45 (c)	- 69 (c)
Total High Forest Reserves	1634	1592	1585	- 42 (c)	- 7
Wildlife Reserves – HFZ	116	116	116	0	0
Unreserved Forest – HFZ	402	101	170	- 301 (d)	+ 69
Total High Forest	2152	1809	1871	- 343	+ 62
Savanna Woodland					
Forest Reserves/Integrated Managed Area	880	880	1,273	0	+ 393 (e)
Wildlife Reserves	1104	1104	1104	+ 0	+ 0
Unreserved Woodlands	7068	6469	6133	- 599	- 336
Total Savanna Woodland	9052	8453	8510	- 599	+ 57
Industrial Plantations	68	154	266	+ 86	+ 112
Natural + Planted Forests	11272	10416	10647	- 856	+ 231
Total Cropland	4320	6394	6394	+ 2074	+ 0
Unimproved Pasture, Bush Fallow, Other	8250	7032	6801	- 1218	- 231
Volta Lake	12	12	12	0	0

Notes

- Dedicated Community Forests
- Community protection of fragile sites, ecologically sensitive, cultural etc. sites
- Converted to planted forests deforestation
- Integrated management of unreserved woodlands for wood, food, etc.
- Deforestation
- Integrated management of unreserved woodlands for wood, food, etc.

Table 4.1b Ghana Land Use (Biomass Pools in tB)

Land Use	Base year Biomass Density (tB/ha)	1994	2020	
		(Base year)	Business-as-usual Scenario	Abatement Scenario
High Forest Zone				
Forest Reserves	146	129,210	129,648	135,780
Timber Production Area	146	51,392	51,392	54,312
Conversion Forest	55	21,835	19,360	15,565
Wildlife Reserves	146	16,936	16,936	16,936
Unreserved Forest	90	36,180	9,090	15,300
Total High Forest	-	253,753	226,426	237,893
Savanna Woodland				
Forest Reserves	30	26,400	26,400	38,190
Wildlife Reserves	30	33,120	33,120	33,120
Unreserved Woodlands	25	176,700	161,725	153,325
Total Savanna Woodland	-	236,220	2,245	224,635
Industrial Plantations	60	4,080	9,240	15,960
Cropland	5	21,600	31,970	31,970
Bush Fallow etc.	1	8,250	7,066	7,066
Total Biomass Pool	-	525,703	495,947	517,524

Table 4.2 Abatement Scenario (Forest Protection) Compared with Business-as-usual Scenario

	Unit	1994	2020	
			Business-as-usual	Abatement
Landuse – High Forest	103 ha	2,152	1,809	1,871
Landuse – Savanna Woodland	103 ha	9,052	8,453	8,510
Biomass Carbon Density – HFZ	tC/ha	73	73	102
Biomass Carbon Density – SWZ	tC/ha	15	15	18
Soil Carbon Density – HFZ	tC/ha	140	140	170
Soil Carbon Density – SWZ	tC/ha	40	40	44
Total Carbon Density - HFZ	tC/ha	213	213	272
Total Carbon Density – SWZ	tC/ha	55	55	62

Note: tB = Tons Biomass, tC = Tons Carbon

4.2 ENERGY SECTOR ABATEMENT

4.2.1 Introduction

This section examines the abatement of greenhouse gases (GHGs) in the energy sector. The energy sector is currently the largest emitter of GHGs. The abatement in the sector was considered a time frame within 1994 to 2020.

In estimating the baseline emissions, Vision 2020 which is the government's main development plan and other estimates of energy demand were used. The energy supply situation was also considered. The emissions of CO_2 equivalent of GHGs to 2020 were estimated with these as inputs. This is called the baseline emission in the sense that Ghana's development path was considered with no aim of reducing GHGs. The result showed that the CO_2 equivalent of emissions for the baseline would increase from 7,278 Gg,. in 1994 to 118,405 Gg in 2020.

Four abatement scenarios were looked at:

(i) replacing some biomass with LPG.
(ii) use of biogas and LPG to some biomass from 2010 to 2015 when only LPG and biogas will be used with the largest proportion of cooking being of biogas.
(iii) gradual penetration of solar PVs to the existing mix
(iv) gradual penetration of biogas instead of a huge penetration as in second and third scenarios.

The CO_2 equivalent reductions from the from the abatement measures of scenarios I, II, III, IV are 495,506 Gg, 700,044 Gg, 712,515 Gg and 543,778 Gg respectively. The cost implications of the reductions are important.

The cost of reduction of a Gg. of CO_2 equivalent of emissions for scenarios I, II, III, IV are $32.22, $2,701.56, $6,932.22 and $9,448.86, respectively.

This abatement assessment has shown that significant amounts of GHG emissions can be reduced in the energy sector through certain abatement options.

4.2.2 Abatement Assessment

In carrying out the abatement assessment, 1994 was used as the base year. The total GHG emissions in CO_2 equivalent for the five sectors are presented in Table 4.2 with the energy sector being the leading emitter in 1994.

Abatement assessment includes the estimation of a baseline emission.

4.2.3 Energy Demand Structure

Available energy data show that transportation is the largest user of petroleum products (60%), followed by residential and commercial (24%), then agriculture (8%) and industry and mines (8%). About 50% of urban households have access to electricity while only 10% of rural households have electricity.

Biomass is the main source of energy for cooking for urban households (82%) while about 15% of households use LPG. In rural areas about 97% of households use biomass for cooking, 2% use kerosene and 1% use electricity and LPG.

The energy demand is derived from the energy growth rates based on the projected growth rate of the economy. This is presented in Table 4.3.

4.2.4 Business-as-usual Scenario

The business-as-usual scenario is the emissions that would be forthcoming based on our development plan without any consideration for GHG emissions.

With the derived growth rates as inputs the business-as-usual emissions of CO_2 equivalent of GHGs to 2020 were estimated. The results showed that the CO_2 equivalent of emissions for the business-as-usual would increase from 7,278 Gg. in 1994 to 118,405 Gg in 2020 as shown in Table 4.3.

Table 4.3 Energy Consumption (1991-2000)

Fuel Type	Percent Per Year
Crude oil	9.2
Gasoline	1.6
Jet kerosine	3.6
Kerosine	0.2
Diesel	3.0
LPG	14.0
RFO	0.6
Electricity	3.0

Source: Ghana's Energy Sector GHG Inventory, 1998

4.2.5 Abatement Options

Four abatement options were considered.

Option I

Replacement of fuelwood and charcoal with LPG at the rate of 10% a year from 1995 to 2020.

Option II

a) 10% increase in use of LPG from 1995 to 2020.
b) a penetration rate for biogas use of 10% a year from 2010 to 2015 and 100% from after 2015 for cooking purposes.

Option III

In addition to measures in option II penetration rates of households in the use of solar PVs for lighting purposes to reduce the use of petroleum products and electricity were considered.

a) 5% from 2000 to 2004
b) 10% from 2005 to 2010
c) 20% from 2011 to 2014
d) 50% from 2015 to 2020

Table 4.4 Business-as-usual Scenario of CO_2 Equivalent (Gg) Emission

Year	**1994**	**1996**	**2000**	**2004**	**2008**	**2012**	**2016**	**2020**
Biomass Consumed TJ	233033.10	297550.97	485163.67	791046.56	1289780.54	2102953.14	3428809.59	5590583.56
CO_2 Emissions from Fossil Fuels (Gg)	3048.40	3892.50	6343.62	10348.00	16872.14	27509.58	44853.64	73132.68
Methane Emissions From Biomass(Gg)	155.80	198.94	324.37	528.87	862.31	1405.98	2292.41	3737.72
Nitrogen Oxide Emissions from Biomass (Gg)	0.80	1.02	1.67	2.72	4.43	7.22	11.77	19.19
CO_2 Equivalent of CH_4 (Gg)	3817.00	4873.93	7946.81	12957.06	21126.15	34445.63	56162.69	91571.78
CO_2 Equivalent of N20 (Gg)	256.00	326.89	532.98	869.01	1416.90	2310.21	3766.74	6141.57
Business-as-usual CO_2 Equivalent	7278.00	9093.32	14826.41	24174.07	39415.19	44539.16	72619.93	118404.87

Option IV

In this option, option III was modified by considering a gradual penetration rate for biogas for cooking by 10% of households per year from 2010 to 2020.

Emissions Reduction and Cost Implications

The abatement options have the corresponding reductions of emissions and cost implications. The summary of emission reductions and the cost per dollar of a Gg CO_2 reduced for the four options are as given in Table 4.5.

Table 4.5 Emission Reduction Cost

Options	**CO_2 Reduction**	**$/Gg**
I	494,506	33.22
II	700,044	2,701.56
III	712,515	6,932.22
IV	543,778	9,448.86

Option I offers the most cost effective measure. Compared to the other options, it reduces emissions significantly. Its employment potential is the most desirable. It has a better long-term sustainability. It does not involve entirely new technology.

CHAPTER FIVE

5.0 SUSTAINABLE DEVELOPMENT AND PLANNING

5.1 NATIONAL DEVELOPMENT GOALS AND THE ENVIRONMENT ROLE OF NDPC

Vision 2020 recognizes sustainable development as the basis for the achievement of a middle income country status by the year 2020. The development objectives in the vision imply that significant increases in human, financial, material and natural resources will be committed to increase production in all the productive sectors, in technological development, in the expansion of services and in growth in the energy sector. In the absence of preventive measures, the likely environmental consequences of the expected increase in economic growth will take the form of industrial and energy related production, deforestation, land degradation and over use of water. To ensure sustainable economic growth in which the environment and development will complement each other, sound management of natural resources, proper waste management practices, as well as environmentally friendly technologies will have to be adopted in the process of growth and development.

In addition, Ghana's commitment to the achievement of the goals and targets of international efforts such as Agenda 21, UNFCCC etc., requires that our long-term goals be geared towards reflecting these commitments.

5.2 THE GOALS OF GHANA'S LONG-TERM ENVIRONMENTAL DEVELOPMENT

The environmental goals for sustainable development in Ghana-Vision 2020 are outlined as follows.

- to establish and maintain a sound built and natural environment that can sustain productive economic activities and pleasant living conditions for both present and future generations, and

- to establish an environmentally conscious society that can exercise self-discipline at all times with regard to individual and community behaviours towards the environment.

The following objectives, targets and strategies are to be adopted under the long-term environmental development.

5.2.1 Objectives

- maintaining ecosystems and ecological processes essential to sustain life and support socio-economic development.
- ensuring sound management of natural resources and the environment in general.
- protecting humans, animals and plants, their biological communities and habitats, against harmful environmental impacts and destructive practices and preserve biological diversity.
- proactively finding solutions to all kinds of environmental problems including those of global dimensions.
- raising environmental consciousness of the entire population.

5.2.2 Target

The set targets include, inter alia;

- present levels of both chemicals and particulate air pollution reduced by 50% by the year 2020;
- processes of deforestation and desertification stopped and reversed by the year 2020;
- sustainable exploitation and protection of forest resources achieved.
- use of renewable sources of energy increase
- use of chemicals fertilizers decrease;
- quality of water and air improve

5.2.3 Strategies

Strategies to be adopted are:

- integrate environmental consideration into national and sub-national levels of development decision-making;
- increase access to information on and improve the understanding of environmental issues;
- establish an appropriate institutional framework and mechanisms to facilitate integration of development and environment
- encourage the adoption of more effective management practices and technology
- ensure compliance with environmental standards and regulations
- apply the “polluter pays principle” to check reckless environmental destruction

- promote international co-operation in matters of the environment

- encourage use of organic base fertilizers from human, animal and plant waste.

5.3 ENVIRONMENTAL MANAGEMENT AND NATIONAL DEVELOPMENT

In 1988, the country carried out proximate estimates of the cost of environmental degradation. The proximate analysis showed that the cost of environmental degradation was equivalent to about 4% GDP. In March 1988, the Government initiated a major effort to put environmental issues on the priority agenda. The exercise culminated in the preparation of a strategy to address the key issues relating to the protection of the environment and better management of the country natural resource base. The objective of what has become known as the National Environmental Action Plan (NEAP) defines a set of policy actions, related investments, and institutional strengthening activities to make Ghana's development strategy more environmentally sustainable.

A National Environmental Policy has been adopted to provide the broad framework for the implementation of the Action Plan. The policy aims at ensuring a sound management of resources and the environment, and to avoid any exploitation of these resources in a manner that might cause irreparable damage to the environment. The implementation of the NEAP started from 1993 and was completed in 1998. Various government ministries, agencies and NGO's were involved in the implementation. Notable among these are the Environmental Protection Agency, Ministry of Food and Agriculture, the Meteorological Services Department, the Lands Commission, the Department of Geography and Resource Development of the University of Ghana, and other research institutions. The key issues 'defined' during the preparation of NEAP were categorized as follows: Land Management Forestry and Wildlife, Water Management, Marine and Coastal Ecosystems, Human Settlements, Mining, Manufacturing Industry and Hazardous Chemicals.

5.4 SECTORAL DEVELOPMENT POLICIES VERSUS CLIMATE CHANGE

Achieving a level of industrialization which provides significant employment opportunities and economic diversification is a priority and becoming a middle level industrial country by the 2020 requires substantial financial investment and energy inputs. Developing the human resource base for industrialization as well as sound rural livelihoods also requires provision of broad educational opportunities to the population and developing rural infrastructure further. Manufacturing industries typically suffer from high operating and capital costs and poor infrastructure, such as roads, communication as well as water and electricity supply.

The rate of electrification presents the challenge of providing energy in a suitable form to a large population-primarily rural but increasingly urban-while at the same time minimizing GHG emissions and maximizing carbon sequestration (carbon dioxide-fixing by vegetation). Rural electrification is seen primarily as a means of providing lighting to households.

Switching the form of energy used by urban poor from charcoal to kerosene or gas can reduce the rate of deforestation due to the reduced demand for biomass for fuel wood or charcoal. With the new goal of carbon sequestration, increasing the quantity of biomass is more important than ever. In most countries, however, rates of biomass harvesting exceed natural regeneration and effects of regeneration efforts.

5.5 IMPACT OF CLIMATE CHANGE ON ENERGY AND INDUSTRIAL PRODUCTION

The energy sector has already started showing signs of being susceptible to climate change, particularly the effect of highly variable precipitation patterns on hydropower production. The drought of early eighties (1980-1983), did not only affect export earnings through crop losses but also caused large-scale human suffering and called into question the nation's continued dependence on hydroelectric power. As a result of the hydrologic failure during the drought, the development of petroleum fired thermal plants is now seen as the major alternative source of electricity in Ghana.

Aspects of climatic change, such as decreased precipitation and increased temperatures in some areas, are likely to cause a reduction in biomass production, particularly due to water stress on the woody plants and also to general land degradation. Decreased agricultural productivity due to changing agro-ecological zones, lack of water for irrigation, and outbreaks of pests and diseases would also decrease the amount of biomass available for energy (e.g., bagasse from sugar production, stalks and twigs from small-scale cropping and tree trimming, biogas from animal manure and waste wood from timber industries).

5.6 CONTRIBUTION OF SECTORAL PROJECTS TO CLIMATE CHANGE ISSUES

5.6.1 The Renewable Energy Program

The Renewable Energy Program aims at promoting the development of Renewable Energy Technologies that are less polluting than the conventional fossil fuels. This program covers a number of specific projects - biomass and solar energy discussed as follows:

5.6.2 Biomass Energy Projects

The biomass energy projects being undertaken include:

Developing a National Woodfuel Policy, which would ensure that the production and use of woodfuels are made environmentally friendly and sustainable. The District Assemblies could adopt such policy guidelines as bylaws.

Conserving forest resources through improved methods for charcoal and firewood production

Decreasing consumption of firewood and charcoal by using more efficient cooking devices, and switching to natural gas, propane etc.

Expanding the productivity and use of existing bio-energy sources such as biogas from organic, animal and municipal waste; and production of briquettes from logging and wood processing residues. The feasibility, economic viability and social acceptability of introducing biogas and sawdust briquette as alternative energy forms are currently being investigated.

Planning for the future security of biomass supply through the implementation of a sustainable program of forest regeneration and afforestation.

5.6.3 Solar Energy Program

At the moment direct solar radiation does not represent a major form of energy in Ghana. It is only used in its natural form in drying several items including agricultural crops, fish, sawn timber, clothing etc. The Ministry of Mines and Energy has therefore, embarked on a program to assess, demonstrate and evaluate the technical, economic and social viability of promising solar energy technologies in Ghana, especially with regard to the development of rural communities. The specific solar programs that are currently underway are:

- The prospects for solar water heating in Ghana;
- The prospects for solar crop drying in Ghana;
- Off-grid solar PV electrification pilot project, in the West Mamprusi District of the n Region
- Feasibility study for a pilot solar thermal plant in Ghana.

5.6.4 Off-Grid Solar PV Electrification Pilot Project

Ghana receives solar irradiation level ranging from 4-6kwh/m^2 daily with corresponding peak annual sunshine duration of 1460-2190 hours. The specific objectives of two of the solar projects currently in progress are:

- to design, install and monitor pilot solar PV electricity system for Wechiau;

- to establish the technical performance, social acceptability and cost-effectiveness of their operation;

- to prepare an action and work program whereby solar PV electricity will form an integral part of the overall National Energy Program.

- to establish locally manufacturing capacity in solar technology such as charge controllers and inverters. Marketing of small systems to households to provide one or two lights and power for radio. Development of solar-powered battery charging system for deployment in rural areas, to establish standards for photovoltaic equipment and components, locally produced and imported, including licensing program for installers and standards for installation and design

5.6.5 The National LPG Promotion Program

The LPG Program was initiated in 1990 to promote the wider use of Liquefied Petroleum Gas as a substitute for charcoal and firewood in order to:

- slow down the rate of deforestation caused partly by the production and use of woodfuels; and
- reduce pollution arising from the direct flaring of Liquefied Petroleum Gas (LPG) into the atmosphere.

Since the inception of the program, LPG consumption in the country has risen from 6006 metric tonnes in 1990 to 26,200 metric tonnes in 1994.

5.6.6 Energy Efficiency and Conservation Program

The National Energy Efficiency and Conservation Program covers the following areas: Energy Conservation in Industry, Energy Conservation in the Residential, Commercial and Public sectors and Energy Conservation in the Transport sector. Some energy conservation activities undertaken include:

Energy audit of firms, industries and public institutions were carried out and the savings from energy conservation measures documented.
The pattern of energy utilization has been established and the potentials for introducing energy conservation measures assessed;

Demonstration of the cost effectiveness of energy conservation measures in the industrial sector has been undertaken;

5.7 NATIONAL ENVIRONMENTAL FRAMEWORK IN RELATION TO UNFCCC

5.7.1 Environmental Legislation

Ghana's 1992 Constitution also reiterates the country's commitment to sound environment management. Article 36(9) of the Constitution stipulates that "the State shall take appropriate steps needed to protect and safeguard the national environment for posterity, and shall seek cooperation with other states and bodies and for purposes of protecting the wider international environment for mankind. Article 41 is worth noting since it describes the duties of a citizen. Article 41(k) stipulates categorically that ".......... it shall be the duty of every citizen...... to protect and safeguard the environment".

5.7.2 Ministry of Environment, Science and Technology

One of the major outcomes of the 1992 Earth Summit in Ghana was the creation of the Ministry of Environment (currently Ministry of Environment, Science and Technology) in March 1993. The Ministry has established an Advisory Committee with a secretariat based in the ministry to facilitate the implementation of Agenda 21. The membership is drawn from both government and non-governmental organizations, which have a role to play in ensuring that development is undertaken in a more sustainable and environmentally sound manner.

5.7.3 Environmental Regulatory System

The Parliament of the Republic of Ghana subsequently enacted and promulgated the Environmental Protection Agency Act 1994 (Act 490), thus abrogating the EPC Amendment Decree 1976 (SMCD 58). The EPA Act 1994 (Act 490) established the Environmental Protection Agency in place of the erstwhile EPC as a regulatory and enforcement Agency under section 12(2) of the Act. The EPA Act 1994 (Act 490) confers on the Agency implementation objectives and regulatory functions. By the enactment of the EPA Act 1994 (Act 490), non-compliance to environmental regulations has become criminal, liable on conviction to fines or to terms of imprisonment in Ghana. The Act, however, ensures the application of a set of systematic measures in a manner to promote compliance (i.e. pro-active self-regulation) in accordance with a set of measures as laid down EIA procedures and regulations (Environmental Assessment Regulations, 1999, LI 1652).

5.7.4 Administrative Measures to promote Compliance

5.7.4.1 EIA Procedures:

Environmental Impact Assessment (EIA) is recognized as a major environmental management tool. EIA first became a requirement in Ghana in 1989, following a Government directive to the then Environmental Protection Council (EPC) to apply EIA to ensure that development activities are carried out in an environmentally sound manner. This Administrative Directive was given legal backing with the enactment of 1994, Act 490. The adoption of LI 1652 has made the administration of the EIA Procedures in Ghana more effective.

5.7.4.2 EMP Process

The EPA has initiated Environmental Management Plan (EMP) preparation aimed at initiating an evolving process of environmental awareness and management development over a period. All existing industries and newly operating projects are required to submit EMPs.

5.7.4.3 Compliance and Enforcement Measures

To ensure collaboration between law enforcement and regulatory agencies an **Intesectoral Network,** called Compliance Enforcement Network (CEN), was established in 1995 by the Ghana EPA.

CEN comprises representatives of all the law enforcing agencies, the Attorney General's Department, and eight other regulatory bodies including the Mines Department, Factory Inspectorate Department (FID), Town and Country Planning Department (TCPD), Ghana Standards Board (GSB) and the Customs, Excise and Preventive Service (CEPS) with EPA as the co-ordinating Agency.

The activities of the CEN include joint-field-inspection and verification of compliance with enforcement notices/prohibitions issued to offenders.

5.7.5 Ghana Environmental Resource Management Project (GERMP)

The vehicle for the implementation of the NEAP was the Ghana Environmental Resource Management Project (GERMP).

In line with the general goal of the NEAP and National Environmental Policy, the Project sought to develop capacity for the government and people of Ghana to manage the environment more effectively. GERMP was based on the following:

- Developing an Environmental Resource Management System for Ghana through institutional and technical capabilities for effective environmental monitoring, policy formulation and co-ordination.
- Developing and supporting a program to combat soil degradation and erosion, as these are pervasive environmental problems. This involves the introduction of improved land and water management based on community participation in planning, implementation and monitoring of measures to reduce land degradation.
- Preventing further destruction of the fragile resource in the coastal zone through the demarcation and management of five coastal wetland sites as Ramsar sites.

Ghana has adopted an integrated approach towards sustainable development of its resources. As a result, the design of GERMP was based on the following:

- The inter-sectoral nature of many environmental concerns;
- The fact that many areas of government are to be decentralized to District Assemblies;
- The need to ensure that communities are involved in decisions about the use of environmental resources; and
- The fact that significant portions of the NEAP are to be implemented through planned or on-going sector specific projects supported by the donor community, particularly in the forestry, urban, industrial and energy sub-sectors.

Significant gains have been made as a result of the successful implementation of GERMP. However, detailed description of the outcome falls outside the scope of this report.

5.8 CO-ORDINATION OF CLIMATE CHANGE AND UNFCCC ACTIVITIES IN GHANA

A National Committee on Climate Change is hosted by the Ministry of Environment, Science & Technology. This committee (made up of representatives from Ministries, Universities, Research Institutions, the private sector and Non-Governmental Organizations) has been mandated to review policies and programs that can complement the national development priorities while at the same time contributing to reduction of greenhouse gas emissions and increase in carbon sinks. The Ministry is the focal point for the UNFCCC activities in the country.

The main Country Implementing Institution (CII) for the technical coordination of activities on Climate Change, the UNFCCC and other environmental conventions ratified by Ghana, is the Environmental Protection Agency. Since 1997, a special Conventions and Projects Implementation Department has been established within the Agency to perform, inter alia, the following functions:

(a) Serve as the focal point for National, Regional and International Projects and Conventions implemented by the Agency;
(b) Liaise with other departments to generally facilitate the coordination of Ghana's involvement in the preparation, ratification and implementation of Conventions and Protocols on the environment;
(c) Act as the "desk" for the implementation of climate change related issues.

Experts selected from the Universities, NGOs, Research institutions and Ministries, Departments and Agencies have also been organized into Working Groups and Climate Change Study Teams to assist with the implementation of the Climate Change Project. They form a core of experts who execute various activities in identified areas within the national economy that affect greenhouse gas emissions and sinks and also provide technical support to projects under the national climate change activities. This initial National Communication is based on the results obtained from the working groups and study teams.

5.9 SOCIO-ECONOMIC DEVELOPMENT PROSPECT UNDER THE IMPLEMENTATION OF THE UNFCCC

5.9.1 Formulation of National Development Priorities

The management of the country's environmental resources is being based among others on policy formulation, planning, legislation, institutional capacity building, monitoring/evaluation and problem solving, implementation of decisions and compliance and enforcement. At each stage, the operation of the system will be made dependent on an effective process for reaching decisions and clear responsibilities for implementing those decisions. This will involve decisions made at the highest level of government, by sectoral agencies, by District Assemblies, and by traditional and other community authorities. Most environmental concerns are inter-sectoral and decisions involve choices between alternative, and possibly conflicting courses of action, which carry costs and benefits.

The need for a clear decision making process is equally important at the local level as at the centre. Government policy on decentralization, the identification of District Assemblies as District Planning Authorities and the formation of District Environmental Management Committees provide a firm basis for local management of the environment. It is proposed to strengthen the regional offices of the Environmental Protection Agency and provide training for district level staff as a way of developing a system for local environmental management. The importance of this system cannot be overemphasized as conservation based on community participation, reinforced by locally decided bye-laws, will always be more effective than a centralized, top-down or legislative management system.

5.9.2 Environmental and Economic Significance

As already stated the energy sector is the main source of GHG emissions in most African countries. The sector directly contributes GHG to the atmosphere in the course of energy production, conversion and use. Wood, charcoal, coal and refined petroleum products are used for primary and secondary production of energy used in industry, transport and by households. The design of the energy sector thus affects not only the current pattern and levels of emissions but will to a large extent determine the future development path and GHG contributions by Africa's industrial sector as well.

The sector includes the extraction and processing of fossil fuels-mainly petroleum, natural gas and coal-and production of electricity by thermal, hydroelectric, geothermal, solar and nuclear processes. Hydropower dominates electricity sources in most sub-Saharan countries. The energy sector also includes the collection and use of biomass, such as fuel-wood, crop residues and animal waste. Biomass may be used directly or processed through fermentation to produce biogas (mostly methane), or through carbonization to produce charcoal, and other usable energy products.

Industrial activities in Africa reflect her natural resource endowment. Processing and manufacturing industries are generally underdeveloped relative to the production and export of raw materials. The main industrial activities are based on processing agricultural products and minerals, import substitution of manufactured goods and conversion. Main industrial outputs are: cement, printed goods, metal (e.g. aluminum, recycled steel) petroleum products (including petro-chemicals), textiles, gold, diamonds and other minerals, food and leather products and other manufactured goods. While GHG emissions from the industrial sector are low compared to other sectors in Africa, and with the same sector in the industrialized countries, the development strategies of many African countries focus on substantially expanding industrial activities. Hence it is the potential growth of this sector-which may both provide the economic development so urgently needed on the continent and increase GHG emissions- which warrants serious attention.

Energy and industrial development policies must now be re-examined from the perspective of climate change. They should be assessed in terms of their capability to mitigate the impacts of climate change and reduce the growth of GHG emissions. Some options can be exercised relatively quickly and with little or no capital investment. Other options, such as replacing capital stock, are of a long-term nature, while options such as planning structural change in the energy and industrial sectors have an even longer time horizon but they should be embarked upon immediately.

5.9.3 Strategies to Integrate Climate Change Concerns into the National Development Framework

The main elements of a proposed strategy to reduce greenhouse gases could consider short-term action programs that might be carried out, taking into account the 25-year Development Plan of Ghana. Some areas for possible action include research and systematic observation, monitoring and analysis of the greenhouse effects and climate change. Specific elements worth considering include:

- the creation of a “Climate and Greenhouse Gases Database" inventorying of climate and air pollution data and CO_2 emissions;
- more effective climate and greenhouse gases monitoring; and
- sea level monitoring through an inventory of the existing tidal stations and data collecting sub-centres, establishment of the computerized tidal data processing system, forum for interagency co-ordination of tidal and sea level rise monitoring, the installation of additional tidal gauges and establishment of maritime monitoring stations.

Another area for possible action consists of efforts to reduce greenhouse emissions. Main elements worth considering include:

- energy conservation (promotion of energy conservation in large energy consuming industries such as mining, cement and steel industry; information and training on energy conservation; national energy conservation campaigns; and technical guidance regarding new and alternative energies);
- a program to promote the use of highly energy efficient appliances;
- a program to promote energy conservation in buildings (through financial assistance for investments to improve energy efficiency in existent buildings, energy efficiency standards and energy audits for high energy consuming buildings);
- a program to promote the use of energy-efficient equipment in the public sector (e.g. use of fluorescent lamps);
- application of clean energy technology such as small scale hydro power systems,
- promotion of the use of LPG
- promotion of alternative energy sources such as solar, wind and wave energy;
- technical improvements in agriculture and animal husbandry with the aim to reducing emissions of methane and nitrous oxides;
- waste management (R&D on methane reduction practices; increased recycling);

- monitoring of greenhouse gas emission from industry, for instance through emissions inventories for particular industries;

- controlling emissions from the transportation sector (inventory of technologies producing lower CO_2 emissions; promotion of the use of natural gas in vehicles; promotion of catalytic converters for motor vehicles); and

- sink enhancement through the enhancement of phytoplankton activity in the sea and forest management (reforestation; measuring of CO_2 sink capacity of different forests, and inventory of biomass of typical forests to determine the capacity as CO_2 sinks).

CHAPTER SIX

6.0 RESEARCH AND SYSTEMATIC OBSERVATION

6.1 CLIMATE SCENARIOS DEVELOPMENT

As part of the Ghana climate change country studies, national climate change scenarios have been developed. Climate Change Scenarios for the climatic variables mean monthly rainfall amount, maximum, minimum and mean daily temperatures have been constructed to cover the whole of Ghana for the years 2000, 2005, 2010, 2015, 2020, 2025, 2050, 2075 and 2100. This was done in accordance with the requirements of the Country Working Groups for Climate Change Vulnerability and Adaptation Assessment on Water Resources, Agriculture and Coastal Zone.

Monthly means for the period 1961-1990 of the above climatic variables were computed for twenty-two (22) stations in Ghana. These stations were later grouped to define climatic means for ten specific areas of the country and used as baseline climates of these areas. With the establishment of these baseline climates, climate scenarios were constructed.

There are in general three basic groups of methods available for the construction of climate change scenario. These are the process-based methods, empirically based methods and synthetic or statistical methods. For this study, a process-based method was selected. Process-based methods rely primarily upon the use of General Circulation Models (GCMs) in conjunction with Simple Climate Models (SCMs). Inspite of their limitations, GCMs provide a powerful tool to generate physically realistic scenarios of future climate. In order to assess the impacts of future climate change upon natural and socio-economic systems however, some manipulation of GCM data is often necessary.

In developing climate changes scenarios for Ghana, the 'Linked Model' approach was adapted. In this approach, the results of GCM experiments are combined with those of simple time-dependent climate models through appropriate scaling techniques to obtain internally consistent global and regional changes of various climatic variables.

These changes can then be added to the observed baseline climatology for a particular region of the earth to obtain a range of geographically explicit future climate change scenarios.

Three GCMs, whose experimental results validated best against global observed rainfall patterns, were selected. These are the Hardly Centre Model 2 (HADCM2), the UK Meteorological Office Transient Model (UKTR.) and the UK Meteorological Office High Resolution Model (UKHI).

The average of the three (3) GCM experiments results was used in the calculations. This was to eliminate any internal consistencies that might be within individual models.

The simple climate model used is known as MAGICC (Model for the Assessment of Greenhouse Gas Induced Climate Change) developed by the Climatic Research Unit (CRU) of the University of East Anglia (UEA). MAGICC consists of a set of coupled gas cycle, climate and ice-melt models that allows the user to determine the global mean temperature and sea-level consequences of user-specified green house gas and sulphur dioxide emissions. While GHGs increase global temperatures, the presence of sulphate aerosols can counteract some of the effects of greenhouse warming. The temperature changes calculated using MAGICC took into consideration the effects of aerosols through the regionalisation of the projected concentrations of SO_2 up to the year 2100.

To link the results of the MAGICC experiments with the average results of the 3 GCM experiments, a computer software known as SCENGEN (Scenario Generator) was used. SCENGEN is also developed by CRU and enables the user to combine results from simple climate models and GCM experiments together with observed global and regional climatologies to construct a range of Climate Change Scenarios for any part of the globe.

For greenhouse gas emission scenarios, one of the Inter-governmental Panel on Climate Change (IPCC) emissions scenarios, the so-called IS92 scenarios was used. The mid-range IS92a scenario, amended for the IPCC, 1995 report, was used. This Scenario projects that CO_2 emissions will rise from 7 billion tones of carbon per year in 1990 to 20 billion in 2100. This is based on a world population doubling by 2100 while economic growth continues at 2 - 3% per annum.

This scenario leads to the equivalent of doubling pre-industrial CO_2 concentrations (280 ppm) by 2030, and trebling by 2100. This includes the effects of other greenhouse gas emissions converted into their CO_2 equivalents. In all calculations the climate sensitivity which refers to the long term (equilibrium) change in global mean temperature following a doubling of atmospheric CO_2 were set at 1.5 °C that is low, 2.5° C which is the mid-range value or 4.5° C which is the high value in line with IPCC recommendation.

A range of climate change scenarios was thus obtained for each of the climatic variables. The mid-range values were added to the baseline climate to obtain the climate scenarios for the various years starting from the year 2000 to 2100. With the exception of precipitation for which unequal weights were assigned to the GCMs, all other variables equal weights were used in averaging the GCM results.

In the case of precipitation, the correlation coefficients of the GCMs experiments with observed data were used as weights. The temperature changes calculated using MAGICC took into account the cooling effect of atmospheric aerosols through both direct and indirect sulphate aerosol forcing including shoot as well as forcing due to aerosols from biomass burning.

For the individual models, which make up MAGICC, the following parameters were selected.

<u>CARBON CYCLE MODEL</u>

Dn 80s =1.1GtC (This variable defines the 1980s - mean value for land-use change CO_2 emissions. The value 1.1GtC (Gigatonnes of carbon) per year which is the IPCC 1995 mid-range value.

CURRENT AEROSOL FORCING

Direct : - 0.3 Wm^{-2}
Indirect : - 0.8 Wm^{-2}
Biospheric : - 0.2 Wm^{-2}

CLIMATE MODEL

Climate Sensitivity (ΔT2x) = 2.5 °C (This is the IPCC mid-range value which has a range of 1.5 °C to 4.5°C). In constructing the change scenarios, three estimates of atmospheric sensitivity were used that is the low, mid and high.

Upwelling rate : Variable. - This is a measure of the strength of the thermohaline circulation in the oceans.

The changes in the climatic variables, temperature (actual changes) and precipitation (percentage changes) due to greenhouse gas and aerosol effects for the low (1.5°C), mid (2.5°C) and high (4.5°C) Atmospheric Sensitivities were read from five 5° latitude by 5° longitude grid cells which partially or wholly lie over Ghana. The grid cells bounded by the following longitudes and latitudes were used in the study.

latitude 0° - 5° N and longitude 5° W - 0°
latitude 5° N - 10° N and longitude 5° W - 0°
latitude 5° N - 10° N and longitude 0° - 5° E
latitude 10° N - 15° N and longitude 0° - 5° E

The change scenarios obtained for these grid cells were then marched with the areas of Ghana marked A to E2 to obtain climate change scenarios for these areas for the years 2000, 2005, 2010, 2015, 2020, 2025, 2050, 2075 and 2100.

To obtain estimates of the climatic variables where projected changes have been calculated, the mid-range change scenarios were imposed on the baseline climatologies of the delineated areas of Ghana for each of the years 2000, 2005, 2010, 2015 and 2020, 2025, 2050, 2075 and 2100. It should be noted that no down scaling of the GCM changes were performed for the individual stations within any of the 5° Latitude/Longitude grid cells.

Based on the above approach, projections for the climate elements precipitation (monthly totals and mean daily intensities) and temperature (mean daily, mean maximum and mean minimum temperatures) were made for the ten areas mentioned above.

The daily mean rainfall intensities were obtained simply by dividing the mean monthly totals by the mean number of rain days of each month of the baseline climate. In doing this it was assumed that the mean number of rain events will not change significantly within the time scale for which these scenarios have been developed.

The sea level rise consequences of Climate Change using the three GCMs mentioned above and the IS92a emission scenario were computed. In the case of sea level rise also, the IPCC low, medium, and high atmospheric sensitivities were used to obtain a range of values for each of the years 2000, 2025, 2050, 2075 and 2100. Here larger time steps were used because of the small nature of the changes between years.

Observation

As mentioned earlier, there have been increases in temperature over the whole of the country between 1961 and 1990 the period used as the baseline for this scenario development. For the country as a whole rainfall amount also showed a downward trend.

From the projections for temperature, rainfall and sea level rise, the following deductions were made: -

(a) That mean daily temperatures will increase by about 2.5° C to 3.2°C, if the mid-range atmospheric sensitivity of 2.5°C is assumed, over the 1961 to 1990 baseline temperatures by the year 2100. This is higher than the global average of about 2°C over the same period. These changes could, however, be lower or higher depending on the way the atmosphere will respond to increases in the concentrations of greenhouse gases. The range of uncertainty in these projections is about 1°C to 3.5°C due mainly to oceanic inertia. It should, however, be noted that even if a 1°C rise in temperature is attained by 2100 above current mean temperatures, it would be larger than any century-time-scale trend for the past 10,000 years. The rate of climate warming in Ghana during the baseline period is about 0.2°C per decade which is comparable to the projected decadal rate of increase of about 0.25°C to 0.32°C between the years 2000 and 2100. The differences might be attributed to the increased effect of greenhouse gas concentrations in the past and current periods on global climate between 2000 and 2100.

(b) Annual totals of rainfall amount will decrease throughout the country except in regions E1 and E2 where very slight increases are expected . On monthly basis, however, there will be some slight increases during the dry months, that is from November to March again over the entire country except regions E1 and E2. In the two regions decreases are projected during the months of December to May while June to November show increases causing a net effect of very little increase in annual totals. The predicted trend in rainfall in all regions is similar to the observed trend during the baseline period. For Ghana as a whole, however, the observed rate of decrease in rainfall of about 5.4% per decade during the period 1961 to 1990 is larger than the average predicted rate of decrease of about 4% per decade between 2000 and 2100. Projected changes in rainfall are also subject to uncertainty mainly due to the uncertainty in the way the atmosphere will respond to increased concentrations of greenhouse gases.

(c) For sea level rise, the global averages based on the IS92a as amended for the IPCC 1995 report have been used. Using an atmospheric sensitivity of 2.5°C the projected rise in sea level will range from 2cm in the year 2000 to about 48.9cm by 2100. There is a wide range of uncertainty in sea level rise projections due to atmospheric sensitivity. For example under the same emission scenario but with an atmospheric sensitivity of 4.5°C the sea level could change by as much as 85.9cm by 2100.

6.2 INSTITUTIONAL FRAMEWORK AND CAPACITIES

Ghana as a developing country is yet to put in place structures specifically aimed at addressing climate change related issues. However, there exist national institutions and private organizations whose mandates/activities border on climate and climate change issues.

Some institutions have been identified that must be strengthened (both technically and financially), to undertake research and systematic observation aimed at contributing actively to national, regional and global climate research programs; such as World Climate Research Program and World Weather Watch. That notwithstanding, some of the local institutions are in the position to provide capacity building.

This chapter lists some of the important institutions that have been involved in the climate change activities in Ghana. It must be noted, however, that the list is by no means exhaustive.

6.2.1 Meteorological Services Department

The primary function of the Meteorological Services Department (MSD) is to provide efficient weather services through the collection, processing, storage and dissemination of meteorological data to end-users.

Recipients of information from the MSD include the Ministry of Agriculture, Lands and Survey Department, Universities, Airlines, Maritime Operations, Banks, Cocoa Farmers and producers of other crops and grains. Since these clients of MSD provide indispensable services to the public, the data from which the MSD provides analytical meteorological information should be complete, accurate and reliable to ensure prompt delivery of services to clientele.

The MSD is one of the institutions which were selected under the Ghana Environmental Resources Management Project (GERMP) to achieve the National Environmental Action Plan objective of strengthening the capacity of national institutions to manage environmental resources using existing structures.

Under the GERMP, the Department embarked on computerization of its climate database in 1994. A lot of progress was made with a sizeable proportion of the data now in digital form. However, due to the volume of data being handled the existing equipment used, particularly computers, are not able to cope with the task. There is therefore the need to upgrade or replace existing equipment to enhance the computerization process.

Inadequate professional staff is another source of concern to the department. Since none of the country’s universities offer courses in meteorology professional staff are trained abroad. Due to the high cost involved the department usually resort to funding form the World Meteorological Organization and other donor countries to train its personnel. These sources are, however, not regular and there are currently a lot of personnel waiting to be trained in the various fields of meteorology. This has become even more urgent due to the number of professional staff who have retired in the last few years or about to retire.

Efficient telecommunication system, which is vital to achieving the objectives of the Department, is also lacking. Radiotelephones are needed at the synoptic stations to send data to the forecast office for processing in order to come out with a reliable forecast both for public and aviation use. Currently a number of these radiotelephones are not serviceable and this is hampering efficient service delivery.

6.2.2 Remote Sensing Applications Unit

The Remote Sensing Applications Unit (RSAU) was established in 1993 by the University of Ghana and equipped with funds from the Government of Ghana, the Danish International Development Assistance (DANIDA) through the Institute of Geography of the University of Copenhagen and the United Nations Development Program.

Under the Ghana Environmental Resource Management Project (GERMP) the capabilities of the Unit have been enhanced to enable it undertake the production of land use information under the Environmental Information System Development (EISD) component of the GERMP. The Government of Ghana, DANIDA, and the International Development Association (IDA) of the World Bank provided funding.

In addition to producing land use information the GERMP also had the objective of building capacity at RSAU to make it a self-funding but non-profit making organization by providing services in respect of the following:

- Spatial data management and analysis for both Government agencies and interested private sector institutions in Ghana
- Environmental remote sensing and geographic information systems development and applications
- Training and research support for natural resource appraisal and monitoring including rural and urban land use patterns and trends.

This is being pursued through the creation of awareness about Geo-Information, its applications and benefits; consultancy services in a wide range of remote sensing and GIS applications; and technology transfer including training.

The execution of the Land Use and Land Cover mapping project of GERMP and the client services projects undertaken for clients has given the UNIT the requisite experience to undertake the development of the GIS databases. As a result of this RSAU has a good amount of digital spatial data on themes such as topography, drainage, settlement locations, administrative boundaries, land use and land cover road network, protected areas, etc.

RSAU can therefore support the Climate change/Sea level rise program by providing all stakeholders access to these data sets as well as assisting other national experts and institutions to develop a coastal zone vulnerability assessment using our Geographic Information and image processing System.

RSAU has a training laboratory, for up to 20 trainees, equipped with modern equipment resource library and also has the capacity to provide effective training in its areas of competence.

6.2.3 Council for Scientific and Industrial Research

Council for Scientific and Industrial Research (CSIR) was re-established by Act 521, 1996 and was mandated to carry out functions including but not limited to:

- Pursuing the implementation of government policies on scientific research and development;
- Encouraging, in the national interest, scientific and industrial research of importance for development of agriculture, health, medicine, environment, technology and other services sectors and to this encourage close linkages with the productive sectors of the economy;
- Undertaking or collaborating in the collation, publication, and dissemination of the results of research and other useful technical information; and
- Co-operating and liaising with international and local bodies and organizations, in particular the universities and the private sector on matters of research.

There are a number of research institutions under CSIR whose activities have relevance to climate change activities. These include Crops Research Institute, Animal Research Institute, Forestry Research Institute, Institute of Industrial Research, Water Research Institute, Soil Research Institute, Savanna Agricultural Institute, Institute for Scientific and Technological Information and Science and Technology Policy Research Institute.

6.2.3.1 Water Research Institute (WRI)

Vulnerability assessment of water resources in Ghana was mainly carried out by a research team (put together as a Country Working Group) from this institute.

There is, however, the need to strengthen capacity in the water vulnerability assessment in two main areas of data collection and research.

In the area of data collection, there is the need for equipment replacement and installation of new ones. Training of personnel to man the new equipment will also be relevant. Other collaborating institutions to be strengthened for data collection include Hydrological Services Department, Meteorological Services Department and Water Research Institute.

In research, WRI will need to be strengthened to undertake continuous research in climate change and impacts on water resources. Capacity in hydrological and water resources management modelling will need to be enhanced in the Institute. In this direction, there will be the need to establish some collaboration with other research centers with keen interest in this area of study. Meteorological Services Department will also need to be strengthened in the area of climate research to support the hydrological modelling.

6.2.4 Environmental Protection Agency

The Environmental Protection Agency (EPA) envisions:

- a country in which all sections of the community value the environment and strive to attain sustainable development, with sound and efficient resource management, taking into account social and equity issues
- an Agency dedicated to continuously improving and conserving the country's environment in particular.

The mission of the EPA of Ghana is to co-manage, protect and enhance the country's environment, in particular, as well as seek common solutions to global environmental problems.

To enable EPA to achieve its mission, the following corporate objectives have been established. EPA seeks to:

- create awareness to mainstream environment into the development process at the national, regional, district and community levels
- ensure that the implementation of environmental policy and planning is integrated and consistent with the country's desire for effective, long-term maintenance of environmental quality
- ensure environmentally sound and efficient use of both renewable and non-renewable resources in the process of national development
- guide development to prevent, reduce and, as far as possible, eliminate pollution and actions that lower the quality of life
- apply the legal processes in a fair, equitable manner to ensure responsible environmental behaviour in the country
- continuously improve EPA's performance to meet changing environmental trends and community aspirations
- encourage and reward a commitment by all EPA staff to a culture based on continuous improvement and on working in partnership with all members of the Ghanaian community.

The most important measure of the success of the Agency's programs that will be based on these objectives is the extent to which human health and welfare and ecological integrity are maintained. In order to assess the implementation of core activities, EPA is developing measurable and time-bound indicators. The current preliminary list of goal areas includes a range of key environmental concerns which can be categorised as either "Desired Environmental Outcomes" (i.e. ultimate "ends") or as "Strategic Outcomes" (i.e. the key "means" by which the ends will be achieved).

6.2.4.1 Desired Environmental Outcomes

The goal areas for developing indicators include:

- clean air
- clean surface water
- significantly reduced rates of desertification
- significant reduction in all forms of land degradation
- prevention and abatement of increase of GHG emissions under climate change
- ozone layer protection
- safe drinking water.

6.2.4.2 Strategic Outcomes

- awareness creation
- effective Coastal Zone Management
- effective and consistent compliance and enforcement
- ecologically sound management
- environmental education (formal and non-formal)
- reduced generation of hazardous wastes and proper management of residual wastes
- effective pollution prevention/control
- effective sanitation infrastructure and practices
- sound chemicals management

EPA has been the implementing Agency for the climate change activities in the country. This has been done by way of co-ordinating technical and scientific studies and research works, which culminated in the preparation of this communication.

CHAPTER SEVEN

7.0 EDUCATION, TRAINING AND PUBLIC AWARENESS

7.1 Ghana Government Policy on Environmental Education

The successful implementation of Ghana Government Policy on environment, including aspects on climate change, is based on the premise that the citizenry understands the functioning of the environment and the related issues in order for the citizenry to contribute meaningfully to its protection, improvement and enhancement.

To achieve this, continuous and detailed environmental education programs have to be implemented at all levels so that every Ghanaian becomes aware of the problems and fully assumes his responsibilities in the protection of the environment. Environmental Education therefore forms an integral part of the educational system.

Sustained effort is being made to promote awareness among policy makers, provide training for resource managers at appropriate levels and promote greater public awareness and motivation for environmental action.

The government believes that economic prosperity of the nation depends on a high quality environment; losses being experienced reduce the living standards of the present generation; and that the prosperity of future generations will be prejudiced by today's excesses.

7.2 EPA's Mission (Environmental Education)

On the basis of the government policy on environmental education EPA's mission on environmental education is:

- to ensure that all sections of the population understand environmental systems and processes for the protection, improvement and enhancement of the environment for present and future generations.

To achieve this, EPA is assisting the institutions responsible for education in Ghana, such as formal and non-formal, the media, etc. to assume responsibility for the delivery of environmental education as a legitimate aspect of their activities. EPA is therefore facilitating, among others, the following:

- train and equip sectoral agencies in environmental education skills and other facilities.
- ensure mass participation in environmental decision making and management
- improve access to and provide information on environmental issues
- promote the development of training materials
- promote continuous education to ensure the development of a cadre of environmental professionals

- develop school/community participation through the institution of awards and competitions for environmental efforts
- integrate environmental ethics throughout Ghanaian culture

Due consideration is being given the non-formal sector: viz.,

To reach the youth and adults, individually, collectively and segments of the population-from worker to manager and the decision maker, family and all those responsible for bringing up the young

There is increasing need to develop additional training materials appropriate to the situation in the country and to make environmental data and information more generally available to the public.

In all these aspects of the government policy actions due consideration could increasingly be given to climate change issues both in the formal and non-formal education systems.

7.3 Formal Education System

Attitudes towards the environment are generally acquired early in life and at the time of schooling. Consequently, the Ministry of Education in collaboration with Environmental Protection Agency prepared environmental related themes which were integrated into the school curriculum as part of education reform program which was introduced in the country in 1987. The themes, which include climate change and its related issues like deforestation and bush fires, have been introduced into certain relevant subjects of the curriculum such as Social Studies, Agricultural and Environmental Studies, General Science and Life skills.

A survey of the status of Environmental Education in Ghanaian Schools and Colleges revealed among other things that teachers were finding it difficult to teach the subject due to lack of reference materials. It will therefore be necessary, for education on climate change in the schools to be effective, to develop teaching, learning materials on Climate Change.
Essay competition also be organized for school pupils. Topics on Climate Change and related issues could be as some of the topics for the competition.

7.4 NON-FORMAL EDUCATION SYSTEM

7.4.1 Non Formal Education Division of the Ministry of Education

The Non-Formal Education Division (NFED) of the Ministry of Education has Primers for Adult Literacy Programs. There are twelve themes in the Primers, which relate directly or indirectly to the environment, based on the use of forest, water, soil and other basic resources.

The Primers contain lessons on each topic which facilitators use to assist learners to identify their duties and rights as good citizens. This includes sound environmental management. The EPA has trained the National Training team of the NFED in Environmental Management Awareness Creation. The team has in turn trained their facilitators.

To make awareness creation on climate change effective specific issues on the subject will have to be included in the primers. The facilitators could thus use them to educate the adult learners all over the country.

7.4.2 Religious Organizations

Religious Organizations are responsible for the moral and spiritual development of all sections of the population. It is therefore one of the effective channels of communication in Ghana.

The EPA is therefore working with and through Religious Organizations as part of its Environmental Education Strategy to reach the public. A committee comprising recognized religious bodies in Ghana has been formed and a week-long annual celebration has been instituted. The objective of this program is to assist the religious organizations to incorporate environmental management issues into their worship. During the celebration, the religious organizations organize environmental education activities to create awareness in their members. Trees are planted, seminars and durbars are organized. To communicate the issues of Climate Change to the members of the religious groups in addition to what is already being done specific activities to reduce GHG will be organized on similar lines. Documentaries on Climate Change available could be shown in all religious activities during the celebration.

7.5 DISTRICT ASSEMBLIES

District Assemblies and Metropolitan Assemblies are the highest political and administrative machinery at the local levels. The local Government Act 462 of 1993 states that, "the Municipal/Metropolitan/District Assemblies (MAs/DAs) shall be responsible for the development, improvement and management of human settlements and the environment in the districts". To empower DAs/MAs to put environmental issues on the priority agenda they were assisted by the EPA to form District Environmental Management Committees (DEMCs) with the responsibility for environmental issues in the districts.

The DAs/MAs have the authority to supervise monitor, coordinate and ensure that the right thing is done. They also have the responsibility of making appropriate bylaws and ensuring their compliance. The EPA has assisted all the 110 DAs/MAs in the country to draw-up local Environmental Action Plans to manage the environment. This plan contains programs in the reduction of GHG like afforestation, pollution control and bush-fire management. Some of the DAs/MAs are implementing their action plans while others are looking for funding.

Specific projects in climate change will be developed and implemented in the districts. District Assemblies will be assisted to enact bylaws related to climate-Change.

7.6 MASS MEDIA

The Mass Media is one of the most effective channels of awareness creation. The EPA therefore uses the Mass Media in its awareness programs at the national, regional and district/municipal levels. The Agency has meetings with journalists where journalists are given information and materials for awareness creation in both the print and electronic media.

The materials are on contemporary local, regional and global environmental issues. Issues on climate change could be serialized for publication.

7.7 NGOS/COMMUNITY BASED ORGANIZATIONS (CBOs)

Ghana has a diversity of NGOs/CBOs concerned directly or indirectly with protecting and enhancing the environment. They have various projects in environmental protection. Some of these projects are tree planting, environmental awareness creation and agro-forestry. Since NGOs/CBOs are located in the communities they are able to communicate effectively with the local people. Specific programs on climate change could be drawn for them for awareness creation.

CHAPTER EIGHT

8.0 INTERNATIONAL CO-OPERATION

Realizing that no country on its own can address the climate change problem, but countries have common but differentiated responsibilities towards achieving the ultimate objective of the United Nations Framework Convention on Climate Change, Ghana has worked in close collaboration with international organizations both on bilateral and multilateral basis.

The driving force behind these co-operations has been both technical as well as financial. Technically, there was lack of basic capacity to undertake studies in areas of greenhouse gas inventory, abatement of increase in greenhouse gas emissions and vulnerability/adaptation assessment. Financial assistance was also granted under these co-operations to allow Ghana prepare this initial national communication.

This section of the communication discusses some of the co-operation Ghana enjoyed during the period of 1996-2000, when it started putting together various elements of information in fulfillment of its commitments under Articles 4 and 12 of the Convention.

8.1 CAPACITY BUILDING TO RESPOND TO THE UNFCCC

Ghana is one of the four countries including Zimbabwe, Kenya and Mali in Sub-Saharan Africa that participated in the GEF/UNDP pilot phase project RAF/93/G31 on "Building Capacity in Sub-Saharan Africa to respond to the UNFCCC". The Capacity Building project has been designed to assist Sub-Saharan countries to undertake more detailed review and assessment of information on climate change and also contribute to the IPCC efforts to develop methodologies for GHG estimations that is acceptable to all country parties of the Convention.

The activities initiated in the four representative countries including Ghana, created or strengthened national institutions to give the country the capacity to respond to the Convention. These included the development of inventories of greenhouse gas emissions and their sinks, cost-effective policy options based on these inventories, projects suitable for public or private funding and the development of African positions on relevant issues.

On completion of the project:

- Ghana EPA has been strengthened to coordinate the activities that are necessary to develop policy options related to climate change and to comply with the appropriate provisions of the UNFCCC;

- a climate change policy dialogue process, among governmental, non-governmental, academic, business, and grassroots sectors, has been created intended to foster understanding of climate change issues and linkages to sustainable development;

- an inventory of greenhouse gas emissions, and of their removals by sinks, has been conducted following accepted international methodologies, such as those of the IPCC and OECD,

- cost-effective policy options for abatement of increase of greenhouse gases and adaptation strategies have been developed;

- enhanced regional capabilities have been created in the areas of climate change assessment; abatement of increase of greenhouse gases, and project development through programs that strengthen existing institutions; and

- a number of project proposals have been developed on further work needed on inventories of greenhouse gas sources and their removals by sinks, as well as on climate change abatement and adaptation.

8.2 NETHERLANDS CLIMATE CHANGE STUDIES ASSISTANCE PROGRAM

The Netherlands Climate Change Studies Assistance Program which started in 1996, is an initiative of the Netherlands Government, Ministry of Foreign Affairs, Directorate General for Development Co-operation and managed by the Institute of Environmental Studies (IVM), Vrije Universiteit, Amsterdam.

The aim of the program is to assist developing countries to create a greater awareness of climate change issues and to increase the involvement of policy makers, scientists and the general public. To reach this goal, the Program enables the responsible ministry, mostly the Ministry responsible for Environment, to initiate climate change studies, which are carried out by appropriate scientific institutions.

At the start, the Netherlands Climate Studies Assistance Program included 7 countries: Bolivia, Costa Rica, Ecuador, Ghana, Senegal, Surinam and Yemen. Subsequently, six other countries joined the program: Mongolia, Kazakstan, Bhutan, Mali, Zimbabwe and Columbia.

The studies in Ghana consisted of impact and adaptations, studies in the Water Resources and Coastal zone sectors. These studies were made to complement those studies funded by the Global Environmental Facility.

CHAPTER NINE

9.0 PROPOSED CLIMATE CHANGE PROJECTS

9.1 INTRODUCTION

Based on the studies carried out under the UNDP/GEF Capacity Building Project (GHG inventory and Mitigation studies) and the Netherlands Government Change Assistance Project (Vulnerability Studies), the country has developed project concepts or outlines aimed at:

- 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.

9.2 GREENHOUSE GAS EMISSION ABATEMENT PROJECTS

9.2.1 Land Use Changes and Forestry Sector

Projects identified under land use change and forestry are:

<u>PROJECT F1</u>

Project Title

Phytothermal Energy Production (Bio fuels Production)

Project Linkages

Changes in energy policy have favoured the development of wood energy systems. Within the Kyoto Protocol, there is an incentive to substitute wood and other biomass for more energy intensive materials and fossil fuels. Environmental costs of fossil fuels are also making wood fuels more attractive.

Project Rationale

In Ghana and sub-Sahara Africa, fuelwood and charcoal account for more than 70% of national energy demand. As taxes on fossil fuels escalate, it will lead to less use of these fuels and will promote an increased use of other non-fossil energy sources. In the substitution of fuelwood for fossil fuels, benefits occur at the time when fossil fuel combustion is avoided.

Substitution management would be an optimal strategy where biomass growth rates are high, and biomass can efficiently displace high-emission fuels or products.

The benefits are considered permanent, and fossil fuel substitution can be achieved repeatedly with continuing cycles of forest harvest from fast growing biomass with mini - rotations of 2-5 years.

The development and adoption of new technologies for the production, transport, handling and storage of woodfuels, more efficient combustion devices and improved systems for planning, management organisation of wood energy systems are helping to make woodfuels quite cost - effective and cost-competitive energy sources.

Project Objectives

To build national/sub-regional capacity of scientists and decision-makers in phytothermal energy production

To improve significantly the knowledge related to the real impact of woodfuel extracted from forests and to assess the potential for mitigation

To promote forest regeneration, slowing-down deforestation, and increasing areas in plantations and agroforestry systems

To substitute fossil fuels with fuelwood from sustainably managed forests

To study the economic feasibility of wood energy in our country which is heavily forested and with well-established wood processing industries

To adopt new biomass technologies;

Description of the Project

Biomass is essentially a form of stored solar energy; forest products and agricultural industries have long burnt biomass residues to generate steam and electricity. Farmers must now grow crops specifically for their energy needs.

In energy farming, trees will be cultivated in short-rotation coppice and grow at least 5+ meters high in 3 years. A two-three year cycle of *Cassia/Eucalyptus/Leucaena/Gmelina* will yield up to 40m^3 of wood per hectare per year.

Burning chips creates steam to run stem turbines; gasified, it can fuel an internal combustion engine or gas turbine. There is a need for survey and research in the carbonization efficiency and techniques in the use of different types of wood fuel and species.

Stakeholders

Decision makers in the Energy, Environment, Forestry and Agricultural Sectors, NGOs Researchers and academia, Farmers, community-based organizations (CBO), women groups.

Expected Outcomes

This project can help reduce CO_2 emissions significantly; afforestation on degraded land in combination with subsequent harvest can offer $C0_2$ benefits in the shortest time when the harvested wood will displace fossil fuels. Improved scientific, and technological capacities for planning and sustainable wood-fuel management

Job opportunities created in the rural areas by the establishment of energy plantations.

Planned Activities

Review of existing technologies and practices

Carbonization efficiency
Different energy types fossil fuels (kerosene, LPG etc., bio fuels (charcoal, fuelwood etc)
Different end uses (Industrial, Domestic)
Different Stoves and devices

Pilot studies on possibilities of generating bio-energy.

Indicative Costs (\$880,000)

Estimated Project Duration: Ten (10) years

PROJECT F2

Title of Project:

The use of remote sensing for monitoring forest cover changes and for establishing base-line data.

Project Linkages:

This project will contribute to the attainment of Ghana's Forest and Wildlife Policy (1994). The project will ensure the protection of our forest heritage, safeguarding of the forest environment and preservation of biodiversity in a sustainable manner.

Project Rationale

In Ghana today, there is a marked degradation of forest cover within the high forest and savanna woodland areas due to unsustainable forest exploitation and agriculture.

Due to massive degradation of forestlands during the last decade, data on forest resource inventories carried out in 1986 - 1994 no longer reflect the reality of the forests. It is therefore necessary to update this data in order to avoid an under-estimation of the forest potential as carbon stocks.

Existing forest inventory systems conducted at five or ten-year intervals may both be adequate to assess changes in Afforestation, Reforestation and Deforestation (ARD) activities.

It will enhance knowledge of the forestry resource base, its protection, and preservation of biodiversity.

It has definite advantages compared to classical mapping of vegetation.

It is an essential tool and even a competitive one for continuation of its activities of reconnaissance and management of forest resources.

Swiftness of providing satellite data in digital form at reasonable cost for land use change and forestry LUCF and GHG inventories.

Satellite imagery will improve surveillance of the reserved or protected forests.

Project Objectives

To devise a monitoring methodology for forest vegetation cover on a regular and continuous basis.

To protect our forest heritage, safeguard the forest environment and preserve biodiversity.

To determine the rate of forest change to provide information for climate change and development policies.

To assist in developing strengthening capabilities in the use and development of remote sensing technology and GIS, as tools for measuring land cover and forest resources.

Description of Project

The use of Remote Sensing technology is available for identifying locations or sample plots where land use cover changes indicate reforestation and deforestation activities that have occurred.

To use remote sensing technologies and Geographic Information System (GIS) information systems to map the land use and land cover change in the main ecological zones.

Stakeholder/Beneficiaries

Climate Change Experts, Community based organizations, NGOs, Decision-makers, Forest Managers, Scientists and researchers

Expected Outcomes

- Continuous reliable and updated information (in digital database) concerning the trend, magnitude and of degradation, or reconstruction of the forest vegetation.
- Capacity developed in the handling of remote sensing methods and GIS.
- Institutions strengthened
- Up-to-date / activity data for the GHG inventories

Planned Activities

- Bibliographical research
- Harmonization of data
- Collection and purchasing of equipment for the implementation of the project
- Validation of data
- Image Processing and Interpretation

Indicative Cost: Cost is being estimated

Estimated Project Duration: - 5 years

PROJECT F3

Project Title

Rehabilitation of degraded forest areas.

Project Linkages to National Priorities

This project will contribute to the attainment of National Forest and Wildlife Policy (1994) by promoting resources development aimed at reforesting suitable harvested sites, rehabilitating degraded mining areas, afforesting denuded lands, regenerating desired wildlife species and habitats. Moreover, to promote tree planting and agroforestry systems as positive community - building actions which generate raw materials and income while improving the quality of the environment. The project is to ensure the renewal of forest resources through regeneration and afforestation with a view to sustaining the potential for carbon sequestration.

Project Rationale

It is necessary for a developing country like Ghana to achieve net forest growth to make a positive contribution to reduction of global CO_2 emissions. . In Ghana as well as in sub-Saharan Africa, the ratio of deforestation to reforestation is 29:1 (FAO, 1997) and deforestation contributes 17-18% of anthropogenic GHG, emissions. Further reduction in forest cover and degradation of forestland in Ghana could reinforce the greenhouse effect.

Measures to slow down the rate of deforestation will have significant benefits such as:

- protecting remaining intact forests
- preserving biodiversity
- combating soil erosion and desertification, protecting watersheds, coastal/wetland ecosystems and
- reducing $C0_2$ emissions.

Strategies addressing climate change through forest management and afforestation should be integrated with strategies addressing the sustainability of other forest-based values with due recognition of the livelihood of forest-dependent people and communities.

Project Objectives

- To encourage development of private plantations for the fulfillment of plantation target to restore degraded forests covering about 400,000 ha.
- To motivate the local communities to participate in the conservation of forests and carry out silvicultural activities with a view to increasing revenues, restoring biodiversity and increasing the forest vegetation cover.
- To increase forest area by afforestation and reforestation as one of the few proven ways to effectively increase the up-take of atmospheric CO_2 by the biosphere.

- To provide income to local people and increase the amount of carbon sequestered.

Stakeholders

Traditional Rulers, Local Communities, Wood Processing Industries and Women Groups

Expected Outputs

- Many degraded plots replanted and rehabilitation of forest cover being achieved
- Deforestation slowed down on communal lands
- Reduction of human pressure on natural stands
- Abundant private forest plantations - about 400,000 ha established within 30 years
- Jobs provided to local populations
- Forest - dependent communities would have direct and effective participation in planning and decision-making in forest plantations development
- Net addition to the standing inventory of biomass carbon.

Planned Activities

- Draw up a sensitization program on the consequences of forest clearing and bush fires.
- Planting about 10,000 ha/year of degraded forest resources and off-reserves mostly with fast-growing indigenous and exotic species for poles, and lumber.
- Agroforestry practices implemented for fuelwood, fodder, soil nitrogen fixation, fruit trees, and nut production.
- Set up a Support Program for the creation of private, community and individual plantation forests.
- Sensitization of potential planters.
- Guidance of the participating groups - private sector and communities and individuals in the setting up of nurseries and plantations.
- Production of Planting Stock
- Setting up of plantations with selection of adapted species and soils.

- Identification of genetic variability associated with regionally important tree species and their ability to respond to climate change to optimize $C0_2$ sequestration, and storage of carbon.

- Setting up fire-management and control brigades to protect the newly planted trees and natural forests.

- Implementation of Incentive measures to farmers such as high yielding crop varieties.

- Wood fuel development in Savannah areas.

- Retrain Extension Workers.

- Monitoring of established plantations.

Indication Costs/Year $1.50 million

Duration : 5 – 10 Years

PROJECT F4

Project Title

Joint forestry project to offset GHG emissions.

Project Linkages

Responsibility for historical CO_2 emissions rests largely with the industrialized world. AIJ & CDM are financial mechanisms aimed at assisting developing countries in a reduction strategy requiring international cooperation and participation.

The Climate Change Convention and Kyoto Protocol require developed nations to provide technological and financial support to developing nations responding to their obligations under the Convention.

Project Rationale

New Power Plant Companies in developed countries using fossil fuels could offset the lifetime $C0_2$ emissions by sponsoring sustainable forest projects (e.g. low impact logging/reforestation) in another country in the tropics with higher potential growth rates and faster carbon accumulation.

A number of projects to avoid, sequester or reduce GHG emissions through forest management practices are being jointly implemented by developed and developing countries, and there is the feasibility of achieving the objectives of the Climate Change Convention through such projects.

Project Objectives

- To regenerate degraded forest areas and reduce the deforestation rate.
- To facilitate agroforestry and tree planting as an alternative source of income.

Description of the Project

Primarily a bilateral agreement or investor pools seeking to offset their GHG emissions and an implementing agency – Forest Service/Private forest company in Ghana.

Thus many corporations in developed countries are seeking partnerships with forest conservation organizations in developing countries.

The project will develop a sustainable forest management component that will sequester a defined range of carbon, and at the same time provide income to local people.

An international corporation in a developed country will provide funds to a Timber Utilization Contract (TUC) holder to implement:

- tree planting
- training staff to use existing technology to undertake low impact harvesting operations

Stakeholders

Forest dependant communities, Private Forestry Sector – holders of Timber Utilization contracts, Ministry of Lands and Forestry, Ministry of Environment, Science and Technology, Environmental Protection Agency, Ministry of Finance and Donor Agencies

Expected Outcomes

- With this project, degraded forestland will increase biomass production/ha, and sequestered carbon can be credited to the overseas funding agency.
- Improved forest management practices such as low-impact-logging will help to reduce damage to the residual forest, decrease erosion, increase biodiversity protection, and hence reduce forest land degradation.
- Active local support and participation is a critical factor in the success and durability of the project.
- Experienced and committed implementing agencies – Forestry Service and overseas counterparts, will demonstrate their ability to beverage as well as attract other funds.

Planned Activities

- Landuse and Carbon sequestration (LUCS) models have proven to be a useful tool for estimating the amount of carbon sequestered by a particular project. It approximates the land-use and relative biomass changes over time with or without the Project; hence help to determine the target area to be planted over a 20-30 year rotation.
- Planting of community woodlots for poles and timber.
- Implement agroforestry practices for fuelwood, fodder, soil nitrogen fixation, fruits and nut production.
- Provide training and extension for community forest fire brigades to protect the newly – planted trees and natural forests.

Risk

JI & CDM could do more harm than good; for example if natural forests are replaced by monoculture exotic plantations, or if sustainable forest projects are under cut by "carbon subsidies".

If CDM or JI is used as an excuse for "business as usual"; re-planting trees in far-away countries is easier, but may be less effective/efficient than reducing pollution at the source.

Indicative Costs/Year US$ 5. 0 Million

Expected Project Duration - 10-20 years

9.2.2 ENERGY SECTOR

PROJECT E1

Project Title: Establish level of vehicular emission

Rationale:

Vehicular emissions used in the climate change studies were based on estimates of energy consumption by the transportation sector. For purposes of adequate planning for the sector and correct emissions from the sector so as to manage the mitigation of GHGs from that sector it is important to correctly estimate vehicular emissions.

Objectives:

To establish petroleum usage and associated emissions of GHGs. It will also help meet UNFCCC commitment on inventory.

Project Description:

Undertake field surveys and review existing data that would assist to estimate petroleum usage. Variables needed would include vehicular population, types and ages of vehicles, petroleum usage and types. The project will help gather, collate and analyze data to establish the level of emissions, etc.

Area of Coverage: Entire country

Planned Activities:

Activities will include collection and analysis of data on petroleum usage, vehicular population, types and ages of vehicles.

Linkages:

In addition to improving the climate change planning, this project will help in the comprehensive planning of the transportation system, which could cut down cost to nation from the present unplanned system.

Output/Outcomes:

The exercise will help improve GHG inventory. It will assist in estimating benefits from switching to technologies like railways. It will also help in transportation planning and standardization.

Stakeholders:

Decision makers in Energy-Environment-Forestry sectors as well as the National Climate Change Committee, The Ministry of Transport and its implementing Agencies, The road transport sector in the country and sub-region, The Ministry of Health, International Organizations, African and International Consultants, The National Road Safety Commission, The National Development Planning Commission, The Ministry of Trade and National Standards Board and District and Regional Assemblies.

Indicative Cost: US$48,000

Estimated duration: 18 months

PROJECT E2

Project Title: Improving the efficiency of transport system in Ghana.

Rationale:

Travelling patterns in Ghana are skewed towards road transport. It is estimated that about 97% of all passenger travel is by road vehicular transport. Other modes of transport account for the rest. This road transport system in Ghana is very inefficient with the bulk of transport consisting of small vehicles and private cars. There is also the centralization of commercial activities at the heart of cities causing heavy traffic congestion in the two main cities of Accra and Kumasi. This has led to the necessity to improve the efficiency of the system.

Project objectives

The project aims at improving the quality of the environment through the reduction of exhaust emissions by reducing the number of road transport vehicles in particular corridors and decongesting city centres of commercial activities.

Project Description

The project will consist of surveys to determine the classification, purpose of journeys and number of vehicles within various transport corridors.

Another survey will be conducted to determine the level of emission of the various classes of vehicles and their impact on the environment.

A component of the project will involve review of studies and projects related to the use of other modes of transport such as rail. It will also review policies dealing with appropriate and efficient public transport system. It will also consider the decongestion of city centres of commercial activities and re-zoning area vehicle stations for other places. A costing of various modes of transport system will also be done.

Area of Coverage: Vehicular travel within the two main cities of Accra and Kumasi.

Planned Activities

The activities will include the following:

- Reduce and change the travel modes of people from private to mass systems to reduce exhaust emissions.
- Formulate policies towards the improvement of mass public transport system.
- Explore the possibility of the use of other modes of transport for both inter and intra city travels, such as rail, buses, etc.
- Evolve other measures to provide environmentally friendly systems.

- Discourage the use of small private vehicles by efficient traffic management measures.
- Decongest city centres of commercial activities and re-zoning vehicle stations for other places.

Linkages:

Improvement in transport efficiency will transmit to the efficient running of the economy, reduce costs and improve the economy through its distributive sector.

Expected Outcome

- Reduce the level of exhaust emissions.
- Efficient public transport system.
- Use of alternative modes of transport such as rail for mass transit and freight.
- Evolve various traffic management measures to encourage public transport use as against the use of small road transport vehicles.
- Re-zone shopping centres and stations for other places at the outskirts of cities.
- Reduce emission of exhaust fumes, evaporation from carburetors, fuel and rubber particles from tyres.
- Fuel reduction will reduce emission of GHG.

Stakeholders:

Decision and policy makers in the Ministry of Transport, Ministry of Mines and Energy, Ministry of Tourism, the Ghana Railway Company Ltd. and Ghana Airways, Members of the General Public, i.e. Ghanaians and the West African Sub-region/Tourists, Transport operators and users, African and International Consultants, Town, and Country Planning, Regional and District Assemblies

Expected duration: 24 months

Indicative Cost: This is not immediately available.

PROJECT E3

Project Title: Railway network enhancement

Rationale:

The Greater Accra Metropolitan Area (GAMA) is one of the ten administrative regions of Ghana and covers the national capital Accra, the Amasaman district and the port city of Tema and their immediate hinterlands of about 30km radius. It is the most densely populated region of Ghana.

There is a single-track single line with gauge of 1060mm and an axle loading of 16 tons. The maximum curvature is 200mm and maximum gradient is 1.80mm. Stations currently exits at Accra Central, Odaw, Achimota, Batchona, Asoprochona and Tema.

Currently, it can be considered that the suburban train provides 4 services a day between Accra station and Nsawam and carry about 350 passengers. This service is awfully inadequate considering the huge congestion on the roads during the morning and evening peak hours. There is an urgent need to upgrade the system.

Objective:

The objective is to improve and upgrade the railway system in the defined Greater Accra Metropolitan Area (GAMA).

Project Description:

The proposed Accra-Tema Railway system shares the main lines (to Kumasi and Takoradi) north out of Accra Central station as far as the Achimota switch. The single track line crosses three important roads at-grade, namely, Graphic Road, Ring Road and Nsawam Road, These roads are always congested during the morning and evening peak hours.

The degree of upgrading of the Accra-Tema suburban railway system clearly depends on the type of service to be offered. In the short term the level of demand may not justify a very intensive service, hence the level of investment cost could be kept minimal. In the long term a speed/high frequency service may become necessary, which would need much tract reformation, the grade-separation of road crossing and possibly the laying of a new junction at Achimota to allow faster movement between the tow lines. Signalling and communications should get improved as well as station structures and facilities. New stations should be built while some existing stations are rehabilitated. Track alignment may be necessary at the Tema end to avoid the current close proximity to the sea.

There will be three main options:

OPTION 1

Option I involves the setting up of rapid, frequent service by DMU, (diesel multiple unit) between Central Accra and Dome, on a double track (compared to the existing single track) as far as Achimota, while maintaining the existing service between Central Accra and Nsawam. It involves the establishment of six new stations, and the Tema branch. This option involves a high level of investment, renovation and development.

OPTION 2

This option involves the setting up of a DMU service between Central Accra and Dome on a single track, while maintaining existing service between Central Accra and Nsawam. It has a lower level of investment, renovation and development.

OPTION 3

This option is geared towards a situation in which the suburban train operates jointly with "trotros", by operating in the same corridor, as in Option 2. It involves an intermediate level of investment, renovation and development.

Planned Activities:

Option 1 will consist of the construction of double tracks between Accra and Achimota with the completion of the double-tracked section to be achieved before commencing any programmed introduction of DMU commuter services. There will also be a construction of four major overpasses where railway lines cross the road network.

Option 2 will consist of a single-track system for the first ten years of operation, with the possibility of development to double tracks. There will be a construction of two overpasses way as to allow for a later doubling of the track.

Option 3 will involve a double-track system between Accra Central and Achimota from the start with a construction of two overpasses as in Option 2.

Linkages:

This enhanced railway system will complement the planned West African Railway system by extending the planned one to Kumasi and Takoradi.

Output/Outcomes:

There will be three main outcomes and benefits. These include
For passengers who will switch from bus to rail, their benefits consist of the difference in travel time and fares between the bus and train. Presently it takes about one and half (1½) hours to travel by bus from Accra to Tema during the peak hours. A train can make the journey in thirty (30) minutes. It is also expected that the fare by train will be cheaper than by a bus.

Environmental benefits – The introduction of the service may lead to a large reduction in the number of buses on the route resulting in less pollution less noise and fewer accidents.

The reduced congestion may lead to a reduction in operation cost of car, taxis and public transport vehicles.

Stakeholders:

Users and operators of railway in urban centres, country and the sub-region, The Ministry of Transport, The Ghana Railway Company, Institution of Engineers, Transportation Consultants (local and international)

Indicative Cost:

	OPTION 1	OPTION 2	OPTION 3
PROPOSED INVESTMENT REQUIRED:	**$111,888m**	**$52,836m**	**$68,376m**

Estimated Project duration: Three (3) years

PROJECT E4

Project Title: Solar energy project for communities

Rationale:

There are several villages within the ten regions of Ghana, which are far from the district capitals where the national electricity grid can be reached. Such villages are without electricity. The essence of this proposal is to pick a village each from the 10 regions as a prototype project for implementation. In the initial stages, the project will consist of a solar battery charging center. In areas where the project is self-financing, it could be upgraded to providing electricity for the villages.

Project objectives

The objective is to have a village owned and controlled center that will address an identified need, build unity and improve the health, social and educational conditions of the people.

Project Description

The project will involve building a solar battery charging center. The centre will have two charging stations to service batteries, a common room with demonstration system consisting of one 50pW solar panel, controls, battery, lights, a television, a radio cassette recorder and an office/storage room.

Planned Activities

The project will consist of three components viz.: - a renovation of existing building, training of attendants and installation of solar-charging equipment. Local masons, carpenters, painters and local labor will assist in the project. The local skills and renovation of existing building will be the contribution from the community.

Linkages:

In addition to the direct benefit of improving the lighting system for the community, it would have health, educational and social impact by affording them the opportunity to view television and/or tune in to radio for such enhancing programs.

Expected Outcome

Constant source of power in the home through recharged batteries.
Expanded evening hours to complete work that requires light (e.g. Washing, tailoring, food preparation, etc.
Extra study time for students

Better reading, correspondence viewing of television and listening to radio for educational programs.

Stakeholders:

Village Unit Committee, Village Health Committee, The Community, The District Assembly, The Donor Community, Ministry of Energy, The Solar Energy Unit of the Kwame Nkrumah University of Science and Technology and the University of Ghana, Institute of Industrial Research of CSIR.

Expected duration: 12 months

Indicative Cost: US$115,000.00

PROJECT E5

Project Title:

Piping of gas from the proposed West Africa Gas Pipeline to and within some urban areas of Ghana.

Rationale:

There is a project about to take off which involves the construction of a gas pipeline from Nigeria to South Western part of Ghana. The main objective is to supplement energy derived from hydropower sources.

Project objectives

The objective of the project is to replace the use of some biomass with natural gas in the urban areas.

Project Description

As indicated above, a project is about to take off which involves the construction of a gas pipeline from Nigeria to Ghana.

This proposed project will consist of constructing additional pipelines inland to the main urban areas along the coats of Ghana and further inland to Kumasi where the demand for cleaner energy is also very vital for the country. The essence is to distribute gas from the main pipeline from Nigeria to these areas in Ghana for domestic consumers who depend on biomass for cooking purposes and industries, which hitherto depend on residual oil for their boilers for the purposes of generating energy.

Planned Activities

The West African Pipeline which is 1000 km. will be laid under the sea. The pipeline for this project will be on the ground and extra care will be taken to forestall illegal connections. The pipeline is estimated to cover 900 km. When the distribution within the cities and urban towns are added, the pipeline is estimated to be about 1,200 km.

Linkages:

The project will improve the economy by reducing deforestation and ill-health through the use of biomass. It will also reduce expenditures on biomass.

Expected Outcome

This project will replace the use of some biomass for mainly domestic users with gas. Since 82% of urban households use biomass as the main source of energy for cooking, significant deforestation will be reduced and hence an increase in sinks and enhanced biodiversity.

Additionally, biomass users, especially, women will be saved from diseases arising from smoke pollution.

Stakeholders:
Residents of the cities and urban towns to be affected, the various assemblies in those areas, Ministry of Energy, Donor Agencies and Consultants and the Nigerian Government

Expected duration: 24 months

Indicative Cost US$

The estimated cost of the pipeline gas from Nigeria to Ghana is US$400 million. As a rough estimate, we expect this pipeline to cost about US$480 million. This is based on the Nigerian-Ghana line estimate.

9.3 VULNERABILITY PROJECTS

9.3.1 Coastal Zone

PROJECT C1

Project Title

Information Support System for the Sustainable Management of the Coastal Zone Of Ghana

Project Linkages to National Priorities

In pursuit of its objectives to obtain sound management of the environment, the EPA prepared the Ghana Environmental Action Plan (1991). The plan describes the broad policies required for the sustainable development of the natural resources of Ghana. It recognizes that the management and conservation status of the coastal zone is low. Coastal management under the current trends is sectoral with a number of institutions playing some role in the planning co-ordinating and monitoring of developments within the zone.

Coastal erosion and flooding continue to devastate settlements. Saltwater intrusion in both surface and groundwaters is increasingly becoming a problem for water supply. The predicted rise of sea level is expected to exacerbate the conditions of the coastal zone. A preliminary assessment suggests that the East Coast of Ghana covering the coastal area east of Prampram comprising the delta of the Volta River will experience the worst effects of sea-level rise. Already, coastal erosion and flooding within these shorelines are of national significance. The physical changes brought about by climate change to the coastal zone will also have a profound influence on coastal habitats, bio-diversity and socio-economic activity.

Several studies have proposed the establishment of a central body to co-ordinate all development activities within the coastal zone. This body is referred to in this proposal as the Coastal Management Board. The proposed Board will require accurate data to be able to ensure the sustainable exploitation of resources within the coastal zone. These data are not always available. For instance, rates of shoreline recession are required to plan the establishment of set-backs for the management of erosion, areas that are vulnerable to flooding and inundation needed to be delineated to assist the management of flood-related emergencies when they occur in the coastal zone. Coastal habitats that will be affected by sea-level rise and the expected impacts of sea-level rise on bio-diversity need to be determined accurately to ensure rationale management of coastal resources

Project Rationale and Objectives

- To provide the information required in support of the rationale management of the coastal zone.
- To collect more accurate data

Brief Description of the Project

The coastal area of Ghana is divided into three segments:

- The East Coast (Prampram to Aflao 149 km);
- The Central Coast (Ankobra Estuary to Prampram 321 km); and
- The West Coast (west of the Ankobra River Estuary to Ghana's border with La Côte d'Ivoire 95 km).

Each of the coastal segments described above has uniform characteristics that make it amenable for treatment as a geomorphologic unit for management purposes. By far, the most challenging of the areas is the East Coast. It has been estimated that more than two-thirds of the land to be lost as a consequence of sea-level rise will lie within the East Coast.

The proposed project will attempt to define the three-meter contour, which has been determined to be the Risk Zone. This will be achieved by the Aerial Videotape-assisted Vulnerability Assessment. The data collected under the preliminary studies on sea-level rise and its impact on the coastal zone will be utilized to improve on the topographic data available.

Stakeholders Identified

Coastal District Assemblies, Policy makers - Ministries, Chief fishermen, Chiefs of the Coastal Zones, Non-governmental organizations, Communities Based Organization, Women Groups

Expected Outcomes

- Provision of a description of all potential coastal hazards
- Assessment of historical rates of shoreline recession using remote sensing techniques
- Delineation of areas prone to coastal erosion
- Presentation of contours of vulnerable areas to flooding and their return periods
- Evaluation of the impact of sea-level rise on coastal habitats
- Determination of the values at risk to sea-level rise
- Provision of information on management strategies for adapting to sea level rise.

Planned Activities

- Data gathering
- Data analysis
- Data presentation

Indicative Cost: **US$685,000**

Expected Duration: 2 Years

9.3.2 Water Resources

PROJECT W1

Project Title: Relocation of river in-take points and expansion of reservoirs for water supply systems in the country.

Project Linkages

The national development plans envisage the provision of potable water to cover over 60% of the rural and urban communities by the year 2020. This calls for expansion of existing water resource infrastructure with increasing water demand associated with population increase and requirement for better socio-economic conditions.

Climate change with its associated reductions in flows and water resources in our sub-region puts the country in a more vulnerable situation and in which case the national goal may not be achieved if appropriate measures are not taken.

Project rationale and Objectives

Initial assessment of impacts of climate change on water resources indicates reduction in flows. The observed situation is the drying up of intake points or the water sources being below the intakes during the low flow periods.

Another problem is that reservoirs fill up quickly during the on set of rains, however, during dry seasons (which are becoming much more prolonged) available water resources in the reservoirs are not sufficient for treatment to meet demand. This problem may be due to the small sizes of the reservoirs.

The project is aimed at carrying out a survey of all the intake points in the country with the view to assessing their vulnerability. Measures required to be adopted for implementation, in reducing vulnerability will be put forward.

The specific objectives include the following:

- Inventory of all intake points and their catchment areas. Reservoir specifications, where in existence, will be catalogued.
- Flow characteristics and assessment of impacts of climate change on the flows will be carried out.
- Estimation of water demand for the present and future based on socio economic indicators and climate change impacts will be carried out.
- Assessment of water resources vulnerability in each catchment.
- Evaluation of risk of failure of the existing reservoirs and the adequacy of the intake points.
- Recommendations for appropriate measures based on the findings from the above.

Project Description

The project will cover all water intake points for water supply and irrigation in the country. The study will cover catchments unit and will involve fieldwork, data collection and analysis.

Expected Outcomes

- An inventory of intake points, catchment areas and existing reservoirs.
- Assessment of available water resources in the catchments and impact under climate change.
- Assessment of water demand up to the year 2030.
- Vulnerability of water resources to climate change.
- Recommendations for infrastructural changes including intake points and reservoir capacities to meet water demand under climate change.

Planned Activities

- Collection of data and information on all existing water resources systems in the country.
- Field visits to intake points and catchments to validate the existing information.
- Collection of hydrometeorological and hydrological data for stream flow simulation and evaluation of climate change impacts on water resources.
- Evaluation of water demand under climate change for the year 2030.
- Assessment of water resources vulnerability under climate change.
- Evaluation of existing infrastructure to meet water demand and recommendations.

Stakeholders involved in the project.

- Decision makers for water supply and irrigation development – Ministry of Works and Housing and Ministry of Food and Agriculture.
- Water Supply Company, Irrigation Development Authority and Water Resources Commission.
- Research institution, Environmental Protection Agency and local and international consultants.

Indicative Cost: $1,000,000

PROJECT W2

Project Title: Climate change impacts and vulnerability assessment of water resources of the Densu basin.

Project Linkages

Densu basin has the highest population density in the country and contains important commercial centres like Accra and Koforidua. Urban Water demand (in 1996) was about 308,000m^3/day. However only 145,000m^3/day could be met leaving a short fall of about 163,000m^3/day.

Water shortages in the dry seasons in certain parts of the basin are common and frequent. The inadequate water resources in the dry season have linkages to impacts of climate change and variation and this scarcity impinges on our national socio-economic development.

Pollution of the river environment from mainly human activities also contributes a high pollution loading into the river system and makes water treatment cost very high. With rapid increase in population coupled with general reduction in flows under climate change, sustainable water resources management becomes imperative. This study is meant to provide the necessary inputs for water resources management for national development.

Project Rationale and Objectives

The basin has important industrial and agricultural activities and has also the highest population density. The basin is however, located in the dry Coastal River System.

Preliminary study of climate change vulnerability and adaptation assessment on water resources of Ghana indicates that the Coastal river system will in general be marginally vulnerable or face water management problems by the year 2020. The study used the representative basin approach (Ayensu basin for the Coastal river system) to arrive at the above conclusion. Population and its rate of growth in the Densu basin are quite high and different from the Ayensu basin even though the hydro climatic conditions in the two basins are very similar.

The water uses in the basin are for domestic and industrial needs with limited irrigation. It is envisaged that the increases in water demands will accelerate, given the rate of urban migration in the basin while water resources diminish. The over all objective of the project is therefore to specifically model the impacts of climate change on the water resources of the Densu basin, assess its vulnerability to climate change for various supply and demand scenarios and put forward adaptation strategies for reducing the probable impacts.

The specific objectives are:

- To assess the potential impacts of climate change on the magnitudes of surface and groundwater resources of the basin.
- To assess the impacts of climate change on water quality and how it can affect water availability.

- To evaluate water demand based on the socio-economic factors or indicators in the basin.
- To evaluate impacts of climate change on domestic, industrial and irrigation water demands.
- To examine the joint effect of land use and climate change on the quantity and quality of water resources in the basin. This aspect of the study will include sediment yield analysis in the basin and the potential effect on the Weija reservoir where water is stored for treatment and supply to Western parts of Accra.
- To assess the overall vulnerability of the water resources of the basin to the impacts of climate change.
- To assess climate change impacts on socio-economic conditions through biophysical impacts.

Project. Description

The project will address the research needs raised under specific objectives in section C. It is also a follow up study to the preliminary work on Climate Change Vulnerability and Adaptation Assessment on Water Resources of Ghana.

Expected Outcomes

- Estimates of the quantity and quality of surface and groundwater resources of the Densu basin under climate change by the year 2030, 2060 and 2100.
- Projections of water resources demand under climate change for socio-economic development in the basin.
- Sediment yields in the basin and its impacts on existing reservoir in the basin.
- Measure of vulnerability of the water resources of the basin.
- Specific adaptation strategies in the basin for implementation.

Planned Activities

- Data collection –
- (Hydrometeorological, water demand data and socio-economic indicators)
- Modeling of impacts of climate change on the surface and groundwater resources.
- Modeling of water resources vulnerability in the basin.
- Modeling of sediment yield under climate change and land use change scenarios.
- Evaluation of water resources vulnerability in the basin.
- Assessment of adaptation strategies and formulation proposals for reduction in the degree of vulnerability.
- Workshop for initiation and termination of project.
- Visits to Research Centres involved in Climate Change Studies for exchange of ideas.
- Report preparations.

Stakeholders.

- Decision makers in water supply and irrigation development.
- Ghana Water Company Limited (GWCL) and Community Water Supply and Sanitation Division.

- Research Centres, Universities and Environmental Protection Agency.
- International Organization.
- African and International Consultants.

Indicatives $800,000

Estimate project duration. 1 year

PROJECT W3

Project Title: Climate change impacts and vulnerability assessment of water resources of the Volta basin.

Project Linkages

The Volta basin is an international basin covering six countries. The water resources of the basin are important for hydropower generation, irrigation, domestic and industrial water supply, fishery production, Lake Transport, eco-tourism and conservation of wildlife. Water resources are thus essential for socio-economic development of the sub-region.

Considerable investments have been made in constructing Akosombo and Kpong dams on the main Volta for hydropower generation and electricity generated is jointly used by the republics of Ghana, Togo and Benin under international Agreement.

Continuous declines in the lake levels in the past years with associated power crises such as in 1983/84 and 1998 put the economics of the countries in jeopardy. The declining lake levels may, however, be due to reduction in catchment precipitation and inflows into the lake, among other things.

The rapidly rising population in the riparian Countries and the need to meet food security as a national policy under current climatic uncertainties will require more water resources for crop irrigation and animal husbandry. From preliminary studies, climate change may impact negatively on the water resources of the basin, which is going to be under pressure from changes in socio-economic conditions. Climate change impact assessment in the basin for water resources management will therefore be crucial for sustainable development.

Project Rationale and Objectives

A preliminary assessment of the impacts of climate change on the water resources of the White Volta basin, a tributary, indicates that the water resources of the basin are vulnerable. The vulnerability of the water resources of the whole basin, including the Volta Lake, is yet to be established.

Population increase and improvement in the socio-economic condition will require increases in water demand. Climate change may further increase the water demand for the projected baseline socio-economic conditions.

With decreasing water resources and increasing water demand, water resources management becomes a critical issue in reducing vulnerability in the basin. The study aims at generating the necessary information for sustainable water resource developments and management in the basin.

Water quality could be seriously affected with regard to negative land-use practices and possible reduction in flows due to climate change. This will be of concern to policy makers and needs to be addressed.

Reductions in lake levels as a result of changes in temperature and evaporation as well as reduced flows into the Volta Lake under climate change may have far-reaching implications for hydropower generation and lake transportation. Study will examine these changes under climate change and possible impacts including socio-economic impacts on the countries served by the Akosombo hydropower scheme.

In general, the overall objective will be the impact assessment of climate change on water resources of the Volta basin with the view to formulating appropriate adaptation policies for integrated water resources management for sustainable development.

The specific objectives are:

- to assess the potential impact of climate change on the magnitudes of surface and groundwater resources in the basin with the view to formulating appropriate adaptation strategies for water conservation.
- To assess the impacts of climate on water quality and how it can affect water availability.
- To evaluate impacts of climate change on domestic, industrial and irrigation water demands in the basin with the view to assessing vulnerability in these areas.
- To assess the impacts of climate change on hydropower generation in the basin. Results will be used to formulate appropriate adaptation strategies for alternate source of energy production to meet rising demand.
- To evaluate the potential impact of climate change on lake transportation and future development of the industry.
- To assess potential impacts of climate change on flooding and plan adaptation strategies for flood mitigation in the basin.
- To assess the potential impacts of climate change on droughts in the basin and plan adaptation strategies to mitigate effects.
- To examine joint effect of land use and climate change on the quantity and quality of the water resources of the basin. This aspect of the study will include sediment yield analysis from the catchments into the lake and reservoirs of the basin.
- To assess climate change impacts on socio-economic conditions through the biophysical impacts.

Project Description

The project will address the research needs raised under specific objectives in sections C. It will essentially look at the impact of climate change on a number of issues relevant to water resources management.

Reductions in lake levels as a result of changes in temperature and evaporation as well as reduced flows into the Volta Lake under climate change may have far-reaching implications for hydropower generation and lake transportation. Study will examine these changes under climate change and possible impacts including socio-economic impacts on the countries served by the Akosombo hydropower scheme.

In general, the overall objective will be the impact assessment of climate change on water resources of the Volta basin with the view to formulating appropriate adaptation policies for integrated water resources management for sustainable development.

The specific objectives are:

- to assess the potential impact of climate change on the magnitudes of surface and groundwater resources in the basin with the view to formulating appropriate adaptation strategies for water conservation.
- To assess the impacts of climate on water quality and how it can affect water availability.
- To evaluate impacts of climate change on domestic, industrial and irrigation water demands in the basin with the view to assessing vulnerability in these areas.
- To assess the impacts of climate change on hydropower generation in the basin. Results will be used to formulate appropriate adaptation strategies for alternate source of energy production to meet rising demand.
- To evaluate the potential impact of climate change on lake transportation and future development of the industry.
- To assess potential impacts of climate change on flooding and plan adaptation strategies for flood mitigation in the basin.
- To assess the potential impacts of climate change on droughts in the basin and plan adaptation strategies to mitigate effects.
- To examine joint effect of land use and climate change on the quantity and quality of the water resources of the basin. This aspect of the study will include sediment yield analysis from the catchments into the lake and reservoirs of the basin.
- To assess climate change impacts on socio-economic conditions through the biophysical impacts.

Project Description

The project will address the research needs raised under specific objectives in sections C. It will essentially look at the impact of climate change on a number of issues relevant to water resources management.

Expected Outcomes

- Estimate of the quantity and quality of surface water and groundwater resources of the Volta basin under climate change by the year 2020, 2050 and 2100.
- Projections of water resources demand under climate change for socio-economic development in the basin.
- Projections for potential hydropower generation under climate change for future planning of energy development for the country.
- Information for drought and flood mitigation plans for the basin under climate change.
- Information for the management of the Volta Lake transport in the country.
- Knowledge for long-term water resources conservation plans in the basin.

Planned Activities

- Data collection from riparian countries of the basin.
- Land-use survey using Remote Sensing application.
- Workshops for initiation and termination of the project.
- Modeling of impacts of climate change on the water resource supply.
- Modeling of various water demands and supply in assessing vulnerability.
- Visits to Research Centres involved in Climate Change studies.
- Report preparation

Stakeholders

- Decision makers in the energy, water supply, irrigation development and Volta Lake transportation.
- Research Centres, Universities and Meteorological Stations.
- International organizations
- African and international consultants.

Indicative Cost: **US$1,000,000**

Estimated Project Duration 2 years

9.3.3 Agriculture

PROJECT A1

Project Title: Developing genotypes of cereals that are tolerant to temperature and water stress.

Project Rationale:

Ghana is an agricultural country. Cereal production contributes significantly to Ghana's economy. Over the years field and on-farm trials have established agronomic potential of many cereals varieties in Ghana. With the expected high temperatures and reduced rainfall due to climate change, the future production of cereals in Ghana may be adversely affected. Therefore, testing the different cereal genotypes for their tolerance to heat and water stress would be important in the selection of cereal varieties for future projects on adaptation of maize to climate change.

Objectives:

The broad objective of this project would be to screen the various genotypes of cereals for their tolerance to heat and water stress.

Project description:

Greenhouse facilities would be used to subject the different cereal varieties to different temperatures and water stresses. Heaters would be used to generate different heat conditions in the greenhouses with a range of different water application regimes. Based on their growth performance the cereal varieties would be ranked according to their tolerance to high temperatures and water stresses.

Stakeholders:

Research Institute, Savanna Research Institute (SARI) and Crop Science Department of the various Universities in Ghana, Ministry of Food and Agriculture.

Expected outcomes:

From this study, it is expected to select different varieties of cereals for their tolerance to heat and water stress. The cereals selected would be used in adaptation projects to breed cereals for their tolerance to heat and water stress. Such varieties of cereals could be used to offset any adverse effects due to high temperatures and water stresses on cereal production nationwide.

Planned Activities:

Collection of different genotypes of maize, sorghum, millet and rice.
Growing the cereals in greenhouses.

Subjecting the crops to different temperatures.
Measuring crop performance in the form of growth rates, tillering rates, plant survival rates, biomass production and yields.

Indicative Cost = US$100,000

Expected Project duration: 1½ years

PROJECT A2

Project Title:

Breeding of early maturing varieties of cereals that are tolerant to heat and water stress.

Rationale:

Climate model simulation indicates that temperatures are rising whilst rainfall is decreasing in most of the agroclimatic zones in Ghana. The decline in yields of cereals across the country may be attributed, in part to climate change. Projects on adaptation to climate change should be selected such that there is no loss of resources even if adverse impact of climate change does not occur. The availability of early maturing as well as drought tolerant will be ideal to cope with uncertainties in climate change.

Objective:

To breed for varieties of maize, sorghum, millet and rice that are early maturing as well as tolerant to heat and water stress conditions.

Project Description:

Drought-resistant varieties obtained would be used to breed for other cereals that are also early maturing. The combination of these characteristics i.e. early maturity and drought tolerance will counteract the adverse effects of climate change on cereal production. The heat-tolerant, early maturing cultivars would improve adaptation of cereals to climate change. Once such cultivars have been developed, they have to be subjected to field agronomic trials with different levels of fertilization and water regimes before adoption for adaptation strategies.

Stakeholders:

Agricultural Research Institutes, Agricultural Faculties of Universities of Ghana, NGOs, Farmers and Ministry of Food and Agriculture, Grains Development Board.

Expected outcomes:

With the availability of early-maturing and drought-tolerant cultivars of cereals, yields of cereals are likely to increase with improved fertilizer use and effective soil and water conservation measures.

Planned Activities:

- Genes of selected genotypes of maize, sorghum, millet and maize will be transferred to early maturing varieties of these cereals in an intensive national cereal-breeding program.

- In-field experiments, the selected varieties will undergo agronomic trials with different levels of fertilization and different conservation tillage systems.
- Farmers would be trained through field demonstrations on conservation tillage technologies.
- Seeds would be multiplied and distributed to farmers.

Indicative Cost **US$100,000.00**

Estimated Projected Duration: 24 months.

PROJECT A3

Project Title: **Improving the quality of agricultural data for climate change analysis**

Rationale:

In Ghana, the traditional methods of crop research do not produce data that are relevant to system-based analysis to project the impact of climate change on crop production. Invariably, the data collected are typically location specific and only attempt to fulfil the interests of the traditional farmer with respect to yield improvement. In using system-based approach to project the impact of climate change on crop production, the whole system involving soil-crop-weather-management data must be well understood. In Ghana, whilst the existing data on soils and weather are quite encouraging, there is a paucity of relevant crop data for use in systems-based models such as CERES model to project the impact of climate change on cereals, specifically.

Objective:

To conduct field-based research to collect data on total biomass, yield at harvest, phenology (dates of seeding, anthesis and harvest) harvest index, dry matter and leaf area index at different developmental stages (i.e. at floral initiation, ear emergence, and physiological maturity) and plant density.

Planned Activities

- Measurement of yield at harvest
- Dry matter and leaf area index at different developmental stages
- Plant density estimation
- Experiments
- Data collection
- Collection of soil data

Test crops:

The test crops for the study are maize, rice, sorghum and millet.

Location:

The experiments for maize will be located at Wenchi and Ejura within the Transition Zone. The experiments for rice will be located at Nyankpala in the Guinea Savanna Zone and Nkroful in the High Rainforest Zone. The experiments for sorghum will be located at Nyankpala whilst the experiments for millet will be located at Manga in the Sudan Savanna Zone.

Indicative Cost: US$100,000.00

Stakeholders:

Crop Research Institute, Soil Research Institute, Soil Science Departments and Crop Science Departments of Universities in Ghana, Grain Development Board, Ministry of Food as Agriculture, Agricultural Research Institute.

Expected Outcomes:

Data will be generated to feed CERES model to simulate the projected impact due to increased temperature and decreased rainfall on maize, sorghum, millet and rice production.

Expected Project Duration: 12 months

PROJECT A4

Project Title

To Improve the Quality of Agriculture Data for Climate Change Impact Analysis

Rationale for the experiment

In Ghana, the traditional methods of crop research do not produce data that are relevant to systems based analysis to project the impact of climate change on crop production. Invariably, the data collected are typically location specific and only attempt to fulfil the interests of the traditional farmer with respect to yield improvement. In using system-based approach to project the impact of climate change on crop production, the whole system involving soil-crop-weather-management data must be well understood. In Ghana, whilst the existing data on soils and weather are quite encouraging, there is a paucity of relevant crop data for use in systems-based models such as CERES model to project the impact of climate change on cereals, specifically.

There is a lack of crop input data to simulate and validate crop models to simulate the impact of climate change on cereal production in Ghana**.**

Objective:

To conduct field-based research to collect data on total biomass, yield at harvest, phenology (dates of seeding, anthesis and harvest) harvest index, dry matter and leaf area index at different developmental stages (i.e. at floral initiation, ear emergence, and physiological maturity) and plant density.

Test crops:

The test crops for the study are maize, rice, sorghum and millet.

Location:

The experiments for maize will be located at Wenchi and Ejura within the Transition Zone. The experiments for rice will be located at Nyankpala in the Guinea Savanna Zone and Nkroful in the High Rainforest Zone. The experiments for sorghum will be located at Nyankpala whilst the experiments for millet will be located at Manga in the Sudan Savanna Zone.

Experimental set up:

Maize variety **Obatanpa**, will be used. The experimental design will be Randomized complete Block Design. The treatments will consist of fertilized and unfertilized plots with three replicates. The land will be ploughed and harrowed.

Millet and Sorghum:

The experimental design and treatments will be the same as those for maize.

Rice:

The experimental design and treatments will be the same as those for maize. However, the plot layouts will be in basins and rice seedlings will be transplanted instead of broadcasting or direct drilling.

Data Collection:

Crop data based on those given in the objectives will be collected and documented to improve the quality of crop data for developing and validating the CERES model for projecting the impact of climate change on cereal production in Ghana.

Stakeholders:

The stakeholders will be: Crop Research Institute, Soil Research Institute, Soil Science Departments and Crop Science Departments of University of Ghana, University of Cape Coast and Kwame Nkrumah University of Science and Technology and the Savanna Agricultural Research Institute.

Expected outcomes:

Data will be generated to feed CERES model to simulate the projected impact due to increased temperature and decreased rainfall on maize, sorghum, millet and rice production.

Indicative Cost: $55,000

Expected project duration:

Data will be collected for one major season. The total project is expected to last for 6 months.

9.4 Projects For Education Training And Public Awareness

PROJECT S1

Project Title: Public Awareness Creation on the Changing Climatic Conditions

Project Description:

The main thrust of the reduction of GHG lies in the creation of environmental awareness with the public. If the awareness program is comprehensive, consistent and coherent it will lead to behavior change towards the emission of GHG.

Rationale

The change in climate as a result of human activities is having a devastating effect on life. There is a marked rise in sea level. Temperatures are high with its resulting effect on health, reduction in agriculture produce and drought. It has therefore become necessary to reduce the emission of GHG which are responsible for the changing climate.

Objectives

The general objective of the awareness project is to sensitize the public to integrate measures in their programs to reduce the emission of GHG.

Specifically, the objectives of the project are to:

- expose the public to the dangers of uncontrolled emission of GHG
- assist the public to identify the sources of emission of GHG
- develop teaching learning materials in Climate Change for schools and colleges
- assist stakeholders to incorporate measures to reduce GHG into their programs

Stakeholders

Decision makers, Non-Formal Education Division of the Ministry of Education, District /Metropolitan/Municipal Assemblies

Activities

Objective 1

To expose the public to the dangers of uncontrolled emission of GHG.

Activities

- Organize TV and radio discussion programs

- TV – Adult Education in major languages used on the national Radio and
- Radio – Discussion and phone in programs.

- Organize durbars
- Show documentaries on National TV on climate change and its effects.
- Include Climate Change issues in NFED Primers
- Organize orientation course for NFED facilitators
- Facilitators use Primers for Adult Literacy Program

Expected Outcome

- Weekly adult education program on National T. V. on dangers of emission of GHG.
- Well-informed public of dangers of emission of GHG.

Objective 2

- To assist the public to identify the sources of emission of GHG.

Activities

Same as Objective 1

Expected Outcome

Same as Objective 1

Objective 3

- To develop teaching/learning materials in Climate Change for schools.

Activities

- Conduct Curriculum Audit to find out to what extent Climate Change issues have been integrated into the school syllabus.
- Contract the development of teaching/learning materials for schools and colleges

Expected Outcome

- Teaching/learning materials on Climate Change.
- Effective teaching of climate change related issues in schools and colleges.

Objective 4

- To assist stakeholders to incorporate measures to reduce GHG into their programs.

Activities

- Identify major activities that emit GHG.
- Organize workshop for representatives of sectors emitting GHG.
- Assist sector to draw-up action plan for reduction of emission of GHG.

Expected Duration: 3 years

Indicative Cost: $3,000,000