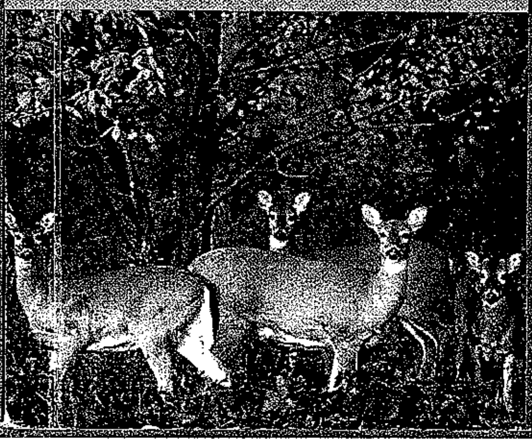
FIRST NATIONAL COMMUNICATION OF KENYA
to the Conference of the Parties
to the United Nations Framework Convention
on Climate Change (UNFCCC)

Ministry of Environment and Natural Resources
National Environment Secretariat

UNEP
United Nations
Environment Programme

GEF
Global Environment Facility



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Republic of Kenya
Ministry of Environment and Natural Resources
National Environment Secretariat

FIRST NATIONAL COMMUNICATION OF KENYA TO THE CONFERENCE OF THE PARTIES TO THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC)

Nairobi, Kenya
JUNE 2002

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The Government of Kenya acknowledges with great appreciation the financial and technical support provided by GEF and UNEP in preparing this initial National Communication. The Government of Kenya also acknowledges the substantive support of UNFCCC Secretariat and the UNDP National Communication Support Programme in facilitating workshops, information, technical materials and analytical tools.

The National Environment Secretariat (NES) of the Ministry of Environment and National Resources executed the climate change enabling activity, through four technical working groups established in line with the four thematic areas of the climate change Convention, namely:

1) National GHG Inventory
2) GHG Mitigation Options
3) Climate Change Vulnerability & Adaptation and Impacts Assessment
4) Education Training & Public Awareness

Technical guidance was provided by the National Climate Change Activities Coordinating Committee (NCCACC), while the Project Steering Committee composed of Director NES, chairs of the four technical working groups and chair of the NCCACC oversaw the preparation of the Communication.

This work is therefore the result of collaboration among experts from government, private sector, academia, NGOs and research institutions.

E. A. Massawa
National Project Coordinator

communications, the country has proposed potential mitigation options/projects which if assisted to implement could meet both objectives of socio-economic development and climate protection.

Other projects for consideration are on awareness creation, as this is crucial if we have to get the whole country's involvement.

The preparation of this document has been confronted with gaps and paucity of data that will be addressed in the next communication. It does however, give a good description of the country and a basis for future studies on climate change.

It is an honour and great pleasure for me on behalf of the Government of Kenya to present the Initial National Communication of Kenya to the Conference of the Parties.

Hon. Isaac A. Ruto, EGH, M.P
Minister For Environment

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ABBREVIATIONS

ACMAD	-	African Centre of Meteorological Application and Development
ADIDSAK	-	Agro forestry for Integrated Development in Semi-arid Areas of Kenya
AFNETA	-	Agro forestry Network for Eastern Africa
APT	-	Automatic Picture Transmission
ASAL	-	Arid and Semi-Arid Lands
ASAP	-	Automated Shipboard Aerological Programme
ASDAR	-	African Satellite Data Relay
AWLAE	-	African Women on Agriculture and Environment
BAPMON	-	Background Air Pollution Monitoring Network
BOD	-	Biochemical Oxygen Demand
CAN	-	Climate Network Africa
CBD	-	Convention on Biological Biodiversity
CBO	-	Community Based Organizations
CBPP	-	Contagious Bovine Pleura Pneumonia
CCC	-	Canadian Climate Model
CCCM	-	Canadian Climate Centre Model
CCPP	-	Contagious Caprine Pleura Pneumonia
CDA	-	Coast Development Authority
CDM	-	Clean Development Mechanism
CFCs	-	Chloroflouralcarbons
COFREP	-	Coffee Rural Electrification Programme
CSD	-	Commission on Sustainable Development
CV	-	Coefficient of Variation
COP	-	Conference of the Parties
COYA	-	Company of the Year Awards
DCS	-	Data Collection System
DEC	-	District Environment Committee
DMS	-	Demand Side Management
DRC	-	Democratic Republic of the Congo
DRSRS	-	Department of Resource Surveys and Remote Sensing
EAIMTR	-	East African Institute of Meteorological Training and Research
ECMRWF	-	East Centre for Medium Range Weather Forecasting
EIA	-	Environmental Impact Assessment
EMCA	-	Environmented Management and Co-ordination Act
EMS	-	Environmental Management Systems
ENSO	-	El Nino Southern Oscillation
ESCO	-	Energy Saving Companies

FACE	-	Free Air CO_2 Enriched
FAO	-	Food and Agriculture Organization
FD	-	Forest Department
FKE	-	Federation of Kenya Employers
GAW	-	Global Atmosphere Watch
GEF	-	Global Environment Facility
GFDL	-	Geophysical Fluid Dynamics Laboratory
GHG	-	Greenhouse Gases
GISS	-	Gordad Institute for Space Science
GOOS	-	Global Ozone Observing System
GRG	-	Gender Research Group
HIS	-	Health Information System
HRPT	-	High Resolution Picture Transmission
ICAO	-	International Civil Aviation Organization
ICZM	-	Integrated Coastal Zone Management
IMCE	-	Inter-Ministerial Committee on Environment
IPCC	-	Inter-Governmental Panel on Climate Change
IRI	-	International Research Institute for Climate Prediction
ISD	-	Indicators of Sustainable Development
ITCZ	-	Inter-Tropical Convergence Zone
KAM	-	Kenya Association of Manufacturers
KARI	-	Kenya Agricultural Research Institute
KBC	-	Kenya Broadcasting Corporation
KCJ	-	Kenya Ceramic Jiko
KEBS	-	Kenya Bureau of Standards
KEFRI	-	Kenya Forestry Research Institute
KEMFRI	-	Kenya Marine and Fisheries Research Institute
KEMP	-	Kenya Energy Management Programme
KENGEN	-	Kenya Electricity Generating Company
KEWI	-	Kenya Water Institute
KFWG	-	Kenya Forest Working Group
KIRDI	-	Kenya Industrial Research and Development Institute
KMD	-	Kenya Meteorological Department
KMS	-	Kenya Meteorological Society
KPC	-	Kenya Pipeline Company
KPCU	-	Kenya Planters Cooperative Union
KPLC	-	Kenya Power and Lighting Company
KREDP	-	Kenya Renewable Energy Development Project
LPG	-	Liquid Petroleum Gas
MAM	-	March to May
MDD	-	Meteorological Data Distribution
MEI	-	Morphoedaphic Index
MENR	-	Ministry of Environment and Natural Resources

MOSAIC	-	Meteosal Operational System for Meteorological Data Acquisition and Interchange
MSY	-	Maximum Sustainable Yield
NAP	-	National Action Programme
NBSAP	-	National Biodiversity Strategy and Action Plan
NCAR	-	National Center for Atmosphere Research
NCC	-	Nairobi City Council
NCCACC	-	National Climate Change Activities Coordination Committee
NDVI	-	Normalized Difference Vegetation Index
NEAP	-	National Environment Action Plan
NEC	-	National Environment Council
NEMA	-	National Environment Management Authority
NES	-	National Environment Secretariat
NIB	-	National Irrigation Board
NIS	-	Newly Industrialized State
NMVOC	-	Non-Methane Volatile Organic Compounds
NOAA	-	National Oceanographic and Atmospheric Administration
NOC	-	National Operations Centre
NOCK	-	National Oil Corporation of Kenya
NWCP	-	National Water Conservation Programme
OND	-	October to December
PDUS	-	Primary Data User Station
PRA	-	Participatory Rural Appraisal
PUMA	-	Preparation of the Use of Meteosat Second Generation in Africa
PV	-	Photo Voltaic
QBO	-	Quasi Biennal Oscillation
RANET	-	Radio and Internet
R & D	-	Research and Development
RFO	-	Residue Fuel Oil
SST	-	Sea Surface Temperature
SWDS	-	Solid Waste Disposal Sites
SWM	-	Solid Waste Management
TDS	-	Total Dissolved Solids
TOT	-	Training of Trainers
TWG	-	Technical Working Group
UNCCD	-	United Nations Convention to Combat Desertification
UNEP	-	United Nations Environment Programme
UNFCCC	-	United Nations Framework Convention on Climate Change
UNICEF	-	United Nations Children's Education Fund
UKMO	-	United Kingdom Met Office
WATBAL	-	Water Balance
WERA	-	Wind Energy Resource Atlas
WMO	-	World Meteorological Organization
WUE	-	Water Use Efficiency

EXECUTIVE SUMMARY

1. Introduction

Kenya ratified the United Nations Framework Convention on Climate Change (UNFCCC) on 30^{th} August 1994 thereby signifying her determination to join the international community in combating the problem of climate change. The compilation of the Initial National Communication of which this is the executive summary goes further to demonstrate that Kenya is willing to meet her obligations under the Convention.

This executive summary includes an inventory of greenhouse gases, reports on climate change impacts, vulnerability assessment, identification of adaptation options as well as climate change related policies and measures.

2. National Circumstances

2.1 History and Geography: Kenya became independent on 12th December 1963. There are 42 ethnic groups each with its own cultures and traditions, some of which are influenced by climate conditions. For example, some communities are predominantly farmers, while others are pastoralists, fishermen, traders, etc. These ethnic groups have, over many years, developed coping mechanisms for climatic variations.

Kenya covers an area of about 592000 km^2. It lies approximately between latitudes 5^0 north and 5^0 south and between longitudes 34^0 and 42^0 east on the east coast of Africa. The equator bisects the country in almost two equal parts. The altitude varies widely from sea level to about 5000 meters above sea level on the central highlands. Lakes occupy about 2% of total area, 18% is occupied by agriculturally high potential areas, while arid and semi-arid lands occupies the reminder.

2.2 Climate: The country's climate is influenced by nearness to the equator, topography, the Indian Ocean, and the inter-tropical convergence zone (ITCZ). The influence of the ITCZ is modified by the altitudinal differences, giving rise to varied climatic regimes. Annual rainfall in Kenya follows a strong bimodal seasonal pattern. Generally, the long rains occur in March - May, while the short rains occur in October – December, but with variations.

2.3 Ecosystem: Kenya is endowed with a variety of habitats and ecological systems, including wildlife, forests, lakes and rivers, wetlands, farmlands, vegetation, marine life forms and micro-organisms. Tourism mainly depends on wildlife, the beach and scenic features. The tourism sector is second to tea in foreign exchange earnings and a major employer in Kenya. Biological diversity is crucial for ecological stability including regulation of climate, economic development, recreation, medicinal use, socio-cultural use and scientific advancement. Protection of ecosystems and plant diversity has the potential of enhancing climate change mitigation capacity.

2.4 Population: Kenya had a population of 28.7 million people in 1999, of which about 80% live in rural areas. The population distribution is uneven from an average of 230 persons per km^2 in high potential areas to an average of 3 persons per km^2 in arid areas. Over 50% of the population is below 15 years. However, intercensal population growth rate has declined significantly from 3.9% per annum for 1969 - 1979 to 2.9% for 1989-1998.

2.5 Land-use: About 18% of total land area is of high to medium agricultural potential and supports about 80% of the country's population. The remaining 20% of the population live in the remaining 80% of the total land area which is arid and semi-arid (ASAL). If climate change results in reduced precipitation in Kenya, then area of ASAL will increase, while the high potential ones would diminish in size.

2.6 Economic Factors: Real growth of GDP has been fluctuating over the years showing a downward trend since early 1990s reaching a negative – 0.3 % in the year 2002. Consequently, poverty has been increasing. The underlying causes for poverty are many, the main ones being poor state of infrastructure, depressed investments, declining tourism activities, slump in industrial production, deteriorating terms of trade and increasing climatic variations.

Poverty contributes to unsustainable use of resources and environmental degradation, such as poor farming practices, overgrazing and reliance on wood as the main source of energy. This is because the immediate survival needs of people often take precedence over the long-term needs for preserving and maintaining the viability and integrity of the environment. Furthermore, public debt which has been increasing is an enormous economic burden.

2.7 Services: The service sector which includes public transport, informal sector, building and construction, banking and finance, storage, trade, communications, tourism, distribution and other services contributes over half of Kenya's GDP and provides over two-thirds of total employment. The potential contribution of the service sector to GHG emissions is through transportation, waste management and deforestation.

2.8 Informal Sector: The informal sector, also referred to as the *Jua Kali* includes all semi-organised and unregulated small-scale activities largely undertaken by self-employed or those employing only a few workers, but excluding all farming and pastoralist activities. It has grown considerably over the last 20 years, employed about 2,987,000 people in 1997 and 3,353,000 in 1998. It represents about 8% of GDP. It is the second largest source of employment after small-scale agriculture.

2.9 Climate Indicators: Indicators of climate change include weather variability, floods, droughts, increased greenhouse gas emissions, temperature changes, etc. Potential use of indicators include alerting decision-makers in government, business, industry, research and civil society organizations and global community to prioritize issues, guide policy formulation, and foster common understanding with a view to initiating action. Indicators will also be useful in determining mitigation options and capacity required. Extreme climate events are associated with disasters and increase in incidences of diseases. Incidences of vector and water borne diseases increase during periods of heavy rains and flooding, while droughts and high temperatures cause famine and malnutrition thereby weakening resistance to diseases.

2.10 Financial Resources: About 91% of total expenditure for research and development funding in 1998/99 was from the public sector, which was equivalent to 0.6% of GDP. The funds were divided amongst the various research institutions. Public research expenditure is heavily biased against industrial research, although the industrial sector could grow to be a major source of carbon dioxide. Mobilization of financial resources is critical and in this light, Kenya welcomes projects under the Clean Development Mechanism (CDM) of the Kyoto Protocol (Article 12) and the Global Environment Facility.

2.11 Policy and Institutional Arrangements: Policies for sound environmental management and sustainable use of resources and appropriate responses to climate change are articulated in a number of official documents. The sector specific policies relevant to adaptation and mitigation of climate change include those for agriculture, forestry, population, energy, water and industrialization. The Environmental Management and Co-ordination Act (EMCA) of 1999 is a framework legislation with provisions for economic incentives, enforcement mechanisms, protection and conservation of the environment, environmental quality standards including issues relating to emissions, impact assessment and modalities for implementing international treaties, conventions and agreements.

EMCA has created an appropriate institutional framework for the effective management of the environment which is to soon supercede the existing structure.

Table 1.1 Summary of GHG emissions from anthropogenic activities in Kenya in 1994 (in Gigagrammes)(Gg)

Sector	Gas Type					
	CO_2 Units	CH_4	N_2O	NOx	CO	NMVOC
Energy	4522	148	1.3	46.7	1645.3	-
Industry	990.1	-		1.5	5.6	6.0
Agriculture	-	576		-	-	-
Land use/ Forestry	-28261	11	0.1	2.7	9.4	-
Wastes	-	15	-	-	-	-
TOTAL	-22751	750	1.4	50.9	1660.3	6.0

3. Greenhouse Gases Inventory

Paragraph 1 of Article 4 of the United Nations Framework Convention on Climate Change (UNFCCC) requires parties to develop, update periodically, and submit to the Conference of the Parties, national inventory of all anthropogenic greenhouse gases emissions not controlled by the Montreal Protocol, to the extent their capacities permit, using comparable methodologies agreed upon by the Conference of the Parties. Kenya being a signatory to the UNFCCC has already undertaken two studies on climate change.

The last study carried out under UNDP/GEF Capacity Building in Sub-Saharan Africa to Respond to UNFCCC had 1992 as the reference year. This was updated for the year 1994 as required by the UNFCCC guidelines. The current work is based on the findings of studies conducted by the National Technical Working Groups under Enabling Activities Project. The studies developed the inventory of GHG from five sectors namely, energy, land use change and forestry, agriculture, industrial processes and waste management (table 1.1) using the revised IPCC guidelines (1996) for national gases inventories.

The gases covered were carbondioxide (CO2) (4522.8 Gg) methane (750 Gg), whose highest emissions are from the agricultural sector (576 Gg) followed by energy sector (148 Gg), Nitrous oxides (N_2O) (1.4 Gg) from the energy sector was 1.3 Gg. Gases emitted with indirect GHG effect include; Oxides of Nitrogen, NOx (50.9 Gg), Carbon monoxide (CO) (1645.3 Gg), and Non methyl volatile organic compounds (NMVOC) (6.0 Gg).

Kenya is a net carbon dioxide sink, absorbing about **22,751** Gg, CO_2 per annum. This is due to regeneration of forest and non-forest trees. Methane emissions were largely from the agriculture sector, followed by the energy sector. The contribution of the waste sector was highly reduced due to the open nature of the waste disposal methods.

Carbon dioxide is the major greenhouse gas emitted. More than 65% of CO_2 emitted is from the transport sector, which is the largest consumer of petroleum products in Kenya. The second largest source of carbon dioxide (CO_2) emission is the industrial sector, mainly cement production. Other important gases emitted include carbon monoxide (CO), methane, oxides of nitrogen (NOx) and nitrous oxide (N_2O). The agricultural sector (including livestock production) is the major emitter of methane (over 70%) followed by the energy sector. The largest source of methane in the agricultural sector is enteric fermentation. Although synthetic fertilizers are a source of nitrous oxide, their total emission is low due to limited use of fertilizers in the country.

4 Vulnerability and Adaptation

The key sectoral vulnerability and adaptation issues from the study are highlighted in this section.

4.1 Agriculture: Agriculture has been the mainstay of the Kenyan economy, but its contribution to GDP declined from 37% in 1964 to 24.5% in 1999. It is the basis for food security, for economic growth, employment creation and foreign exchange generation. Most Kenyan industrial and manufacturing firms are agro-based. The development strategy depends on agriculture and industry for faster economic growth. Most of the agricultural production in Kenya comprises mixed farming – raising of crops and livestock. It accounts for 60% of foreign exchange earnings and provides raw materials for industries. Agricultural production systems in the high potential areas are more intensive as compared to the semi-arid areas. Maize is the staple food crop, while the dry bean is the most important legume crop. Coffee, tea, and sugarcane are the major commercial crops.

Livestock production falls under two systems: dairy, predominantly in the high potential areas and pastoral in the semi-arid areas.

Climate change projections to the year 2030 indicate increasing temperature changes with doubling of CO_2 levels from baseline scenarios resulting into a decline in precipitation in the semi-arid areas. This will lead to reduction in maize yields. The impact of climate change on livestock would be shortage of forage, increased disease incidences and breakdown of marketing infrastructure.

Adaptation options in the agriculture sector would include: development of early maturing and high yielding crop varieties and adaptation of agricultural technologies from analogue environments.

4.2 Water: Kenya is fairly endowed with water in the form of rainfall, ground water, river flows, lakes and oceans. The country is divided into five main drainage basins. Hydrological models have been used to estimate the impact of climate change in several water sub-sectors, viz, soil moisture, ground water recharge, river runoff, lakes and wetlands, water quality and mountain glaciers. Projections indicate that the region from Lake Victoria to the central highlands east of the Rift Valley will experience mild increase in rainfall. Other parts of the country are expected to receive reduced annual rainfall. The highest increments of annual rainfall were observed to be in the areas in the vicinity of Mt. Elgon.

Increasing human population will exert pressure on Kenya's hydrological systems and water resources. This will be further compounded by climate change impacts.

The ability to adapt to variability and change will be affected by a range of institutional, technological and cultural factors at national, regional and local levels.

4.3 Aquatic and Marine Resources: The coastal environment and habitats support some of the most diverse resources in the country. These include mangrove forests, coral reefs, sea grass beds, and rocky and sandy shores. Fisheries activities are pivotal to the household economies of riparian communities. The bulk of the country's fisheries resources come from Lake Victoria, while the aesthetic value of coastal resources contribute significantly to the national economy, mainly through tourism.

Climate change is expected to alter the physical, biophysical and biochemical characteristics of marine eco-systems in Kenya. The Kenyan coast is regarded as one of the most vulnerable to sea level rise. Agriculture, infrastructure and tourism are considered to be under threat.

4.4 Energy: In Kenya, energy is harvested from a variety of renewable and non-removable resources. These include, hydropower, biomass, solar, wind, petroleum and geothermal. Petroleum fuel is the major source of energy used by commercial and industrial establishments. Electricity is the third most used source of energy in Kenya after fuel-wood and petroleum products, but is second to petroleum fuel as a source of commercial energy. About 80% of Kenya's population depend on wood-fuel for its domestic energy needs and by the rural informal industries such as brick making, pottery, jaggery, manufacturing and food processing. The scarcity of fuel-wood and the impact of its escalating prices is acute at the household level because of poverty and limited alternatives.

The most significant impact of climate change on energy will be by extreme weather events such as those caused by the El Nino/La Nina phenomenon. Vulnerability in this sector will be manifest in changes in river flows and increased rates of depletion of biomass.

4.5 Health: Climate and weather variability affect natural processes which in turn affect human health. One of the major impacts will be increased incidences of vector and water borne diseases and poor nutrition.

Development of preventive mechanisms for vector and water borne diseases, surveillance for epidemics that follow episodic weather events and improvement of infrastructure in the health sector are among key policy issues to be pursued.

4.6 Socio Economic Context: Kenya's Human Development Index (HDI) estimated the socio-economic development progress of the nation at 0.539 with variations across provinces and districts.

Such disparities are reflected in differences in regional resource base, infrastructure development and life opportunities. The components of HDI vary widely across the regions with large parts of the country falling in the low human development category and compare with LDCs. Comparing the indices for Nairobi and the rest of the country, it is evident that measures to enhance growth in income should be integrated with other national efforts promoting human development.

Provision of education and life-prolonging services such as good health care are crucial in human development in the country.

Human Poverty Index

Kenya's Human Poverty Index (HPI) value has steadily risen from 26.1% in 1997 to 34.5% in 2001. This reflects in part a fall in life expectancy in the country. When looked at in absolute numbers poverty is a serious national development challenge The Human Poverty Index shows that the level of deprivation in the country is high.

5. Mitigation Options

Attaining the ultimate objective of the convention requires the participation of all Parties in reducing GHG emissions and enhancing sinks. While Kenya is currently a net sink, with increase in socio-economic development and more specifically as the country works to attain its goal of industrialization by the year 2020, GHG emissions will increase. On

Table 1.2: Human Development Index

Province	Life expectancy (1999)	Adult literacy rate (1999)	Annual income per capita KSh.(1999)	Life expectancy index	Education index	GDP index	HDI value
Kenya	54.7	70.9	16,406	0.495	0.642	0.482	0.539
Nairobi	61.6	82.2	78,644	0.610	0.756	0.983	0.783
Central	63.7	83.9	17,829	0.645	0.829	0.339	0.604
Coast	51.5	62.8	18,840	0.408	0.595	0.363	0.467
Eastern	62.3	66.5	15,131	0.443	0.687	0.268	0.525
Rift Valley	61.9	72.6	15,251	0.558	0.652	0.271	0.510
Nyanza	45.7	70.90	14,169	0.345	0.736	0.239	0.440
Western	52.4	64.2	11,191	0.457	0.460	0.324	0.413
North Eastern	52.4	64.2	17,212	0.457	0.460	0.324	0.413

Table 1.3 Human Poverty Index

Province	Population not expected to survive beyond age 40 (% of total population)	Adult Illiteracy rate	People without access to: Clean Water	Health care	Under-weight children under age 5	HPI%
Kenya	34.0	26.4	46.4	51.0	26.4	34.5
Nairobi	40.0	17.8	34.0	45.0	16.3	32.4
Central	31.0	16.1	46.0	51.0	15.7	30.7
Coast	36.0	37.2	28.4	62.0	27.3	37.5
Eastern	31.0	33.5	46.6	75.2	27.8	39.9
Rift Valley	27.0	27.4	59.0	62.0	27.4	36.8
Nyanza	46.0	29.1	64.0	69.4	29.1	44.3
Western	42.0	25.4	61.6	58.8	25.4	41.1
North Eastern	45.0	35.8	34.2	89.0	35.8	44.8

the other hand, the sink capacity of the country is decreasing, as the reafforestation programes have not kept pace with deforestation. On the global scale, Kenya's contribution is negligible but the country is concerned about the protection of local and global environment more especially as the country is extremely vulnerable to the impacts of climate change.

Kenya is committed to work with the international community to combat climate change and has identified mitigation options which if assisted to implement would achieve the twin objectives of sustainable economic development and GHG mitigation. The areas studied included: energy, transport, industry, agriculture, forestry and waste management sectors.

5.1 Energy: The main sources of energy used in Kenya are, namely: biomass, petroleum, and electricity. In terms of quantity, woodfuel accounts for over 70% of the total national consumption. Petroleum is the most important conventional energy source accounting for over 23 % of the total national energy consumption. The government and relevant stakeholders in the sector are actively involved in developing and implementing measures that contribute to abatement of adverse climate change effects and supporting the use of fuel-efficient equipment.

5.2 Transport: The transport sector in Kenya comprises five major types: road, rail, air, sea/lake and pipeline with road dominating. Transport plays a crucial role in the country's development and integration. Motorized transport is by far the most dominant and is a major source of pollution and emitter of GHGs, especially in the urban areas. Motorized road and railway transport are significant contributors of greenhouse gases (GHG). The sector accounts for 56% of the fossil fuels consumed nationally. This is likely to rise in future due to the rapidly rising demand for motorized transport. The main GHG from the sector are carbon dioxide (CO_2). Gases with indirect effect include non methane volatile compounds (NMVOC's), NO_x, and Nitrous Oxide (N_2O). Efforts are being made to identify measures that will lead to the improvement in transportation and control of GHG emission.

The port of Mombasa serves an extensive hinterland in Kenya, Uganda, Rwanda, Sudan, Ethiopia, Burundi and the Democratic Republic of Congo. The heavy commercial vehicles (predominantly diesel users) to these countries, transversing through the country are responsible for heavy emissions of GHG and the destruction of roads.

The following measures have been identified as relevant in mitigating climate change impacts in the transport sector: encouragement of mass transport, tuning of vehicles, improvement of telecommunications to reduce commuting by vehicles, improved traffic management, promotion of non-motorised transport, inclusion of fuel efficiency in driving schools curricula, improved parking arrangements in major towns, environmental standard for transit vehicles, and compulsory inspection of all vehicles. A number of measures are already being implemented. These measures include: promotion of rail transport, extension of oil pipeline, taxation, and pollution control. There remains still a lot of work to be done, especially studies on: demand forecasting, vehicle stock analysis, transport planning and management, development of databanks and models, and improvements in technology.

5.3 Agriculture: Kenya relies heavily on agriculture for food security, economic growth, employment creation, stimulation of growth in off-farm employment, and foreign exchange earnings. About 80% of Kenya's population live in rural areas and depend directly or indirectly on agriculture for their livelihoods.

There have been many cases of land degradation and pollution from the sector. For example, improper use of agro-chemicals have polluted water sources, poisoned and compacted soils. Agricultural intensification is likely to accelerate land degradation and put additional pressure on water, soil, forestry and wildlife resources and has potential to increase emissions of anthropogenic greenhouse gases (GHG) into the atmosphere.

A wide range of measures and policy instruments have been adopted aiming at sustainable development but have also met the objective of addressing GHG emissions in the agriculture sector. These include economic instruments such as subsidies/taxes, regulatory measures, information sharing and research and development projects.

The major constraints to the implementation of mitigation options in the agriculture sector include high financial costs, lack of quality data and information, inadequate extension services, inappropriate technologies, inadequate policies and lack of economic incentives. Approaches to overcome these constraints include provision of financial resources, timely dissemination of quality data and information and availability of economic incentives, access to appropriate technologies, and formulation of appropriate policies. The enforcement of the Environmental Management and Coordination Act will go along way in ensuring harmonization of environmental policies in Kenya including facilitating implementation of the mitigation options.

5.4 Industry: Industrial activities which emit GHGs include manufacture of goods, mining and quarrying; building and construction, electricity generation, food processing and hospitality services. Emission reduction measures have been implemented by some industries in Kenya for considerations other than climate change. Minimising consumption of fossil fuel and promoting afforestation and reforestation programmes will significantly mitigate emission of GHG into the atmosphere.

Environmental concerns are considered in Sessional Paper No 2 of 1997 on the Industrial Transformation to the Year 2020. Some of the legislation which contribute to mitigation measure are: Environment Management and Co-ordination Act, The Factories and Other Places of Work Act (CAP 514), the Local Government Act (CAP 265), Public Health Act (CAP 242) and the Finance Act of 1994/95.

Energy saving measures that also address mitigation of climate change in Kenya has benefited from some local industrial initiatives. They include fuel switch, modification of combustion processes, energy efficiency, and the growing of commercial forests. The private sector will be facilitated to access new sources of funds such as CDM to comply with the requirements of the Environmental Management and Coordination Act.

5.5 Forestry: Forest ecosystems represent an important component in carbon sequestration and conservation. Forests can store from 20 - 100 times more carbon than other vegetation on the same land area, or around 30 - 60 tons of carbon per hectare. The forestry sector is a major contributor of GHG exchanges in Kenya. A recent analysis shows that forests in Kenya are a net sink with an estimated absorption of -28 2621 Gg of CO_2 using 1994 as the base year.

Large-scale deforestation can lead to dangerous levels of emissions of greenhouse gases into the atmosphere. The country can contribute to the objectives of the convention through planned land use changes, proper forestry activities and policies that avoid increased greenhouse gas emission into the atmosphere.

Policies that have direct bearing on land-use change and forest development include the national energy policy, the national food policy, policy on economic management for renewed growth and the National Environment Action Plan. These policies have been strengthened by the Environmental Management and Co-ordination Act of 1999.

Some mitigation options are being considered while others are being implemented. Two mitigation options, have been proposed namely: Reforestation and protection. The benefits of reforestation for Kenya are much higher than those for protection. In addition, proper planning and clear definition of land use policy including classification of forests and their management strategies should lead to sustainable development and enhanced carbon storage. There is also a need to undertake research in various agroecological zones with good tree planting culture with a view to developing strategies for collecting data on trees planted in private and trust (communal) lands, establishing biomass productivity tables for at least 10 widely planted tree species for use in estimating carbon sequestration levels, and developing procedures for enhancing community participation in establishment, management and use of forest resources.

5.6 Waste Management: In Kenya, waste generation has increased considerably due to rapid increase in human population, industrial development, and consumption patterns. Socio-economic activities have since the 1960s, increased the volume and complexity of waste with organic waste constituting by far, the largest portion. Organic wastes generate most of the greenhouse gases emitted into the atmosphere.

Initiatives have been developed for managing waste. These initiatives are intended to improve cleanliness and health, but have some indirect bearing on abating GHG emission. There are also economic and environmental benefits to these initiatives.

Promotion of waste reuse and recycling and raising public awareness should have a positive impact in the mitigation of greenhouse gases as most of the waste is organic which when it degrades, produces CH_4 and CO_2. Inadequate resources for provision of equipment, logistics and also raising public awareness, and building human capacity is hampering sustainable waste management. This results in low levels of reuse/recycling as well as waste generation reduction.

Future initiatives should promote economically sound practices for managing municipal wastes that take advantage of waste reuse and recycling thus abating emissions of GHGS. Currently, there are a number of recycling activities and composting of various waste streams that need to be promoted to minimize waste at source.

6. Research and Systematic Observations

Systematic observations in Kenya are undertaken by a number of meteorological and hydrological stations including, private observing stations in various parts of the country. The Kenya Meteorological Department through its network of observatories and stations carries out systematic observations of a number of meteorological parameters. The department maintains a large climatological data bank dating from 1896 which provides information for monitoring and detecting trends in climatic parameters. However, the number of these stations have reduced in the past decades due to economic constraints limited funds for operation and personnel.

Other problems with data are due to, sparsity of surface and upper air observing network.

Training is required to build the capacities of potential researchers in specialized fields such as climate modeling, climate change detection and attribution, impact assessment, adaptation, and database management.

Kenya has had some studies related to Climate Change Enabling Activities and the project on national communications built on them. These studies include:-

a) The United States Country Studies Programme (USCSP) in 1994.
b) The UNDP/GEF Capacity Building in Sub.Sahara Africa to Respond to UNFCCC – 1996.
c) UNEP/GEF study of IPCC GHG Inventory Methodology Applied to land Use Change in Africa.
d) UNEP study on the implications of climate change, sea level rise and vulnerability assessment of selected coastlines.

7. Education, Training and Public Awareness

Most development activities impact on the environment to varying degrees either negatively, or positively. In order to minimise or mitigate the negative impacts, laws have been enacted to regulate development activities. In particular, the Environmental Management and Co-ordination Act of 1999 has provisions for environmental standards, impact assessment, environmental management, including issues relating to climate and climate change. However, regulations work well if they are complemented by a proactive, and persistent environmental education, training and public awareness programme.

Various stakeholders have developed and are implementing a variety of environmental education, training and public awareness programmes. In particular, formal and non-formal education and training activities are being conducted by schools, colleges, technical training institutions, tertiary institutions and civil society organisations. With the operationalisation of Article 6 of the UNFCCC, it is expected that many activities will be carried out by the government in partnerships with development partners, multi lateral development agencies and civil society organisations to raise the level of awareness on climate change issues at all levels.

1. INTRODUCTION

Climate variations and change affects human activities and life styles, which in turn affects development and economic production. Climate change is not easy to predict with precision because many variables are involved whose possible interactions are difficult to quantify. Consequently, it is necessary to develop policies and response strategies that are sufficiently broad to address the cross-sectoral impacts of climate change, with specific measures to tackle sector-specific problems.

Kenya ratified the United Nations Framework Convention on Climate Change (UNFCCC) on 30th August 1994. The ultimate objective of the convention is to prevent greenhouse gases (GHG) emission into the atmosphere from reaching a level that would interfere with climate.

Available information in the developed countries shows positive correlation between increased carbon emissions and increased incomes under existing technologies. High economic growth is associated with increased carbon emissions, while reduced carbon emission would (given current technological, managerial, demographic and social arrangements) generally be associated with low rates of economic growth.

The challenge for Kenya is to develop strategies, which would promote sustainable development, without contributing to increased emission of GHGs. It is necessary therefore to develop appropriate policies and response strategies to manage GHG emissions. Policies and strategies must be based on reliable inventory of GHG emissions and sinks. This 1st National Communication is the main output of the enabling activity project; ***Kenya: Enabling Activities for the Preparation of Initial National Communication Related to the UNFCCC***, funded by the Global Environment Facility (GEF) through the United Nations Environment Programme (UNEP). The Ministry of Environment and Natural Resources through the National Environment Secretariat executed the Climate Change Enabling Activity. The National Communication is composed of the following information in accordance with the UNFCCC guidelines for the preparation of Non-Annex 1 national communication:

1. National Circumstances
2. Sustainable Development
3. National GHG Inventory
4. Vulnerability and Adaptation to Climate Change
5. Mitigation Options
6. Research and Systematic Observation
7. Education Training and Public Awareness
8. Projects

The activities for the preparation of the National Communication was carried out by a National Communication/Project Management Team and four Technical Working Groups (TWG) established along the thematic areas of the Convention, namely TWG on:-

1. National GHG Inventory
2. GHG Mitigation Options
3. Climate Change Vulnerability & Adaptation and Impacts Assessment
4. Education Training & Public Awareness

1

2. NATIONAL CIRCUMSTANCES

2.1 Geography

The Republic of Kenya covers an area of about 5,000 km^2. It lies approximately between latitudes 5^0 north and 5^0 south and between longitudes 34^0 and 42^0 east on the east coast of Africa (see Fig 2.1). The altitude varies widely from sea level to about 5000 meters above sea level on the central highlands. Lakes occupy about 2% of total area, 18% is occupied by high potential areas while arid and semi-arid lands occupy about 80% of total land area. Its coastline is about 400 km long. The equator bisects the country in almost two equal parts.

Kenya has diverse landforms ranging from the coastal plains through the dry plateaus to the savannah grasslands and the highlands on both sides of the Rift. The vast arid and semi-arid lands of northern Kenya extend from the flat plains in the east to the rugged country west of Lake Turkana.

The major drainage basins in Kenya include the Lake Victoria, Rift Valley, Athi, Tana and Ewaso Nyiro basins and North-Eastern. Drainage is influenced by the country's topography. The main rivers drain radically from the central highlands into the Rift Valley and eastwards into the Indian Ocean and westwards into Lake Victoria, while those north of Mount Elgon and from the highlands along the Sudan-Ethiopian border drain mainly into Lake Turkana.

Although Kenya has numerous rivers, a comparatively small number are permanent, among them are the Tana, Athi, Nzoia, Yala, Sondu, Nyando and Mara. Several of the rivers have been dammed upstream to provide hydroelectric power, irrigation water and water for domestic use.

Kenya's lakes are categorized as fresh and saline/alkaline. Fresh water lakes include Lakes Baringo, Naivasha and Victoria (Africa's largest fresh water lake shared with Tanzania and Uganda). Most other lakes are within the Rift Valley and many of these are alkaline and valuable tourist attractions. The levels and volumes of these lakes fluctuate seasonally. Lake Magadi in the southern part of the Rift Valley is saline/alkaline and is mined for soda ash.

2.2 History

Kenya became independent on 12th December 1963, as a multi-party state. It became a one party state in 1982, but reverted to a multi-party system in 1992. Kenya has 42 ethnic groups each with its own cultures/traditions. Some of which are influenced by climate conditions, which in turn dictate the use of natural resources. For example, some communities are predominantly farmers, while others are pastoralists, fishermen, traders, etc. The characteristics (cultural and climatic) of these ethnic groups (which have developed over many years) incorporate coping mechanisms for climatic variations.

2.3 Climate characteristics

Annual rainfall follows a strong bimodal seasonal pattern. Generally, the long rains occur in March - May, while the short rains occur in October – December, but with variations. Distribution of rainfall is influenced by topography. The country's climate is influenced by its equatorial location, topography, the Indian Ocean, and the inter-tropical convergence zone (ITCZ). The influence of the ITCZ is modified by the altitudinal differences, giving rise to varied climatic regimes. Kenya has seven agro-climatic zone (table 2.1 and figure 2.2)

Figure 2.1 Relief features of Kenya

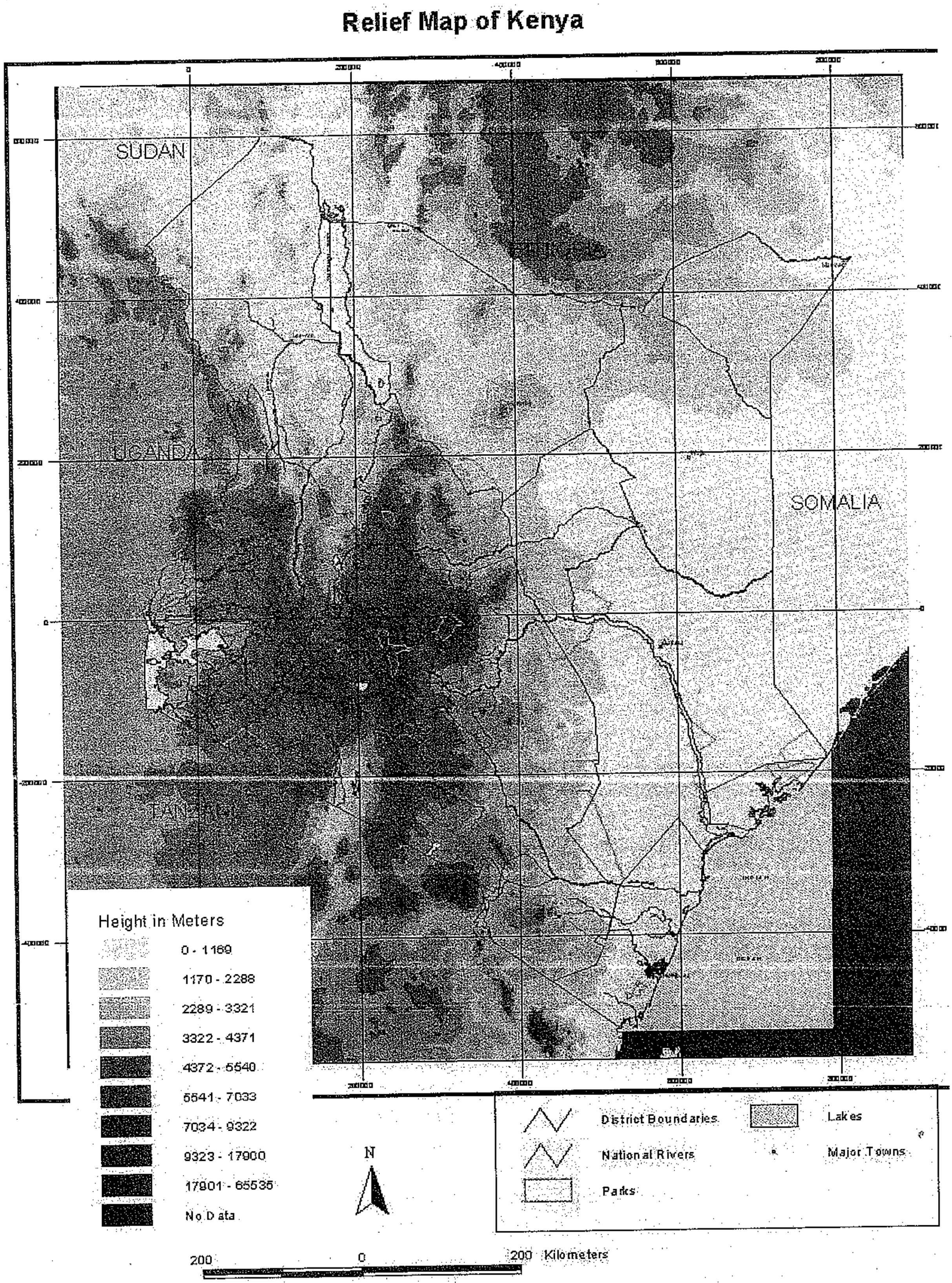


Figure 2.2 Agro-Climatic Zones of Kenya

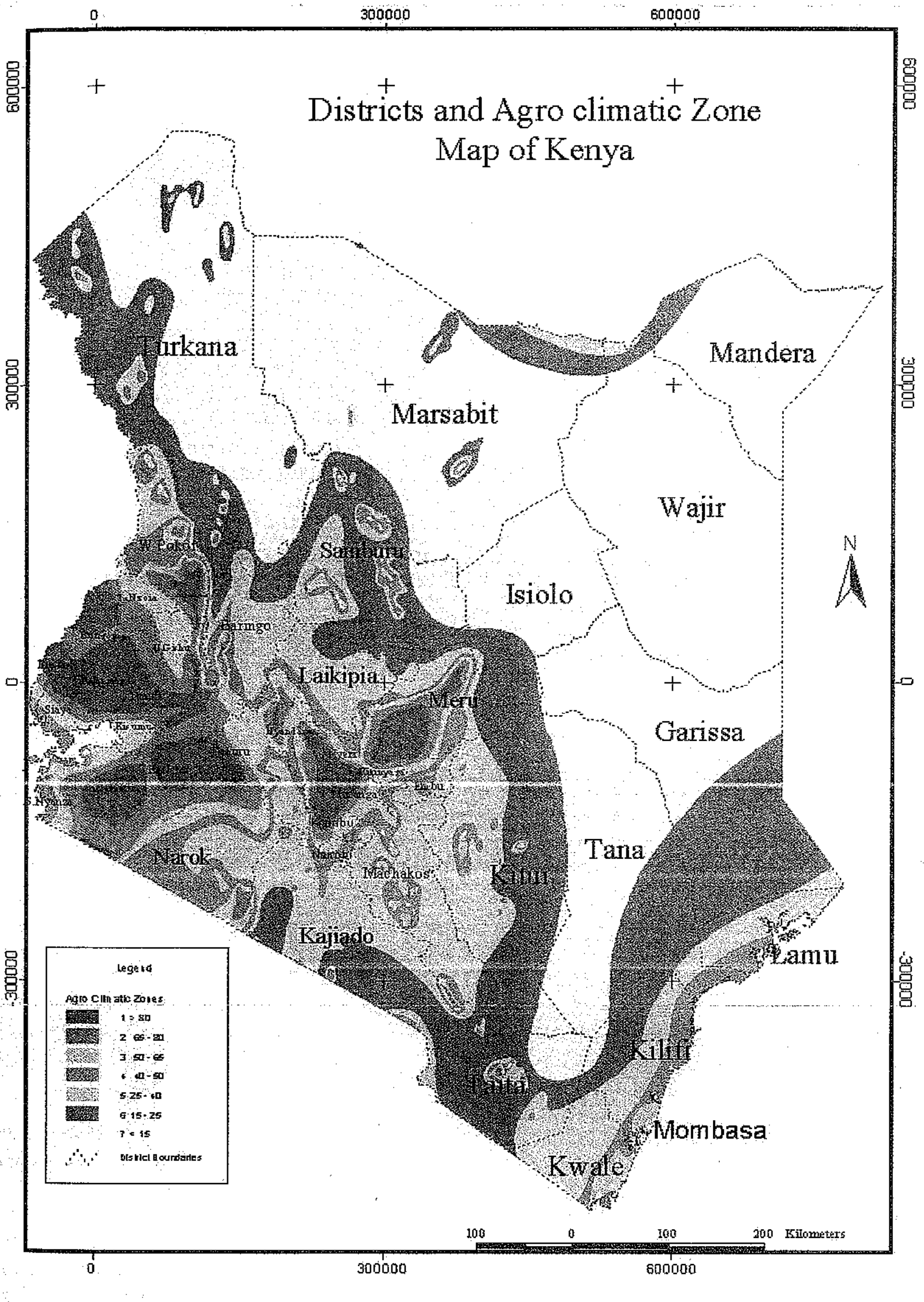


Table 2.1 Agro-climatic Zones of Kenya			
Zone	**Climatic Zones**	**Mean Annual Rainfall**	**% Of Total Land Area**
I	Humid	1,400 - 2,700	3
II	Sub – Humid	1,000 - 1,600	4
III	Semi – Humid	800 - 1,400	5
IV	Medium to Semi Arid	600 - 700	5
V	Semi Arid	500 - 600	15
VI	Arid	300 - 550	22
VII	Very Arid	< 300	46

Source: NEAP (1994)

Altitude exerts the greatest influence on temperature and moisture (Fig. 2.1). There is a wide range between the maximum and minimum temperatures; from below freezing point on the snow-capped Mount Kenya to over 40°C in northwestern, northern and northeastern parts of the country.

Extreme climate events such as droughts and floods are common in Kenya. Some of these events are linked to ENSO.

2.4 Social and Economic Factors Affecting Climate Change

2.4.1 Population

Kenya had a population of 28.7 million people in 1999, of which 80% live in rural areas with a high growth rate of 2.9%. The population distribution is uneven with patterns being linked to agricultural land potential. This also makes the regional population densities remarkably variable, from an average of 230 persons per km^2 in high potential areas to an average low of 3 persons per km^2 in arid areas. Kenya's population is also characterized by rapid rural to urban migration. Over 50% of the population is below 15 years. However, intercensal population growth rate has declined significantly from 3.9% per annum during 1969 - 1979 period to 2.9% between 1989-1998. Additionally total fertility rates have fallen. Such a rapidly increasing population limits the government's ability to satisfactorily provide social services and invest in productive sectors, create employment and deal effectively with serious environmental concerns.

If climate change results in reduced precipitation in Kenya, then the arid and semi-arid areas would increase while the high potential ones would diminish in size. Consequently, the existing population would have to rely on a constricted resource base. This eventuality might increase immigration to urban areas, increase degradation of the environment in rural and urban areas, increase deforestation for settlement and fuel-wood and over-stretching far and stressing the capacity of infrastructures in urban centres. Increased numbers of immigrants to urban areas will further stress urban facilities beyond their carrying capacities in terms of provision of water, education, health, housing, energy and transport.

2.4.2 Welfare and Gender

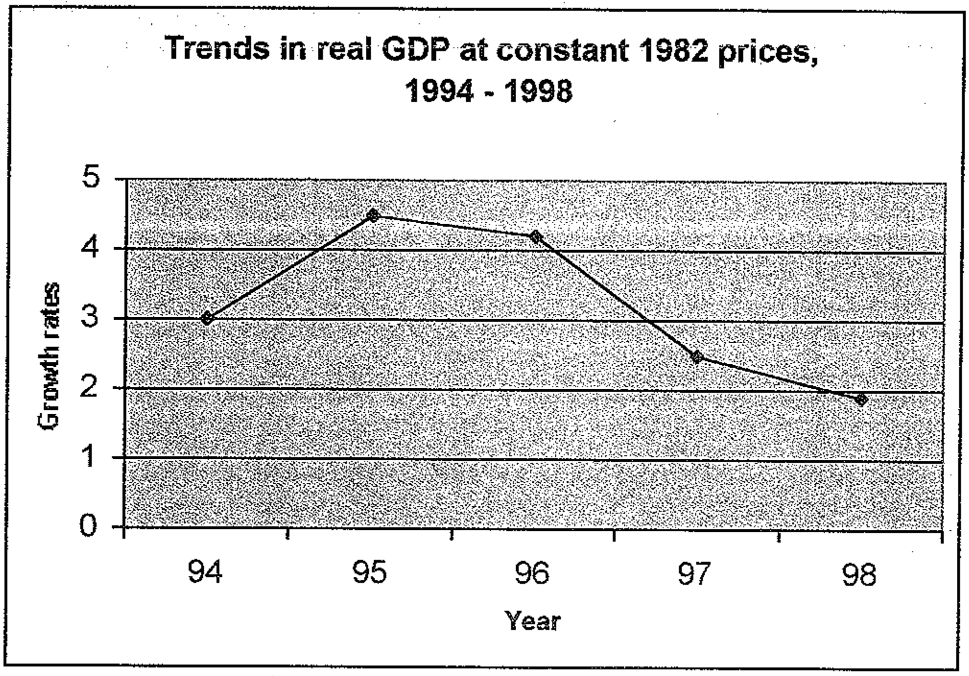
Kenya's immediate major development problem is persistent and increasing level of poverty (figure 2.4) The Human Development Report for Kenya (1999) estimates that half of the population is poor. GDP growth has declined since early 1970s and is now lower than that of population growth.

Poverty contributes to unsustainable use of resources and environmental degradation, such as poor farming practices, overgrazing and reliance on wood as the main source of fuel. This is because the immediate survival needs of people often take precedence over the long-term needs for preserving and maintaining the viability and integrity of the environment. The challenge for Kenya is how to reduce unemployment and poverty.

Kenya's National Poverty Reduction Strategy of 2001 calls for promotion of sustainable livelihoods and diversification of income-generating activities.

Although most of the poor are women, gender imbalances exist because of cultural and other related factors. Issues of gender and climate change are highly correlated because of the productive and

Figure 2.3: Trends in real GDP at constant 1982 prices, 1994 – 1998

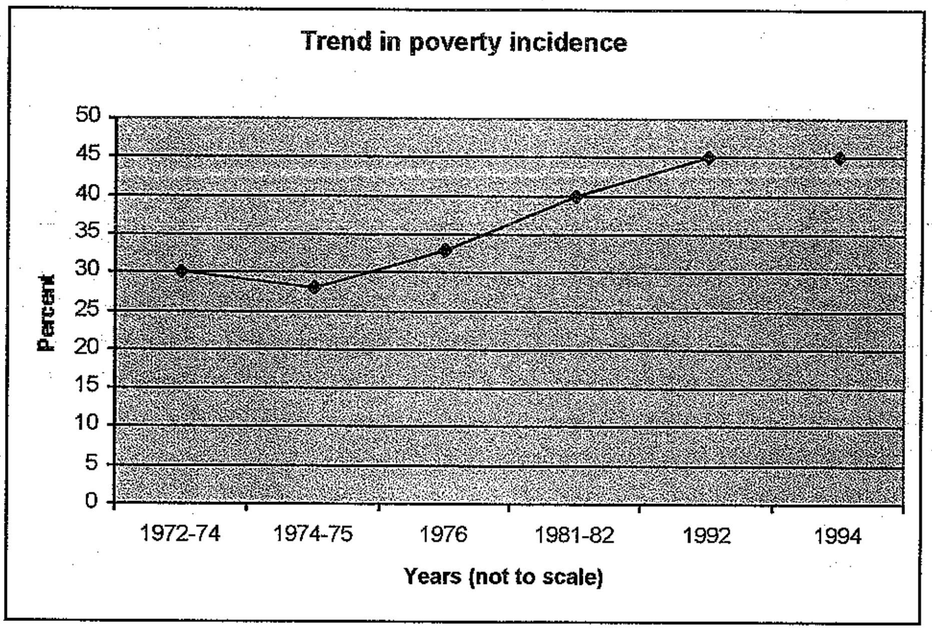


Source: Central Bureau of Statistics (1999)

reproductive role of women. Women interact with the environment in a variety of ways. They are major players in natural resource use and economic development, food production, and are users and suppliers of fuel wood and water.

Women would be most affected by climatic variabilities and other related impacts of climate change as they affect food production, water availability, health, energy scarcity and technological changes. Participation of women in decision-making on issues of land management and ownership is limited. This issue is being addressed through policy and legislative reforms

Figure 2.4 Trend of poverty incidence



Source: Human Development Report, Kenya, 1999

2.4.3 Overview of the Economy

Real growth of GDP has been fluctuating over the years showing a downward trend since 1996 (figure 2.3). The decline recorded a negative growth of - 0.3 % in the year 2001. The economy has been characterized by increasing poverty due to a combination of factors, the main ones being poor state of infrastructure, depressed investments, declining tourism activities, slump in industrial production, deteriorating terms of trade and increasing climatic variations. This has been compounded by a decline in development assistance since early 1990s. In addition, foreign debt, which is an enormous economic burden, continues to grow. Moreover, Kenya depends on agricultural and mineral exports in their raw form and also on tourism, for which it has little influence on.

2.4.4 Land use charges and forests

The economic potential and human settlement patterns are closely linked to the agro-climatic regions (see Fig. 2.2 and table 2.1). Zones I to IV that cover 18% of total land area, are of high to medium agricultural potential (food crop production, cash crops and dairy farming) and supports about 80% of the country's population. The remaining 20% of the population live in zones V to VII, which comprise 80% of the total land area. These zones have the least potential for agriculture but are rich in wildlife, and are therefore important for tourism development.

The concentration of activities and human settlements in the high to medium potential areas creates stiff land use competition. This coupled with heavy reliance on fuel wood and a high population growth has led to deforestation and encroachment of arid areas. This change is evident in the translation of forestland to farmlands, emigration to marginal lands and increased settlement practices requiring sub-divisions of family land. This situation has potential for increasing GHG emissions and for severe impacts of climatic variabilities like floods and droughts. Deforestation increases emission of greenhouses gases into the atmosphere. Additionally, loss of forests reduces carbon sinks. It is therefore important that land use changes involving forestry should be well managed to ensure that least amounts of greenhouse gases are emitted into the atmosphere.

2.4.5 Agriculture

Agriculture is the mainstay of the Kenyan economy. It is the basis for food security, for economic growth, employment creation and foreign exchange generation. The small-scale farm sector accounts for about 75% of the total output in the agricultural sector. Food production accounts for most small-scale agriculture production with cash crops following a distant second. Most Kenyan industrial and manufacturing firms are agro-based. The huge demand for agricultural land has forced many people to emigrate to arid and semi-arid lands, taking with them farming practices that often accelerate land degradation.

The contribution of agriculture to GDP declined from 37% in 1964 to about 24% in 2001. However, the agricultural sector grew on average at a slower pace than overall GDP during the past 30 years (figure 2.5b). Agricultural potential depends on rainfall, soil characteristics, and use of chemicals, but has been adversely affected by land degradation and inappropriate land use practices.

2.4.6 Industry

The contribution of industrial production to GDP has risen over the years (table 2.2 and figure 2.5b). The rate of growth of the sector has been well above that of GDP (Figure 2.5a). Kenya's industrial policy is set in Sessional Paper No. 2 of 1996 on Industrial Transformation to the Year 2020 and the 8th National Development Plan 1997-2001. Rapid industrialization is seen as the quickest avenue for creating employment opportunities, increasing incomes and eradicating poverty. The industrialization policy projects GDP growth at an average rate of 5.9% between 1997 and 2020. Faster economic growth relies on agriculture and industry. However, it is important to critically analyse the industrialization policy and strategies with a view to avoiding increased emission of GHG.

Figure 2.5a: Sectoral Contribution to GDP Growth

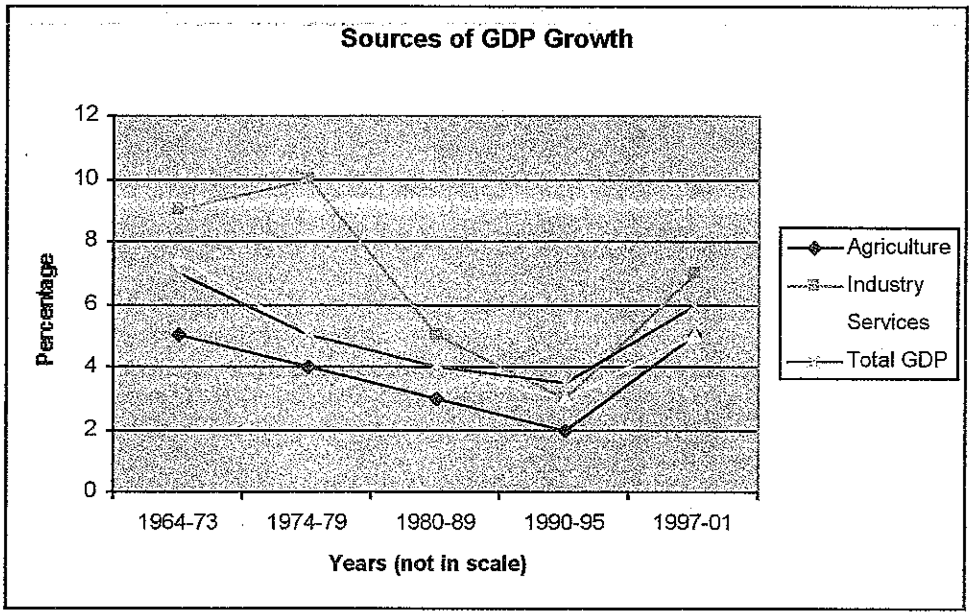
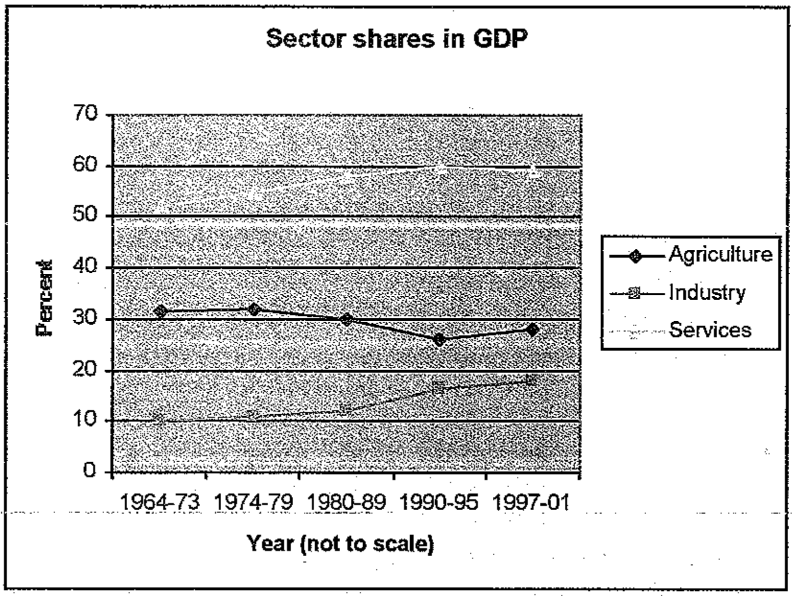


Figure 2.5b: Sector Shares in GDP



2.4.7. Service Sector

The service sector includes transport, tourism, wildlife, energy, informal sector, distribution and other services. This sector contributes over half of Kenya's GDP and provides over two-thirds of total employment. The sector grew faster than agriculture and manufacturing. Its contribution to GDP increased from 53.4% during 1964-1973 to 60.2% during 1990-1995 (table 2.2 and figure 2.5b).

Table 2.2: Key national economic indicators			
Criteria	1994	1996	1998
Population (million)	27	28	28.7
Relevant Areas (km²) Whole Country Arid/semi arid.	587900	587900	587900
Estimated share of informal sector in GDP (%)	6.0	6.1	8.2
Share of manufacturing industry GDP (%)	13.6	13.8	16
Share of services in GDP (%)	58	59	60.2
Share of Agriculture in GDP (%)	25.01	25.00	26
Land area used for agriculture purposes km²	52047	52047	52047
Urban population as % of total population	20	29	33.6
Livestock population (000)	9175	10170	10170
Forest area (km²)	20310	20310	20310
Population in absolute poverty (%)	47.8	48.0	48.02
Live expectancy at birth (years)	(1969) 49	(1989) 59.5	(1989) 59.5
Literacy (%)	72.8	73.4	78

a) Transport

The transport sector in Kenya comprises five major types: road, rail, air, sea/lake and pipeline with road dominating. Transport plays a crucial role in the country's development and integration. Motorized transport is by far the most dominant and is a major source of pollution and emitter of GHG, especially in the urban areas. Emission of GHG by vehicles is due to traffic congestion, poor servicing, old second hand vehicles, poor infrastructure and poor road conditions. Duty on imported second-hand vehicles has been increased to discourage their importation.

b) Tourism and Wildlife

Tourism mainly depends on wildlife, the beach and scenic features. The tourism sector is second to tea in foreign exchange earnings and a major employer in Kenya. National parks occupy about 7% of the total land area in Kenya, though a large population of wildlife is found outside the national parks. Climatic conditions affect abundance and type of wildlife, beaches, mountains and scenic features, all of which attract tourists. Growth in the tourist industry contributes to development through generation of foreign exchange, creation of income earning opportunities, market expansion for agricultural and industrial goods, and development of local entrepreneurship.

c) Energy

Energy is a basic necessity for survival and a critical factor affecting economic development. Petroleum fuels are the major source of energy used by commercial and industrial establishments. Electricity is the third source of energy in Kenya after fuel wood and petroleum products, but is second to petroleum fuel as a source of commercial energy. The demand for electricity by domestic and small commercial establishments increased by 8.2% during 1996-98. However, about 80% of Kenya's population depends on wood fuel for its domestic energy needs. Wood fuel caters for over 70% of Kenya's total energy demand and provides for more than 93% of rural household energy needs. Wood fuel is also used extensively in the rural informal industries such as brick making, pottery, jaggery, manufacturing and food processing.

A great concern in the energy sector is that demand for wood fuel exceeds supply. The scarcity of fuel wood and the impact of its escalating prices are more acute at the household level because of poverty and limited alternatives. These impacts are more felt by women, who are responsible for household cooking.

A practical example of this impact can be explained by a situation in Ngong town,15km to the west of Nairobi, where the escalating prices in fuel wood and poverty have led the use of plastic waste as source of energy. Plastics produce carbon monoxide, which is hazardous to health and contributes to GHG emissions. The women were not aware of the dangers to the environment and their health. However, women scientists who are promoters of new technologies and who try to link policy and research at grassroots level came to the aid of these women (see Box 1).

Box 1: An innovative approach to solving energy problems and reducing emission of GHG in Ngong Town.

In May 1998, a television programme on Kenya the Broadcasting Corporation showed women in Ngong Division using plastic containers as cooking fuel. Ngong is a suburb of Nairobi, an area where deforestation for firewood, human settlements, and food production has taken place over a long period of time.

A group of women scientists, the Gender Research Group (GRG) from Kenya Forestry Research Institute, working in collaboration with Winrock International, the African Women Leaders on Agriculture and Environment Programme (AWLAE) to enhance linkages between policy, research and the woman farmer picked this story. They went on a fact-finding mission, carried out needs assessment on wood and designed an intervention programme. An intervention programme was designed with the participation of the affected women of Ngong using the following procedure(s):

- Participatory Rural Appraisal (PRA);
- Demonstration of energy saving devices to women and other stakeholders;
- Training women to make energy saving devices for use and sale;
- Training women on establishment, management and maintenance of trees and tree nurseries.

These measures enabled the rural women of Ngong to have knowledge, skills and choice of energy saving technologies; increased their incomes from sale of *Maendeleo* Liners and fireless cookers; improved livelihood by providing an alternative source of income; improved health by providing clean energy technology, and make tree and tree products available to these rural women and at the same time provide sinks for GHG.

The government has been promoting energy saving stoves and other alternative sources of energy, including biogas, wind and solar power. Other sources of biomass being investigated, including use of bagasse, short coppice, and use of human solid waste to generate biogas, especially in areas of high population concentration like schools, markets, slums, etc. However, adoption of technologies is constrained by inappropriateness, patterns of settlement, limited promotional strategies and price structures. The energy sector therefore has potential to increase GHG emissions as well as reduce sinks for carbon sequestration.

d) Informal Sector

The informal sector, also referred to as the *Jua Kali* is an important component of the service sector. It covers all semi-organised and unregulated small-scale activities largely undertaken by self-employed or those employing only a few workers. It excludes all farming and pastoralism activities. It has grown considerably over the last 20 years, employing about 2,987,000 people in 1997 and 3,353,000 in 1998. It represents about 8% of GDP (table 2.2). It is the second largest source of employment after small-scale agriculture. Many poor urban women and men depend on this sector for their livelihood. A large proportion of the labour force continue to join the informal sector as opportunities for securing wage employment in the modern sector has become increasingly scarce. There is also a shift of labour from subsistence farming to informal sector due to continued monetisation of the economy. The activities in the sector are carried out by artisans, traders and other operators under a variety of work sites such as temporary structures, markets, developed and undeveloped plots, residential premises or street pavements.

The potential contribution of the service sector to GHG emissions is through transportation, dumping of waste and deforestation. There is however, limited awareness on the impacts of the sector's activities on the environment.

2.4.8 Biodiversity

Kenya is endowed with a variety of habitats and ecological systems, which makes it a custodian of a unique heritage of biodiversity (table 2.3). This rich biodiversity includes wildlife, forests, farmlands, vegetation, wetlands, marine life forms and microorganisms).

Biological diversity is crucial for ecological stability including regulation of climate, economic development, recreation, medicinal use, socio-cultural use and scientific advancement. Kenya will continue to depend greatly on her biodiversity for present and future development.

No.	Description	Percentage land Area
1.	Afro-Alpine glacier and moorland	1.3
2.	Highland moist forest	2.0
3.	Guineo-Congolean rain forest	0.1
4.	Highland dry forest	0.4
5.	Evergreen and semi-evergreen bush land	1.4
6.	Grassland	8.0
7.	Semi-arid wooded and bush-grassland	0.2
8.	Arid thorn bush land and woodland	41.7
9.	Semi-desert	16.8
10.	Coastal forest and woodland	0.1
11.	Groundwater and riverine forest	1.5
12.	Coastal evergreen bush land	0.4
13.	Coastal palm stands	0.1
14.	Permanent swamps	0.1
15.	Freshwater lakes	2.1
16.	Alkaline lakes	0.04
17.	Marine beaches and dunes	0.05
18.	Mangroves	0.2
19.	Coral reefs and islands	0.1

Table 2.3. Biotic Communities, excluding agricultural land and barren areas

Source: Dean and Trump (1983)

The government is committed to the protection of the country's biological diversity. This has been done through legislation and by setting aside a considerable portion of land area (about 8%) as protected areas for wildlife and forestry conservation, and to ensure the survival, conservation and sustainable use of these valuable assets. Kenya has ratified the United Nations Convention on Biological Diversity (CBD). In addition, the government has developed a National Biodiversity Strategy and Action Plan. Many parts of the Action Plans and Strategy are being implemented in form of projects and programmes on biodiversity conservation by the government, private sector and civil society organisations.

Causes of loss of biodiversity in Kenya include habitat destruction, over-exploitation through excessive harvesting or hunting, air and water pollution, introduction of exotic species, and ineffective institutional arrangements. Protection of plant diversity has the potential of enhancing climate change mitigation capacity.

2.5 Information Needs and Indicators

2.5.1 Information on Specific Ecosystems

Climate change is likely to impact on low-lying coastal areas, islands, arid and semi-arid areas, forested areas, areas prone to natural disasters, areas liable to drought and desertification, areas of high urban atmospheric pollution, and areas with fragile ecosystems, including mountainous ecosystems. Some of these likely concerns are summarised in table 2.4. Information on specific needs and concerns will be determined by the development of indicators on impacts of climate. Constraints to development of indicators include lack of access to multi-sectoral data and inappropriate technology for processing and sharing of existing data and/or information.

2.5.2 Indicators of Climate Change

Indicators of climate change include weather variability, floods, droughts, increased greenhouse gas emissions, temperature changes, etc. Potential use of indicators include fostering of a common understanding, facilitating policy formulation and alerting decision-makers in government, business, industry, research and civil organizations and global community to priority issues. Indicators will also be useful in determining mitigation options and capacity required.

Indicators would determine degree and causes of change. Assessing impacts would depend on data

Table 2.4. Likely effects of climate change on specific ecosystems

Area	Likely Effects/Concerns
Low-lying Coastal Area	• Submergence of a large quantity of land and disruption of established ecosystems • Destruction of human settlements • Distribution of agriculture and industry • Complication of water supply • Loss of biodiversity • Siltation • Salanization of agricultural land and changing harvest times
Arid and Semi-arid Areas (Drought and Desertification)	• Deterioration of soil and vegetation cover • Disruption of hydrological cycle • Reduction of water supply • Disruption of livestock industry • Adverse effect on (distress, starvation, famine, and cessation of economic activity) • Dislocation or reduction of wildlife
Forests	• reduction of species diversity and distribution • Deforestation • Loss of forests products and biodiversity • Enhanced land degradation
Mountainous Ecosystems	• Extinction of fragile species
Areas of High Urban	• Environmentally induced diseases (ill health)
Atmospheric Pollution	• Increase waste (dumping)

Source: Adopted from Potential Impact of Climate Change in Kenya *by Climate Change Africa (1997)*

availability, technological know how and availability of financial and other resources. Indicators of specific impacts of climatic variabilities like droughts and floods, and levels of urban atmospheric pollution has not been developed. Kenya is in the process of developing indicators of sustainable development (ISD). The country is one among others being used by the Commission on Sustainable Development (CSD) to test the indicators. In the process. It is hoped that indicators related to climate change could be developed. Some key indicators on broad issues of climate change can be developed with available data and technical know-how (table 2.5). Constraints in developing ISD related to climate change include:

a) Lack of a clear definition of sustainable development in the context of socio-economic status, and the relationship between the goal of mitigation and sustainable development.
b) Inadequate integration of climate change issues in national development priorities.
c) Assessment of sinks, emissions and related issues.
d) Inadequate information on characteristics of gases emitted and their impact on the environment, human health and climate.
e) Inadequate emission standards and regulations.
f) Underdeveloped early warning systems and mitigation options on the dangers of gaseous emissions and their management.
g) Indicators that are socially, politically, economically and environmentally accepted.
h) Inadequate institutional capacity (human, financial and technical) and coordination.

2.5.3 Disasters and Extreme Climatic Events

Extreme climatic events are associated with disasters, and increase in incidences of diseases. Incidences of vector and water borne diseases increase during periods of heavy rains and flooding and so do incidences of landslides, drowning and soil erosion increase. Droughts and high temperatures cause famine and malnutrition thereby weakening, resistance to diseases. Floods, which is a climatic, factor impacts on many sectors, it has been used to develop climate change related indicators (Box 2).

Box 2: Impact of climate variation: Nyando River and its environment

A typical case of the vagaries of weather is given by the Kano and Nyando Plains of Nyanza Province and others in similar geographic regions in Kenya. When the rains come, it is in torrents, floods occur and some of the immediate impacts are:

- Destroyed homes, crops and property;
- Dislocated people;
- Contaminate water resources;
- Increase in incidences of waterborne diseases;
- Increased incidences of famine;
- Silted rivers;
- Enhanced soil erosion;
- Costly and complicated disaster management.

Impacts are economical, social, environmental and political. This is a pattern people in this region have come to dread year after year. What would happen if this pattern changes for the worse due to climate change? Mitigating this situation caused by climatic variability would need data and information for identifying causes, impacts and mitigation options from cross-sectoral actors and stakeholders; and determining ecological functions involved from water catchments to affected areas, etc.

Table 2.5. Key Indicators on Climate Change

Themes issues and objectives	Key indicator
Real economic Growth and poverty eradication	• Increase in potential incomes • Contribution to GDP and national development priorities • Multiplier effect on the national levels through poverty alleviation
Additional financial resources	• Time and ease of accessibility • New and additional financial resources • Non conditionalities
Technology transfer	• Appreciate to national economies and effective utilization of resources • Sustenance of the technology • Use of local skills/resources • Involvement of indigenous private companies/improved or new business as a result of projects
Avoidance of future emissions of GHG	• Measuring sinks and other emissions abatement to facilitate evaluation of real, measurable and long term benefits • Projects benefits from domestic incentives • Availability and accessibility of information to enable measurements.
Capacity building	• Capacity to assess real technology transfer, measure sinks and emissions • Understanding of climate change issues and inclusion of the same in national development planning
Energy Projects	• Efficient energy use • Utilization of renewable sources • Reduction indoor and urban air pollution • Job creation • Improvement in women's health and time use

2.5.4 Systematic Observations, Monitoring, Processing and Exchange of Information

Systematic observations in Kenya are undertaken by meteorological and hydrological stations, which are distributed throughout the country. Private observing stations exist in various parts of the country. The Kenya Meteorological Department through its network of observatories and rain-gauge stations spread all over the country carries out systematic observations of a number of meteorological parameters, namely: rainfall, evaporation, temperature, cloud cover, sunshine, humidity, wind speed and direction, among others. The department maintains a large Climatological data bank dating from 1896. Archived meteorological and hydrological data are needed for monitoring climate with a view to detecting trends in climatic parameters.

The number of rainfall stations in the country has reduced in the past few years due to economic constraints, which has hampered regular station inspections and replacement of unserviceable equipment. Rain gauge stations, which run on voluntary basis, include those managed by schools, administration centres (provincial), national parks reserves, forest stations and individual farms. A Global Atmospheric Watch station has been established on Mt. Kenya. Most of these observation stations are concentrated in high potential areas, yet ASAL experience serious climatic variability situations.

The Central Bureau of Statistics, Department of Resource Survey and Remote Sensing and the Regional Centre for services in Surveying Mapping and Remote Sensing carry out observational/monitoring activities which gather data/information on vegetation index, species distribution and variability, human settlement patterns and socio-economic issues some of which are relevant to climate change. Some sector's specific data are also available.

2.5.5 Education, Research and Technological Development

A major concern of climate change in Kenya is the lack of adequate long period data and information to researchers, planners, policy-makers and the general public. There is need to develop, strengthen and harmonize national research institutions and programmes on issues regarding climate change impacts, adaptation and mitigation. Climate change research should lead to development of technological capacity to enable people reduce social impacts and poverty and improve investors knowledge and capacity to accommodate variations in and causal factors of climate change.

A number of research works have been carried out on weather variability and climate change and their impacts on agriculture, forestry water and aquatic resources, terrestrial ecosystems, human health, human settlement and socio economics, energy, transport, industry and waste management. Institutions involved in studies on weather variability and climate change impacts include public universities and other research institutions such as the Kenya Agricultural Research Institute (KARI), Kenya Forestry Research Institute (KEFRI), Kenya Industrial Research and Development Institute (KIRDI), Kenya Marine and Fisheries Research Institute (KEMFRI) and East African Institute of Meteorological Training and Research.

Research on natural resources and socio-economic issues such as agriculture, forestry, health, fisheries and industry is also undertaken by the same institutions. There are also several institutions researching and teaching on climate related issues. These include School of Environmental Studies of Moi University; Meteorological Department, of the University of Nairobi, and the Faculty of Environmental Studies at Kenyatta University. There are also other institutions such as the Drought Monitoring Centre, and Department of Environmental Studies, Kenya Polytechnic. Furthermore, curricula for public schools, colleges and universities have aspects of environmental education, which in one way or another, touch on aspects of climate change.

2.5.6 Financial Resources

The bulk of research and development funding in Kenya is from the public sector. About 91% of total expenditure, which was equivalent to 0.6% of GDP for the year 1998/99, was funded by the government through its various research institutions. Public research expenditure is heavily biased against industrial research, although the industrial sector is potentially a major source of carbon dioxide.

Availability of financial resources is a major constraint in developing and implementing climate change mitigation measures. Nationally, the priority is on poverty eradication and provision of basic services. Some of the climate change priorities rank low within overall government priorities. Available funds are allocated to the highest government priorities. At the global level, there is competition among nations for limited resources. Mobilization of financial resources is critical and in this light, Kenya welcomes the Global Environment Facility (GEF) and the financial assistance received so far and the Clean

Development Mechanism (CDM) of the Kyoto Protocol (Article 12) where the country looks to being able to leverage more foreign direct investment.

In Kenya, climate change related issues are funded by various ministries, which implement climate change related activities. Over and above this, there are several NGOs and Community Based Organisations (CBOs) who harness funds from various sources.

Private sector involvement in research and development including those related to climate change and technology transfer is minimal. Efforts will be made to interest the sector in this aspect of research. Efforts will also be made to relate climatic information to socio-economic factors.

2.6 Policy and Institutional Arrangements

Policy priorities for developing the above sectoral components focus on:

a) Developing industrial and technological capacities for eradicating poverty and reducing reliance on primary production. The national development plan for 1997 – 2001 says the country should achieve a newly industrialised country status by the year 2020.
b) Promoting environmental conservation and sustainable use of resources.
c) Adapting relevant (appropriate) and affordable technologies for efficient resource use.
d) Repaying debt.

2.6.1 Policy and Plans for Sustainable Development

Policies for sound environmental management and sustainable use of resources and appropriate responses to climate change are articulated in a number official documents. Steps are already being taken to develop a policy for guiding strategies for developing and implementing adaptation and mitigating impacts of climate variability and change. Some of the existing policies and plans are:

a) Sessional Paper No.6 of 1999 on Environment and Development.
b) The National Environmental Action Plan (NEAP) of 1994.
c) National Biodiversity Strategy and Action Plan.
d) Environmental impact assessment regulations, guidelines and procedures.

2.6.2 Sectoral Policies

The management of climate change issues is shared by a number of institutions that administer it from their sectoral concerns. The sector specific policies relevant to mitigation of climate change include:

a) Agricultural policies that emphasize sustainable agricultural production, prohibit clearing of catchments, river basins and cultivation on riverbanks.
b) Forestry policy: It protects indigenous (including catchments forests) and plantation forests, encourages re-forestation, sustainable forest cultivation for firewood, industry and construction, and prohibits extension of settlements into gazetted forests.
c) Sustainable population policy.
d) Energy policy which calls for energy use efficiency, utilization of renewable energy and cleaner technologies, improved forestry management, etc.
e) Water policy that protects water catchments from deforestation.
f) The industrialization policy which promotes sustainable industrial development and development of technologies for clean production.

Some of the above policies provide for incentives. In particular, the Finance Act of 1994/95 allowed duty free importation of anti-pollution devices.

2.6.3. Legal measures and Administrative Framework

The Environmental Management and Co-ordination Act (EMCA) of 1999 has provisions for economic incentives, enforcement, protection and conservation of the environment, environmental quality standards including issues relating to emissions, impact assessment and modalities for implementing international treaties, conventions and agreements. Sectoral laws are expected to be reviewed and harmonized with this framework law.

Preparation of EIA guidelines and related institutional and legal framework for all future development projects in the country is at an advanced stage.

The National Environment Secretariat (NES) is the focal point for all national environmental issues, including climate change. NES has a climate change secretariat headed by a senior officer. Climate change issues are coordinated by the Inter-Ministerial Committee on Environment (IMCE) with representation from all key ministries/departments, academic and research institutions, NGOs and the private sector. IMCE has created eight technical sub-committees on priority areas. The technical sub-committee on climate change is also called the National Climate Change Activities Coordination Committee (NCCACC). The terms of reference for the NCCACC are:

a) Advice on implications of the commitments under the UNFCCC and other international agreements related to climate change.
b) Establish a networked database on climate change impacts, response strategies and research activities.
c) Advice on issues pertaining to the Global Environment Facility (GEF) or any other international financial mechanisms.
d) Translate the objectives of the UNFCCC and related protocols into national development priorities.
e) Harness and coordinate available national expertise, sectoral initiatives, resources mobilization, and strengthen human and institutional capacities as well as develop and harmonize multi-sectoral programmes.

The NCCACC policy recommendations reach the grassroots through institutional representatives, including the District Environment Committees (DEC).

EMCA has created an appropriate institution framework for the effective management of the environment, which once in place will supercede the existing structure. The new structure is as follows:

a) National Environment Council (NEC), which will be the overall policy making organ in government.
b) National Environment Management Authority (NEMA) is the implementation arm, with the following organs:
   - Management Board;
   - National environment trust and restoration funds;
   - Provincial and district environment committees;
   - Environmental planning committees – at national, provincial and district levels;
   - Environmental inspectors;
   - Technical advisory committee on EIA;
   - Standards Review and Enforcement Review Committee.
c) Environmental Tribunal.
d) Public Complaints Committee.

2.7 Conclusion

About 80% of Kenya's population depends directly on land and natural resources for their livelihoods. The impact of weather variability and climate change on land and natural resources has potential to severely affect the lives and livelihoods of most Kenyans. In this regard, the government has initiated policy guidelines for guiding strategies for developing and implementing adaptation and mitigation measures. These have the potential to abate increase of emission of GHG and therefore, mitigate climate change.

There is a definite institutional structure for climate issues. However, it is constrained by inadequate capacity and weak linkages and networking at all levels. Gender roles make climatic variabilities impact more negatively on the female gender. There is an attempt to link policy and gender, in particular on the area of energy. Information to assess potential climate change impacts on various ecosystems is limited. Attempts are being made to develop indicators of climate change.

Kenya has a relatively long history of collecting climatic data through systematic observations however inadequate, but the network of observatories, especially in ASAL needs to be strengthened. Major constraining factors are inadequate financial resources and failure to fully incorporate climate change issues in the development planning processes.

3. SUSTAINABLE DEVELOPMENT AND PLANNING

3.1 Introduction

Climate change and resulting weather variations will have great influence on sustainable development, especially in poor countries. The impact on Kenya by the El Nino event of 1997/98 bears testimony to this. The cost of the 1997/98 El Nino phenomenon was estimated at over US$200million, excluding the number of people who lost their lives, and economic opportunities. The disaster resulted in the reorientation of public investment from economic development to rehabilitation of infrastructure and other immediate emergency requirements.

An interplay of many factors contributed to the severity of the impacts. For example, roads and bridges were in need of repair and were therefore vulnerable to heavy rains and floods, as did inadequate health facilities.

Global climate change is a result of the amount of greenhouse gases emitted in developed countries. Kenya's contribution to the global emission is negligible. Kenya is vulnerable to climate change, which could be exacerbated by the following national circumstances:

a) The country is already experiencing water stress.
b) Food security has suffered serious and frequent adverse impacts from climate variability.
c) Natural resources productivity, including biological diversity has been severely affected by poaching, indiscriminate use, and pollution.
d) Vast areas suffer serious incidences of vector and water-born diseases because of inadequate health infrastructure.
e) The coastal zone is vulnerable to sea level rise.
f) Some infrastructural facilities are exposed to extreme climatic events such as flooding.
g) Desertification is being exacerbated by changes in rainfall and intensification of land use.

Traditionally, the low-lying, semi-arid and arid zones of northern Kenya and the southern rangelands are recognized as drought prone. Climatic variations have increased vulnerability to drought of the dry areas near Lake Victoria and the heavily settled areas in the Rift Valley. The effects of floods on the environment and human settlements have been aggravated by deforestation on hill slopes and riverbanks, which increase run-off and speed of water during heavy rains. Flooding has been experienced in the Lake Victoria Basin (Kano Plains), along the Tana, Yala and Nzoia rivers. There is a danger of downstream flooding due to possible collapse of dams in areas prone to earthquakes. Floods worsen incidences of water-borne diseases such as cholera, typhoid, bilharzias, and diarrhea.

The impacts of the extreme events have potential to destabilize development activities with increases in their frequencies. It is expected that the existing industrial and economic gains will be eroded unless the country's resilience to climate variability and change is enhanced.

3.2 Challenges and Responses

In view of potential and real impacts of climate change, there is need to integrate climate change concerns into the national planning and development processes. This would require wide ranging changes in government policies. For example, policy makers and planners will have to re-think conventional approaches. Environmental issues will increasingly assume a higher priority ranking, while economic and institutional measures and arrangements would have to be sufficiently flexible in order to adapt relatively fast to emerging trends or events. Enhancing the adaptive capability requires significant increased capacity in science and technology and formulation of policies that are sufficiently flexible and receptive to constant change. A higher premium will need to be placed on social learning.

Other important national challenges to sustainable development are: high population growth, increasing levels of poverty, public debt, trade liberalization, and inadequate resources.

a) Population Growth Rate: Kenya's population has been growing at an average rate of 2.9% per annum, thereby exerting pressure on natural resources. Pressure has resulted in increased evidence of desertification and loss of genetic resources. Policies and programmes for managing population growth will emphasize achieving a balance between population growth and desired environment conservation.

b) Poverty: Over 50% of the Kenyan population lives in absolute poverty. Poverty leads to over-use and destruction of the environment where short-term needs are pursued at the expense of environmental sustainability.

c) Public Debt: The country currently suffers an enormous debt burden. The debt service requirement leads to increased pressure on environmental resources to enhance production and improve incomes and revenues needed for debt servicing. Therefore, to ease pressure on resources, the government will pursue both the traditional mechanisms for debt relief and the HIPC initiative.

d) Trade Liberalization: The continuing wave of trade liberalization has exacerbated environmental problems. There is need, therefore for treaties and regulations that vigorously regulate pollution arising from commercial activities locally and internationally.

e) Inadequate Capacities and Funds: The government will continue to collaborate with all stakeholders, development partners, the private sector and civil society organisation in mobilizing resources required to implement environmental policies and regulations in accordance with the principles of sustainable utilization.

3.3 Other Environmental Management Concerns

Poverty leads to over-use and destruction of natural resources as the poor are forced to fulfill their short-term needs often at the expense of environmental sustainability. Environmental degradation contributes to climatic change, which often adversely affect biodiversity and ecosystem management, accelerate desertification and environmental disasters, as well as weaken pollution and waste management.

3.3.1 Biodiversity, Desertification and Ecosystem Management

Kenya is a party to the Convention on Biological Biodiversity (CBD), the Cartagena Protocol on Biosafety and the United Nations Convention to Combat Desertification (UNCCD). The government has prepared a National Biodiversity Strategy and Action Plan (NBSAP), and a National Action Programme (NAP) to combat desertification. The government has also developed a national policy to address conservation and sustainable utilization of wetlands. However, it will be necessary to incorporate climate change concerns into these policies and plans, including strengthening of early warning systems and mechanisms for monitoring food security, weather and climate variations and the environment as well as formulation of response strategies.

3.3.2 Environmental Pollution and Waste Management

Studies indicate presence of oxides of sulphur, nitrogen, carbon monoxide particulates, hydrogen sulphide and other organic gaseous pollutants in the main urban centres of the country. Most local authorities are unable to cope with demands for collection, treatment and disposal of wastes due to inadequate capacity and financial constraints. The City of Nairobi alone produces 1000 tonnes each day of solid wastes, 20% of which is collected. Sewage and solid disposal systems have become seriously inadequate. In addition, agricultural activities, industrial processes, and service providers have become major polluters of the environment. All these environmental problems have serious implications on public health. The government is developing mechanisms for increasing participation of the private sector in waste management. Policies have also been developed to ensure that sewerage and sanitation systems will be considered alongside the development of water supplies. The strategies identified to minimize environmental pollution and improve waste management include developing air quality standards; promoting technologies that minimize harmful emissions; developing and enforcing a waste management policy, and enforcing all provisions of the Environmental Management and Coordination Act.

The effects of climate change poses risks for the stability and survival of ecosystems especially when combined with other threats to the natural and human environment. The current high frequency of the El-Nino/La-Nina episodes may be associated with global warming.

3.4 Institutional Framework

The National Environment Secretariat (NES) was established in 1974 in response to national and international concerns about the quality of human environment which culminated in the creation of the United Nations Environment Programme (UNEP) following the historic United Nations Conference on Human Environment held in Stockholm, Sweden, in June 1972. This new spirit underscored the need for the human race to bring environmental matters to the centre of the development process.

NES was mandated to coordinate the formulation and development of policies for the conservation, protection, enhancement and management of the natural and man-made environments working through the Inter-ministerial Committee on Environment (IMCE). A number of sub-committees of IMCE deal with various thematic areas of environment. For example, climate issues are the responsibility of the National Climate Change Activities Coordinating Committee (NCCACC).

3.5 Environmental Policy Interventions

The Kenya National Environment Action Plan (NEAP) of 1994 was developed through a popular and participatory approach. It made fundamental recommendations, including proposal for a new institutional framework; review and harmonization of environmental legislation; and harmonization and implementation of environmental impact assessment (EIA). These recommendations led to the formulation of the environment policy contained in Sessional Paper No.6 of 1999 on Environment and Development, and the enactment of the Environmental Management and Coordination Act of 1999.

The goal of Sessional Paper No.6 of 1999 on Environment and Development is integration of environmental concerns into national planning and management processes. It provides guidelines for environmentally sustainable development. The objectives, which are to be met include:

a) To conserve and sustainably utilize the natural resources including air, water and water catchments, land, soil fertility, flora and fauna.
b) To enhance public awareness and appreciation of the essential linkages between development and environment.
c) To initiate and encourage well coordinated programmes of environmental education and training at all levels of society.
d) To involve civil society organisations, private sector and local communities in the management of natural resources.
e) To support a coordinated approach to policy formulation on environmental matters.
f) To ensure all development policies, programmes and projects take environmental considerations into account.
g) To ensure that an acceptable environmental impact assessment report is undertaken for all public and private projects and programmes.
h) To develop and enforce environmental standards.
i) To enhance, review regularly, harmonize, implement, and enforce laws for the management, sustainable utilization, and conservation of natural resources.
j) To apply market forces, taxation and other economic instruments, including incentives and sanctions to protect the environment and influence attitudes and behaviour towards sustainable utilization and management of natural resources.
k) To ensure adherence to the "polluter pays principle".
l) To develop adequate national laws regarding liability and compensation for the victims of population and other environmental damage.

The Kenya National Environment Action Plan (KNEAP) of 1994 and the Environmental Management and Coordination Act of 1999 provide a basis for directing efforts to achieving the goal of sustainable development.

3.6 Macro Economic Framework for Sustainable Development

The National Development Plan for 2002-2008 recognizes that environmental and natural resource degradation constitutes a major challenge to Kenya's development efforts. The immediate challenge for Kenya is to reduce poverty and achieve sustained economic growth, while ensuring that environmental considerations are integrated in all major national and sectoral policies, plans, programmes, and decision-making processes. This calls for development of appropriate capacities and tools for identifying constraints and opportunities for sustainable development, taking into consideration the following influencing factors:

a) The satisfaction of human needs;
b) Technological, social and other limitations affecting the ability of natural resources to meet present and future needs of Kenyans;
c) Recognition that environment and development are interrelated; and
d) Emphasis on the ecological responsibilities of the present generation toward future generations.

The National Development Plan for 2002-2008; and the Poverty Reduction Strategy Plan for 2001/2-2003/04 are intended to ensure macro economic stability. The macroeconomic framework aims to revamp growth, raise productivity, encourage private investment, and drastically reduce unemployment and poverty. Poverty leads to environmental degradation as people use the land and other natural resources without regard to their potential to meet their future needs or those of succeeding generations.

The monetary strategies include maintaining price and exchange rate stability, low interest rate and vibrant financial sector and increasing access to credit. Price stability will be achieved by maintaining the annual average inflation at no more than 5% but still able to stimulate the economy by promoting growth and employment. The government will also endeavour to maintain a competitive real exchange rate that ensures favourable balance of payment positions and increased exports. Maintaining low interest rates and creating and sustaining a vibrant financial sector will be achieved by a reduction in the level of non-performing loans, restructuring oligopolistic banking, strengthening supervisory and regulatory roles of the Central Bank of Kenya and restructuring the domestic debt from short to long term.

Kenya's fiscal strategy aims at increasing the level of economic activity by enhancing the role of the private sector. This will be achieved through four key objectives: sustainable reduction in the level of public expenditure relative to GDP; reduction in the level of domestic debt relative to GDP, changing the composition of expenditure to focus more on efficient public investment and operations in the long run; and strengthening the budgetary process.

Economic policy measures and public investments will focus on creating economic opportunities for the poor in marginal and vulnerable regions by providing incentives to small-scale producers, smallholder peasants and traders. The growth strategies contained in the PRSP aim to:-

a) Ease access to markets and market opportunities by the poor through provision, of infrastructure, attractive and affordable credit, etc.
b) Improve effectiveness of public resources geared towards poverty reduction.
c) Enhance protection of marginalized and vulnerable groups.
d) Allocate increased resources to human capital development.
e) Promote improved productivity.
f) Improve conditions in the labour market.

3.7 Conclusion

There is need to integrate climate change concerns and sustainable principles in all national development plans and programmes in order to ameliorate the negative effects of poverty, provide basic needs and meet peoples' aspirations for a better life and ensure effective environmental management. Kenya will continue addressing the challenges of poverty, population growth, debt, trade and capacity requirements among others in order to fully mitigate the impacts of climate change but would need assistance to achieve these objectives.

4. INVENTORY GREENHOUSE GAS EMISSIONS AND SINKS

4.1 Introduction

Paragraph 1 of Article 4 of the United Nations Framework Convention on Climate Change (UNFCCC) requires parties to develop, update periodically and submit to the Conference of the Parties (COP), national inventory of all anthropogenic greenhouse gases emissions not controlled by the Montreal Protocol by sources and removals by sinks, to the extent their capacities permit, using comparable methodologies agreed upon and promoted by the COP. Kenya being a signatory to the UNFCCC has already undertaken some studies related to climate. These include:

a) The United States Country Studies Programme (USCSP) in 1994; GHG emission inventory was carried out for land use change, energy, industry, agriculture and waste management
b) The UNDP/GEF Capacity Building in Sub-Sahara Africa to Respond to UNFCCC (1996-1998); GHG Inventory for the year 1992. This later inventory was updated to 1994 in order to meet the requirements of the UNFCCC guidelines. No further work has been carried out to address the gaps identified in these two studies.

Due to the time limitation in the UNDP/GEF Capacity Building Project, the GHG inventory could not take into account the great variations in climate, soils, topography, animal and crop species, especially at provincial and district levels. Most constraints and gaps identified were due to lack of comprehensive data storage and management systems on an annual basis. Furthermore, it was difficult to obtain information on many newly introduced industrial processes. However, the information could be obtained if sufficient time is allowed for studying these processes under the local conditions and establishing empirical values of emission factors.

The studies considered five major sectors in Kenya: energy (fossil fuels, lubricants and woody biomass); industrial processes (cement production, lime use, soda ash production); agriculture (rice cultivation and livestock production); land use change and forestry (forest clearing, biomass harvest, abandoned managed lands and burning of savannah including grasslands); and wastes (urban solid waste and wastewater).

The gases which were considered in the study include; carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), Nitrous oxides(N_2O) of nitrogen (NO_X) and non-methane volatile organic compounds (NMVOCS). Data were collected from records of various departments of the Kenya government and other sources.

4.2 Methodology and Sources

Greenhouse gas emissions and sources and removals by sinks was calculated following the revised 1996 IPCC Guidelines. The data used were collected from various sources including Ministry of Energy, Central Bureau of Statistics, Kenya Petroleum Refineries, Kenya Pipeline Company (KPC) and the National Oil Corporation of Kenya (NOCK), Ministry of Agriculture, Forest Department, DRSRS, FAO and private sector. IPCC default values were used to fill in the gaps. As local emissions factors have not yet been developed, emission factors recommended by IPCC were adopted except in the case of cement and lime production processes.

Such information could have been obtained if funds were allocated for studying these processes under local conditions and establishing empirical emission factor values for proper estimation of GHG emissions.

4.3 Emissions from Energy Sector

Various forms of energy are used in Kenya, the main ones being petroleum products, coal, lubricants (Table 4.1) and woody biomass.

Greenhouse gases emissions from the energy sector include fuel combustion as well as fugitive fuel emissions, but exclude CO_2 emissions from combustion of biomass that are addressed in land use change and forestry sector.

4.3.1 Carbon Dioxide Emission Process from Energy Fuels

The quantity of carbon is based mainly on the supply of primary fuels and the net quantities of imported secondary fuels.

(a) Stored Carbon: Not all fuels supplied to an economy are burned for heat energy. Some is used as raw material for manufacture of products such as plastics or in a non-energy use, without oxidation of the carbon. This is termed stored carbon and is deducted from calculated carbon emission. Stored carbon was estimated from used fuel.

(b) International Bunker Fuels: Emissions from fuels used by international marine and air transport are excluded from national emission totals.

(c) Biomass Fuels: Biomass fuel is included in national energy and CO_2 emission accounts for information only. In the energy module, biomass consumption is assumed to equal its re-growth. The other forms of biomass are accounted for in the land use change and forestry sector.

Production and imports of each fuel were added together and the exports, bunkers and stock changes were subtracted in calculating the apparent consumption of fuels.

According to the IPCC guidelines, carbon from the manufacture of secondary fuels are ignored in the main calculations as they are already accounted for in the supply of primary fuels. However, information on production of some secondary fuel products is needed to adjust carbon stored in these products. The procedure calculates the supply of primary fuels to the economy with adjustments for net imports (imports-exports), bunkers and stock changes in secondary fuels.

4.3.2 Fugitive Emissions from Oil

The imported crude oil contains a certain amount of gas (mainly methane). Some of the gas evaporates or vents into the atmosphere during storage. During the refining process of crude oil into hydrocarbon products such as gasoline, diesel, LPG, etc, dissolved gases are separated, some of which leak into the atmosphere as CH_4. The emission factor used was that between 90 – 1,400kg/PJ* (for oil refinement)

Table 4.1. Fuel consumption (PJ) and emissions in 1994

Liquid Fuel	Crude	Gasol.	Jet Kerosene	Gasoil	Lubrication oil	Ref.Fd	Coal	TOTAL
Apparent (ToE) Consumption	2107.90	139.72	490.07	139.94	10.68	101.54	76.00	
Conversion Factor	41.868	41.868	41.868	41.868	41.86	41.868	41.868	
App. Cons (PJ)	88253	5849.9	20518	5859.0	447.23	4251.2	3181.9	63905.9
Emission Factor	20.0	18.90	19.50	20.20	20.00	20.00	25.80	
Carbon Content (Gg C)	1765.0	110.56	400.10	118.35	8.9947	85.025	82.094	1312.09
Carbon Stored (Gg C)	0	0	0	0	4.4723	0	61.571	66.0433
Net Emissions (Gg C)	1765.0	110.56	400.10	118.35	4.4723	85.025	20.523	1246.02
Carbon Oxidised (Fraction)	0.990	0.99	0.99	0.99	0.99	0.99	0.98	
Actual Emissions GgC)	1747.4	109.45	396.10	117.16	4.4276	84.175	20.113	1233.31
Actual Emissions (Gg CO_2)	6407.2	401.34	1452.3	429.61	16.234	308.64	73.748	4522.45

Source: Ministry of Energy PJ = Petajoules; TOE = tons of oil equivalent; Ref.Fd = refined feedstock

Table 4.2. GHG emissions from biomass fuel consumption in Kenya (1990 – 1995)

Year	Biofuels	CH_4 Gg/Yr	CO Gg/Yr	N_2O Gg/Yr	NO_x Gg/Yr
1990	Fuel wood	121.309	1061.465	0.834	30.143
	Charcoal	4.475	335.575	0.264	9.529
1991	Fuel wood	126.349	1105.564	0.869	31.395
	Charcoal	4.659	349.435	0.275	9.923
1992	Fuel wood	131.629	1151.764	0.905	32.709
	Charcoal	4.853	363.995	0.286	10.337
1993	Fuel wood	137.117	1199.783	0.943	34.073
	Charcoal	5.057	379.255	0.299	10.771
1994	Fuel wood	142.876	1250.182	0.998	35.502
	Charcoal	5.268	395.074	0.311	11.221
1995	Fuel wood	148.876	1302.481	1.023	36.994
	Charcoal	5.489	411.734	0.324	11.694

** = t/t = tonne of pollutant per tonne of product*
*** = kg per hectalitre*
**** = hectalitres (quantity of measurement used for beverage)*

and between 20 – 250km/PJ (for storage tanks). An average of 880kg/PJ was calculated and used. Methane emissions in 1994 were only 0.076Gg/yr .

4.3.3 Emissions from Burning Traditional Biomass Fuels

Specific ratios of methane and CO to total carbon, N_2O, and NO_x were used to estimate trace gas emissions. Biomass fuel consumption estimates used were based on household surveys undertaken by the Ministry of Energy. The results of trace gas emissions are given in table 4.2.

4.3.4 Conclusion

The most significant GHG emitted from the energy sector in 1994 was CO_2, amounting to 4522.45 Gg. Emissions largely came from fossil fuel combustion. The other gases emitted were CO (1645.256 Gg), CH_4 (148.144 Gg), NO_x (46.723 Gg) and N_2O (1.309 Gg).

4.4 Industrial Processes

GHG emissions from industrial processes include those from cement production, Lime production, soda ash manufacture, and Non-Methyl volatile organic compounds. Their emission factors and estimated emissions are presented in table 4.3.

4.4.1 Carbon Dioxide Emissions from Cement Production

Carbon dioxide emissions were estimated by applying an emission factor (a constant), in tonnes of CO_2 released per tonne of clinker produced to the total amount of clinker produced. The emission factor that was locally derived has a value of 0.6121tCO_2/t clinker. Carbon dioxide emissions from cement manufacturing were estimated as 943.69 Gg of CO_2.

4.4.2 Carbon Dioxide Emissions from Lime Manufacture

Lime is used in pulp and paper industry, construction materials, effluent treatment, water softening, pH control and soil stabilization. Lime production involves three main processes: quarrying the raw materials, crushing and sizing, and calcining at high temperatures of around 1100°C to produce lime and calcium hydroxide. Carbon dioxide is generated during the calcination stage, when calcium carbonate or a combination of calcium carbonate materials is roasted at high temperatures. Carbon Dioxide is produced as a by-product of this process, just as CO_2 is released during clinker production.

An emission factor (EF Lime) of 0.79CO_2/t quicklime was used. This emission factor is for lime kiln-calcite

Table 4.3. Estimated emissions and emission factors for industrial processes

Sources and sink categories	Activity data A	Emission estimates B						Aggregate emission factors C					
	Production Quantity (kt) or hl	Full Mass of Pollutant (Gg)						Tonne of pollutant per tonne of Product (t/t) or kg/hl**					
	CO	CO_2	CH_4	N_2O	NO_x	NMVOC		CO	CO_2	CH_4	N_2O	NO_x	NMVOC
D Organic Chemicals													
Beer Production	3027000**					0.106							0.035
Spirits	16740**					0.251							15.0
Bread Making	156.27					1.25							0.008
Sugar Processing	3038.70					3.04							0.01
E Non-Metallic Mineral Products													
Cement	1541.72	943.69							0.6121				
Lime	30.47	24.07							0.79				
Soda Ash	224.20	21.75											
Pulp and Paper	364.80	2.043				0.55		1.35	0.0056			0.0015	0.0037

feed, which is the one used in this case since most of the lime in Kenya is calcite based. In 1994, 24070.510 tonnes equivalent to 24.07 Gg of CO_2 were emitted from the manufacture of 30469 tonnes of lime in Kenya (table 4.3).

4.4.3 Carbon Dioxide Emissions from Soda Ash Manufacture

Soda ash (sodium carbonate, Na_2CO_3) is a white crystalline solid that is readily soluble in water and is strongly alkaline. Commercial soda ash is used as raw material in a variety of industrial processes, including glass manufacture or simply as an alkali material, which reacts with, and neutralizes acids or acidic substances. Kenya produces only natural soda ash.

During the production process, trona (the principal ore from which natural soda ash is made) is calcined in a rotary kiln and chemically transformed into a crude soda ash that requires further processing. Carbon dioxide and water are generated as by-products of the calcination of trona.

The Central Bureau of Statistics reported that 224200 tonnes of trona were mined for soda ash production in 1994. Using an emission factor of 0.097 tonnes CO_2/tonne of trona, approximately 21747.40 tonnes or 21.75 Gg of carbon dioxide was emitted.

4.4.4 Emission of Non-Methane Volatile Organic Compounds

In the absence of locally derived emission factors, the emission factors in the EMEP/CORINAIR guidebook were used.

a) Emissions from pulp and paper manufacture came mainly from three major processing steps, namely: pulping, bleaching, and paper production. The type of pulping and the amount of bleaching used depend on the nature of the feedstock and the desired quality of the end product. The only plant producing paper uses the Kraft process. In 1994, 364800 tonnes of pulp was produced, which resulted in emission of 550.200t (0.55Gg), 1350.760t (1.35 Gg) and 2040.880t (2.043Gg) of NO_x, NMVOC and CO, respectively.

b) Emission data from food and beverages manufacture was only obtained for beer and spirits. In 1994, 3027000 hl of beer were produced contributing 0.106 Gg NMVOC to the atmosphere. For spirits 16740 hl were produced contributing 0.251 Gg of NMVOC to the atmosphere.

c) Emissions data for only sugar and bread were available from manufacturer of bread and other foods. The emission factor of sugar is 10 kg/tonne of sugar produced and that of bread is 8 kg/tonne of bread. Sugar production in 1994 was 303870 tonnes contributing 3.04 Gg of NMVOC. Bread production for the same period was 156270 tonnes contributing 1.25 Gg of NMVOC to the atmosphere.

4.5 Agriculture including Livestock Production

Agriculture is the main economic activity in Kenya upon which over 80% of the population directly depend for their livelihoods. Over 75% of this agriculture is mostly smallholder peasantry that is characterized by low farm inputs, low yields and low-level crop and land husbandry. Fertilizer usage is low, at an average of 25 kg per hectare. As a result, direct GHG emissions from soil at 0.000648 is quite insignificant hence is currently not a major concern in the inventories. Irrigation development remains low as it presently accounts for less than 3% of the country's agricultural produce. The study covered emissions from enteric fermentation in domestic livestock, animal wastes, flooded rice fields, burning of agricultural residues and use of nitrogenous fertilizers.

Agricultural statistics were obtained mainly from the Ministry of Agriculture and the Central Bureau of Statistics. The statistics for 1990 – 1994 had the following limitations:

a) National statistics for camel population are available only after 1993, consequently 1993 camel population were used; and

b) Upland rice production figures are available only after 1993. In this study the upland rice production has been assumed to be 10% of the total (which is the average for the period 1993 – 1995).

Table 4.4. Summary of emissions of gases from the agricultural sector for 1994 in Gg				
Sub-sector	Type of gases			
	CH_4	CO	N_2O	NO_x
Enteric Fermentation.	549.21			
Anima Wastes	23.42		0.036	
Rice Cultivation	3.0			
Burning of Agri. Resid.	0.0023	0.048	0.00010	0.0026
Synthetic Fertilizers			0.0006	
TOTAL	575.632	0.048	0.0367	0.0026

4.5.1 Methane Emissions from Enteric Fermentation and Wastes from Domestic Livestock

In Kenya, domestic livestock is mostly reared on the range and paddocks. Confinement in stalls is practiced in pig farming from which manure is often stored in solid form around stalls. Anaerobic lagoon systems for treating animal wastes are not practiced within the country. The GHG emissions from animal waste systems were negligible compared to that from enteric fermentation. Total CH_4 emissions from domestic livestock were estimated at 575.6 Gg for the year 1994. (Table 4.4).

4.5.2 Methane Emissions from Flooded Rice Fields

Anaerobic decomposition of organic matter in flooded rice fields produces methane, which escapes into the atmosphere. About 90% of rice grown in Kenya is paddy rice, which is grown under conditions of continuous flooding. However, at some 15,000 hectares, the acreage under rice in Kenya is small. Using IPCC methodology and default factors, total methane emission was 3 Gg in 1994 (table 4.4).

4.5.3 Emissions from Burning of Agricultural Residues

It is estimated that as much as 40% of agricultural residues produced in developing countries are burnt in the fields as a means of field clearing, a common practice in Kenya. However, some of the residues are removed and used as energy sources or as animal feed (e.g. maize cobs and stover, pigeon pea stems, etc.). Burning of these residues emits CO_2, CH_4 and N_2O. For Kenya, 25% is taken as the fraction of agricultural residue that is burned in the field for crops like rice, millet and sorghum, while 75% and 100% is the corresponding ratios for maize and sugar-cane respectively. The resulting emissions are in the range 0.0001-0.0023 Gg/year. The burning of agricultural residues is therefore not a major emitter of GHG in Kenya. According to IPCC guidelines an amount equal to the emissions is taken up by the crops that grow during the year.

4.5.4 Direct Nitrous Oxide Emissions from Agriculture

Only direct emissions of nitrous oxides due to the application of synthetic fertilizers whose statistics are available have been computed. The indirect emissions due to greenhouse farming, leaching into ground water and cultivation of organic soils have not been calculated, nor have the emissions from manure application or nitrogen due to biological fixation been considered. The computations show that the emissions from this agricultural sub-sector were insignificant at 0.000648Gg/year. This may be explained by the fact that fertilizer usage is low at an average 25kg/year/hectare.

4.6 Land Use, Land Use Change and Forestry

Land use change and forestry inventory used the 1996 IPCC guidelines. Unfortunately. the IPCC guidelines could not incorporate land users' data collection methods that are thought important and practicable in areas outside designated forests. The methodology adopted delineates appropriate emission and sink categories, describes the processes and identifies emission sources and sinks. The data was collected from the Forest Department, private sector, DRSRS, FAO, and IPCC documents. Average or IPCC default values were used to fill gaps.

They are few undisturbed primary forests in Kenya. Most indigenous vegetation has been altered through changes in land use and hence altering the forest cover. Changes in land use and alteration in forest has significant influence on GHG emissions because these activities lead to either retention or release of carbon as well as other elements. The extent to which these alterations have contributed to GHG emissions has not been fully established due to various uncertainties. GHG emissions associated with use change and forestry are carbon dioxide (CO_2) and non-carbon dioxide, nitrous oxides (N_2O), carbon monoxide (CO), methane (CH_4) and oxides of nitrogen (NO_x).

4.6.1 Emission and Sink Processes

a) The least amount of carbon is released from commercial harvests and plantations. The total wood consumed was 25,526ktdm giving an annual carbon dioxide released of 26,416,555Gg. Total carbon dioxide released as a result of on-site burning and decay of biomass, was estimated at 6404.34Gg.

b) In the sink process, non-forest trees have the highest carbon uptake followed by natural forests due to the very large area it covers, being 87850 and 3386 kha (kilo hectares) respectively. Their carbon uptakes were 17570 and 1281 kt respectively. However, plantation forests have the highest carbon uptake per unit kha at 5.910kt whereas non-forest trees have the lowest at 0.2kt per kha, while natural forests have carbon uptake of 0.378kt per kilo hectare (table 4.5).

c) The area of CO_2 sink was determined and quantified for naturally re-growing forests, plantations and non-forest trees for the first 20 years. It was found that the total carbon uptake from abandoned lands is 2,250ktC.

d) Abandoned managed lands have minimal carbon uptake because fallowing periods have reduced significantly over time. Abandoned managed forests covered an area of 225kha and the Carbon uptake was estimated at 8250KtC (Table 4.6). Biomass growth exceeds biomass harvests because of abandoned forests, which tend to increase biomass during growth. Carbon intake by abandoned managed lands is lower than carbon release making them a net absorber of GHG. Similarly, carbon intake by the vegetated lands is higher than carbon release hence there is a net absorption of carbon dioxide making Kenya a net CO_2 sink.

4.6.2 Non-Carbon Dioxide (Trace) Gases

Non-carbon dioxide gases (CH_4, CO, N_2O and NO_x) are released to the atmosphere as trace gases during forest clearing activities and subsequent burning of

Table 4.5. Sources and quantities of carbon sink in land use Kenya

Biomass type	Biomass area (kha)	Biomass uptake kt C	Carbon uptake per kha
Plantation	189.1	1117	5.91kt
Natural forest	3386.0	1281	0.38kt
Non-forest trees	87850	17570	0.20kt

Table 4.6. Net release of carbon dioxide

Carbon Activity	Uptake: Amount absorbed Gg CO_2	Carbon Activity Released Gg CO_2	Released Carbon Amount Released Net Gg CO_2
Annual growth	26416.555	Annual harvest	
Abandoned lands	8250	Forest conversion	6404.3357
Total	34666.555		

cleared biomass. They are also released as a result of changes in land use.

a) Methane (CH_4): Methane emission process involves anaerobic decomposition of vegetation, soil carbon and organic debris in a hydrological or other man-made water reservoirs during flooding. Methane sink process occurs during drainage and filling of wetlands. Methane emission and sink processes are difficult to assess because the emissions are highly variable and depend upon flooded ecosystem type and status; depth and length of flooding; and the rate of emission is controlled by temperature, seasonality or diurnal fluctuations. Methane uptake on the other hand, varies with soil water content and temperature. It is not clear if it is a significant process in Kenya.

b) Carbon Monoxide (CO): Carbon monoxide emission results from land flooding following construction of man-made reservoirs and aerobic decomposition of organic matter and vegetation accumulating at the bottom of reservoirs. Carbon monoxide is also emitted by dry soils during chemical decomposition of humus and by increases of soil temperature, moisture and pH. Wetlands therefore increase production of CO. Carbon monoxide destruction, however, outweighs production. Assessment is difficult and is of uncertain importance since CO eventually becomes CO_2. In Kenya, CO emission is considered to be insignificant.

c) Nitrous Oxide N_2O: IPCC describes emissions of N_2O as resulting from land flooding following construction of man-made dams for hydroelectric power. The flooding subsequently leads to anaerobic decomposition of vegetation and accumulated organic debris. IPCC recognises that net emissions of N_2O due to flooding are not well determined, difficult and of uncertain importance at global scale. In Kenya, they are also of uncertain importance since water bodies are not significantly many and data on extent of flooding is not available.

Natural dry land soils also emit N_2O during nitrification and denitrification process. A change in land use resulting from draining of wetlands increases emission possibilities. Again, the estimates are highly uncertain as emission measurements vary temporally and spatially. The measurements are not consistently correlated with soil temperature, moisture and vegetation composition and types. In Kenya wetland drainage is small.

4.6.3 Quantification of non-CO_2 Gases from Land Use Change

Data on the area of hydroelectric reserves and other man made reservoirs are not available, as are the number of days in a year that an area is flooded. The area of wetlands drained and the average daily CH_4, N_2O, CO emission rate before and after draining could not be obtained. Also the number of days in a year a wetland is emitting gases is not recorded. Default data are averaged growth rates for elements sited beyond territorial borders. They exhibit variability within regions and even from site to site. Future communications will attempt to quantify non-CO_2 gases from land-use change.

4.7 Waste Management

The main solid waste disposal method used in Kenya is open dumping. Some recycling is usually facilitated by uncontrolled scavenging. It is estimated that not more than 20% of solid waste generated in (large) urban areas is disposed off in the municipal solid waste disposal sites (SWDS). Such situation leads to aerobic decomposition with little methane (CH_4) emissions.

Total pollution was estimated by combining industrial and residential/commercial loads. Commercial and institutional loads were assumed to have been included in the non-industrial flows. There is little data on industrial sludge in Kenya. Wastewater is usually under the water and sanitation sections/departments where the main focus is on water management rather than wastewater management. The wastewater data consists of assessments of biochemical oxygen demand (BOD) and chemical oxygen demand (COD), which are not carried out on a consistent basis.

In rural areas, where settlements and/or homesteads are generally stand alones in agricultural areas. Refuse collection and disposal is informal and scattered. Wastewater treatment is virtually non-existent due to the predominant use of pit latrines, septic tanks and other informal methods of human waste disposal and the dispersed nature of settlements. For industries and institutions, a certain level of treatment is achieved. On the other hand, urban settlements are more nucleated with higher population concentrations. They therefore generate higher quantities of waste and have higher potential to generate greenhouse gases because of their concentration.

4.7.1 Emission of Methane from Solid Waste Management

Many urban centres in Kenya have established systems of waste management. The big towns on average have formal systems of municipal solid waste management and wastewater treatment. Most of these towns, however, predominantly use shallow, unmanaged and uncontrolled solid waste disposal sites (SWDS), which are neither covered nor compacted. The rate of generation of emission of methane gas (CH_4) from these sites is highly reduced due to the high rate of oxidation associated with their open nature. It was also observed that the existing solid waste management systems only covered small portions of urban areas. Most of the new and expanding residential and commercial sectors, and unplanned settlements are not served, while the main market areas are partially served, while.

This study considered only the wastes generated in urban areas. Waste generated in rural areas will be considered in subsequent communications.

4.7.2 Waste Water Handling

Water coverage in Kenya is estimated at 50% and 75% in the rural and urban areas respectively. Out of the 142-gazetted urban centres in Kenya, only 30% have sewerage systems with only 28% of them connected. Many of the systems suffer from constant breakage or leakage and inadequate capacity to handle their sewage load.

Many towns have anaerobic ponds, sewerage treatment systems with anaerobic treatment, and septic tanks. Most of these facilities however, serve relatively small sections of the central commercial zones and industrial areas as well as the high and medium income residential zones. Large sections of the towns, especially the unplanned informal residential zones do not have wastewater handling services.

The data required for estimation of GHG emissions in this sector include population covered, waste characteristics and handling. The total methane emission from the waste sector was estimated at 15.185 Gg.

4.8 Conclusions and Way Forward

The greatest problem encountered in developing the inventory of greenhouse gases included data unavailability or their unsuitability for inventories, particularly data on trends and rates of land use change. It was not possible to calculate carbon dioxide emissions from soils because of inadequate data and the high variability of soil carbon content. Available land use and forest data are in published literature, which all go to emphasize scientific and not traditional usage of forests. The GHG inventory was carried out under the UNDP/GEF funded project: Capacity Building to Sub-Sahara Africa to Respond to UNFCCC, did not take into account the great variations in climate, soils, topography, animals and crop species, especially at provincial and district levels. Most constraints and gaps identified were due to lack of comprehensive data storage and management systems on an annual basis, especially for industries. Additionally, there is lack of information on many newly introduced industrial processes. The quality of data and information reported can be improved if sufficient time and financial resources is allocated for studying these processes under local conditions and establishing empirical values of emission factors.

These difficulties as identified in the capacity building project still remain as they were not addressed in the current study.

This study showed that Kenya is a net absorber of carbon dioxide (absorbing about 22,751 Gg of CO_2 per year). However, the role of farmland trees in carbon sequestration has not been fully quantified. Consequently, there is need to harmonize land use and forestry activities in order to facilitate data inventory.

Carbon dioxide is the major greenhouse gas emitted mainly from the energy sector (Table 4.7). In 1994, the energy sector emitted 4522.45 Gg of CO_2. These emissions largely came from fossil fuels, particularly from the transport sector, which is the largest consumer of petroleum products. The other gases emitted were carbon monoxide and methane estimated at 1645.3 and 344.8 Gg respectively. Oxides of nitrogen (NO_X) and nitrous oxide (N_2O) accounted for 46.7 and 2.61 Gg respectively. Sugar production was the most significant emitter of NMVOC, accounting for about 70% of total NMVOC emitted in 1994, followed by pulp and paper industry (about 29%) and beer production (1% of the total). Carbon

Table 4.7: National greenhouse gases emissions by sources and removals (for all greenhouse gases not controlled by the Montreal Protocol).

Greenhouse Gas Source and Sink Category	Em. Factor	CO (Gg)	CO_2 (Gg)	CH_4	N_2O	NO_x	NMVOC
Total (Net) National Emission (Gigagram per year)		1656.8	-22751	750	1.4	50.9	6.0
1. Energy	**0.000001**	**1645.3**	**6167.3**	**344.8**	**2.61**	**46.7**	-
Fuel Combustion			4522	148	1.30		
Energy and transformation industries			-	-	-		
Industry			-	-	-		
Transport			-	-	-		
Commercial-institutional			-	-	-		
Residential			-	-	-		
Other (please specify) - Storage			-	0.8	-		
Biomass burned for energy							
- Fuelwood			1250.2	143	1.00	35.5	
- Charcoal			395.1	5.3	0.31	11.2	
Fugitive Fuel Emission			-	0.1	-		
Oil and natural gas system			-	0.1	-		
Coal mining			-	-	-		
2. Indusrial Processes	**45.3341**	**2.04**	**990.1**	-	-	**0.55**	**5.997**
Cement Production	0.6121		944.0	-	-	-	-
Lime Production	0.79		24.1	-	-	-	-
Soda Ash Production	0.097		22.0	-	-	-	-
Pulp and Paper - Kraft	1.5					0.55	
NO_x	3.7						1.35
Kraft NMVOC	5.6	2.04					
Alcoholic Drinks							
- Beer	0.035						0.106
- Spirits	15.0						0.251
Bread and Sugar Production							
- Bread	8.0						1.250
- Sugar	10.0						3.040
3. Agriculture		**0.048**	-	**575.632**	-	-	-
Enteric Fermentation	*1		-	549.21	-		-
Animal Wastes	*1			23.42			
Rice Cultivation	*1		-	3.0	-	-	
Burning of Crop Residues	*1	0.048		0.0023			
Savanna Burning	*1		-	-	-		
Others (please specify)	*1		-	-	-		
4. Land Use Change and Forestry		**9.4**	**- 28261**	**11**	**0.1**	**2.7**	-
Changes in Forest and other woody biomass stock			+26417				
Forest and Grassland Conversion			+6406	11	0.1		
Abandonment of Managed Lands			-8250	-	-		
5. Wastes			-	**15.185**	-	-	-
Solid Waste Management				6.745			
Wastewater and Sludge Treament				8.440			

(+) Before a number means Convert to CO_2 Annual Emission (-) Means a Removal of CO_2 or a Sink

*[*1] The Emission factors are provided elsewhere Annex 1.*

dioxide (CO_2) emission during cement production processes represented the most significant non-energy source, being 944.0 Gg of CO_2 (95.3% of industrial carbon dioxide emissions) in 1994. Lime and soda ash production emitted 24.1 and 22.0 Gg respectively. Land use change and forestry absorbed from the atmosphere 28261 Gg of CO_2 making Kenya a net sink of CO_2. Significant emissions of nitrous oxides and oxides of nitrogen (NO_x) were from burning of biomass energy and pulp and paper industry. The greatest proportions of NMVOC were emitted from food and beverage production and some proportion from pulp and paper production. Carbon monoxide emission from pulp and paper production was 2.04 Gg in 1994. About 95.6 (573 Gg) of CH_4 emission was from enteric fermentation in herbivorous animals.

The country urgently needs to have a programme to collect and analyses data regularly in all the five sectors, especially land use, forestry, agriculture and industry. It will also be necessary to build capacity of the national focal point as well as those of local authorities to collect and store data from the various sectors of the economy, especially baseline data. Further, there is need to develop and use national/ regional emission factors that suit national circumstances better than IPCC default emission factors. The national focal point should, therefore develop an information management systems for archiving and updating inventory data. This will require acquisition of computing facilities using IPCC software and harmonization of data collection and storage and up dating of GHG emissions. Its establishment should be preceded by a detailed and systematic needs assessment exercise.

Research efforts will be used to identify other potential sinks of carbon dioxide such as coffee, tea, coconuts and cashew nuts that are excluded in the IPCC methodology. This is because Kenya has large areas under these crops that are major sinks of greenhouse gases. Efforts will be expanded to develop a more comprehensive list of data sources for the industrial sector, including medium and small-scale industries.

A deliberate effort needs to be made to build capacity and create awareness in data collection, data storage, data management and data availability. Data sources should be identified by the type of GHG, amount emitted, emission processes and/or their potential to emit GHG. The inventories should ensure data quality through verification and validation, and establishment of some confidence levels.

There is need to build the institutional capacity to carry out research and training on climate change issues in support of the preparation and reporting of national GHG inventory.

4

5. CLIMATE CHANGE IMPACTS/ VULNERABILITY ASSESSMENTS AND ADAPTATION OPTIONS

5.1 Introduction

In its Third Assessment Report released in 2001, the Inter-governmental Panel on Climate Change predicts that in the 21st Century, climate change has potential to cause impacts at continental and global scale with developing countries being the most vulnerable.

Kenya's policies for the various ecosystems management have not been adjusted to incorporate climate variability. The recent droughts (e.g. 1984, 1990, 1994, and 1999) and the *El Ninõ* floods (1997/1998) resulted in huge losses in resources, e.g., livestock, biodiversity, and human as well as infrastructural facilities. The costs/losses in terms of human life and capital clearly demonstrate vulnerability of Kenya's terrestrial ecosystems to climatic variations, extreme events and by extension climate change. The major challenge therefore remains that of identifying opportunities that facilitate sustainable development by making use of, and improving existing technologies, and developing policies that make climate sensitive sectors resilient to current climate variability. This will require access to appropriate technologies, information, and adequate funds.

This initial national communication considered impacts/vulnerability and adaptation options in the following sectors: agriculture, water resources, aquatic and coastal resources, human health, terrestrial ecosystems, human settlements, and energy. Given in this chapter are a summary of the results of the assessments.

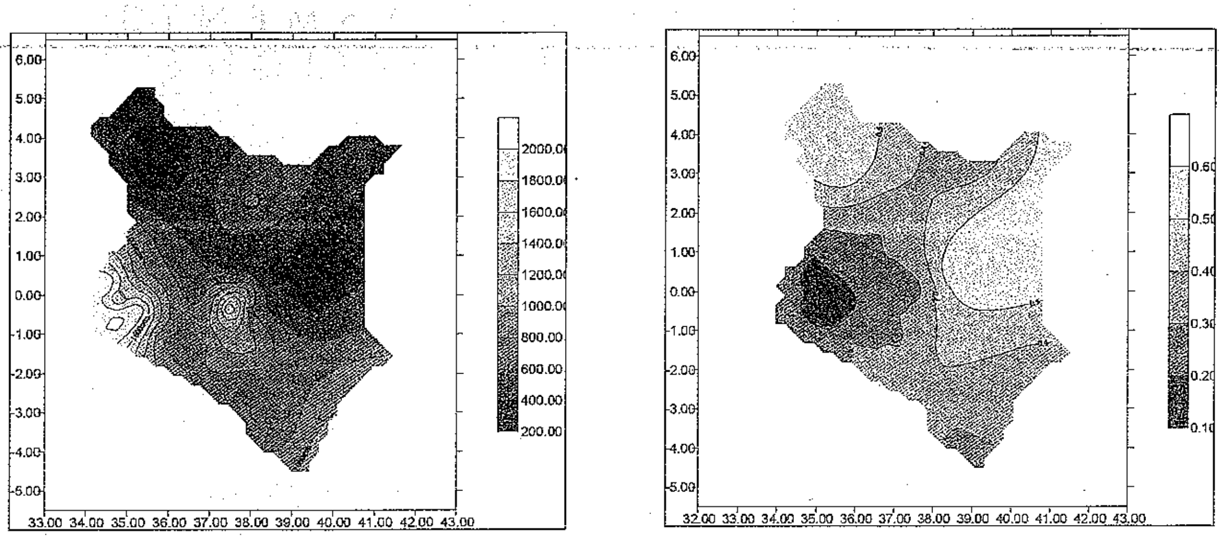
5.1.1 Climatic Patterns of Kenya

The space-time patterns of climate over Kenya is quite complex due to the existence of complex topography and many large inland water bodies, including Lake Victoria, which is one of the largest lakes in the world. Rainfall is the major climate parameter with the highest degree of space-time variability over Kenya. Temperature stresses are also significant over the highlands, in the arid and semi-arid zones, and near the large water bodies. The two seasonal rainfall peaks: March-May and October-November are associated with the passage of the inter tropical convergence zone (ITCZ).

The natural systems that control the space-time patterns of climate over Kenya have been identified as the inter-tropical convergence zone, moonsonal wind systems, the African sub-tropical anticyclones, tropical cyclone activities over the neighbouring regions, easterly/westerly waves perturbations, extra-tropical weather systems, teleconnections with quasi-biennial oscillation, intra-seasonal waves, El-Nino/Southern Oscillation and thermally induced meso-scale systems associated with complex topography and the large water bodies.

Future climate changes are likely to be reflected in space-time changes in the patterns of one or more of these climate-controlling systems. The climate of Kenya is controlled by the seasonal northward and southward movement of the inter-tropical convergence zone (ITCZ). The influence of the ITCZ is then greatly modified by differences in altitude (topographic) within the country leading to regionally

Figure 5.1: Distribution of mean annual rainfall and the coefficient of variation of annual rainfall in Kenya.



varied climate. Generally, there is no appreciable change in mean temperature throughout the year, but there is a considerable variation in temperature geographically, diurnally and seasonally due to altitude. Over two-thirds of the country receives less than 500mm of rainfall per year and 79% has less then 700mm annually. Only 11% of the country receives more than 1000mm per year. Figure 5.1 shows both the spatial distribution of the mean annual rainfall and the coefficient of variability of the annual rainfall in Kenya.

The mean annual rainfall shows a wide spatial variation, ranging from about 200mm in the driest areas in northwestern and eastern parts of Kenya to the wetter areas with rainfall of 1200-2000 mm in areas bordering Lake Victoria and central highlands east of the Rift Valley. The spatial distribution of the coefficient of variation depicts higher values in areas with larger year-to-year rainfall variability indicating low rainfall reliability. Areas with low year-to-year rainfall variability have high rainfall reliability and will generally show low coefficient of variation. Such areas are characterised by a low incidence of droughts and high rainfall predictability potential. Mean annual evaporation from free water surfaces in Kenya range from 1250 to 3120mm with a few areas having rates below 1200mm.

Natural disasters seem to be an integral part of the Kenyan climate. Both droughts and floods occur as periodic episodes caused by anomalies in rainfall patterns. Serious droughts have occurred at least 13 times in the past 50 years, including the 1999 – 2000 drought. Major floods that periodically afflict the Winam Gulf of the Lake Victoria, the Lower Tana basin and the coastal region have occurred at least six times in the same period. Until recently, such episodes were assumed to represent natural fluctuations in global climate. However, the observation that concentrations of GHG have been increasing rapidly, mainly due to human activities, has led to the realization that changes in atmospheric composition are capable of affecting the surface climate of the earth with possible consequences on our natural resources.

5.1.2 Climate Change Signals in Kenya

Climate change studies in Kenya have been limited by inadequate data, especially poor data observation network, relatively short duration of the available climate records, missing values in the available records, changes in instrument site, type, routines, etc. These problems pose serious challenge to efforts to detect and attribute climate change signals. Most studies of climate change signals were based on instrumental rainfall and temperature records. Climate change detection and attribution in Kenya have largely been based on statistical analyses of past trends in the climatic parameters such as rainfall, temperature, stream flow, lake levels, mountain glaciers and paleo-climatological records.

Analysis of annual and seasonal rainfall trends over Kenya have indicated recurrences of below/above normal precipitation in association with anomalies in the large-scale patterns of the climate system. The analysis of annual rainfall series in Kenya based on instrumental records showed that Kenya was mostly characterised by dry conditions in the 1950s and early 1970s, while the wet conditions occurred in early 1960s and late 1980s.

Most lake levels rose significantly during the high precipitation of the 1960s. The rainfall totals for a 36-months period ending 1964 was 140% that of the average for 1931 – 1960. Figures 5.2 (a-d) show variations of mean annual rainfall over some four stations in Kenya. Mean annual rainfall show a decreasing trend for Marsabit and Moyale (inland stations), while the opposite is true for Voi and Lamu (coastal stations).

Figures 5.3(a) and 5.3(b) show distribution of minimum and maximum temperatures over Kenya in which low temperatures occur over highlands east of the rift valley.

A climatic variable, which showed drastic decrease in recent years, is the volume and extent of the Mt. Kenya glaciers. The Lewis glacier on Mt. Kenya has lost 40% of its mass since 1963. In general, Mt. Kenya has lost 92% of its mass in the last century. Lake/sea levels are normally good indicators of climate change. Some changes have been discernible in lake levels over East Africa, especially in the last few

Figure 5.2(a): Variation of the mean annual rainfall and trend for Marsabit

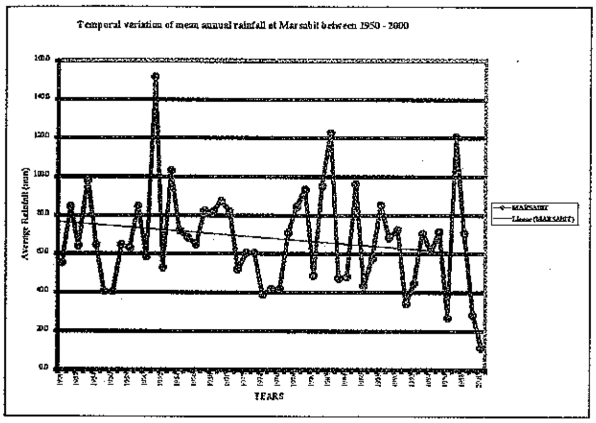


Figure 5.2(b): Variation of the mean annual rainfall and trend for Moyale

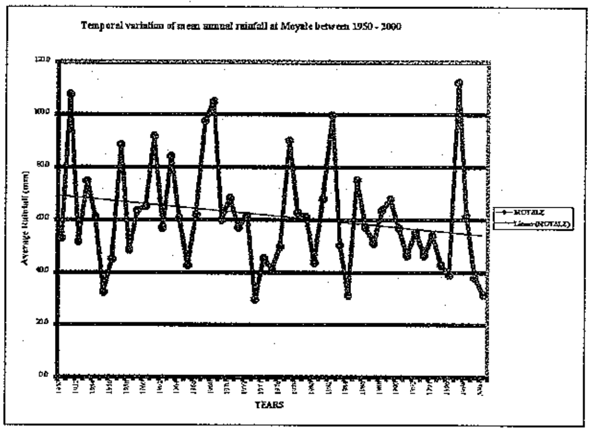


Figure 5.2(c): Variation of the mean annual rainfall and trend for Voi

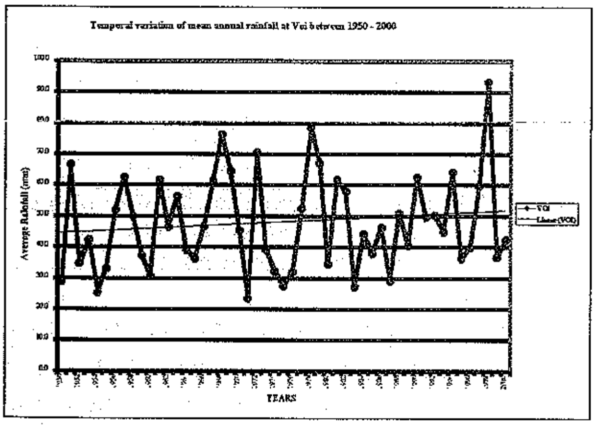


Figure 5.2(d): Variation of the mean annual rainfall and trend for Lamu

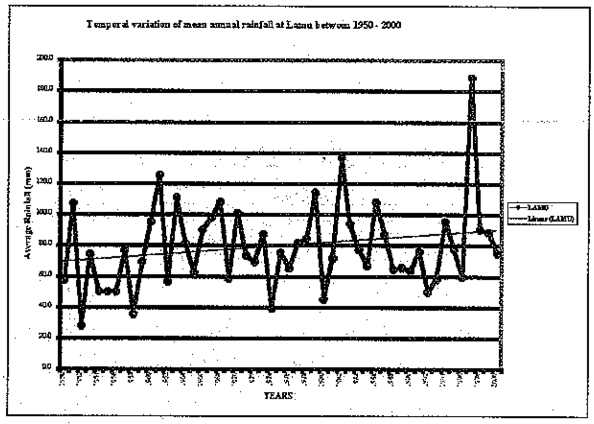


Figure 5.3(a): Distribution of Minimum Temperatures over Kenya

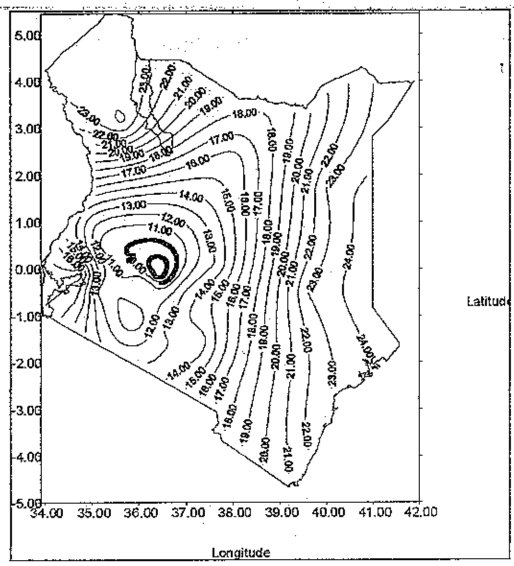


Figure 5.3(b): Distribution of Maximum Temperatures over Kenya

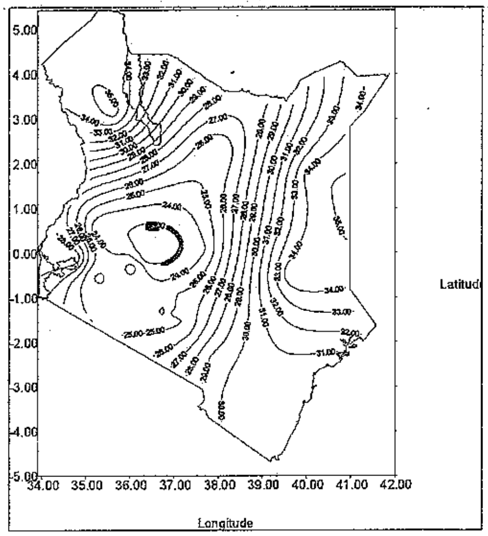


Figure 5.4(a): Distribution of mean annual rainfall over Kenya

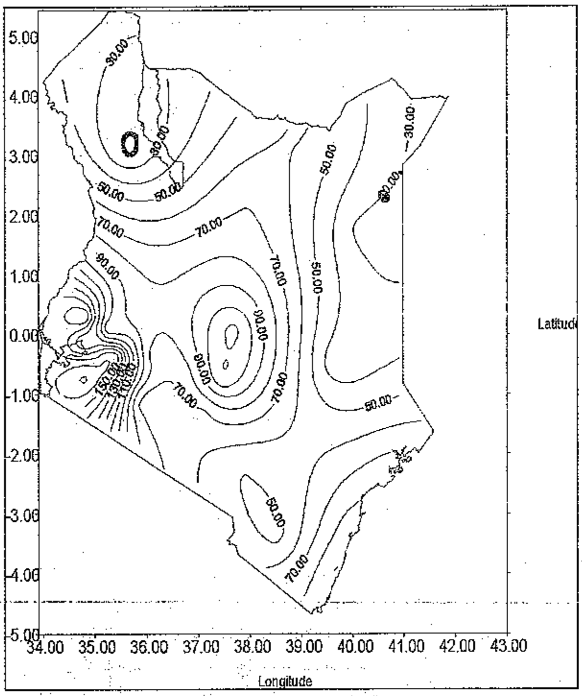
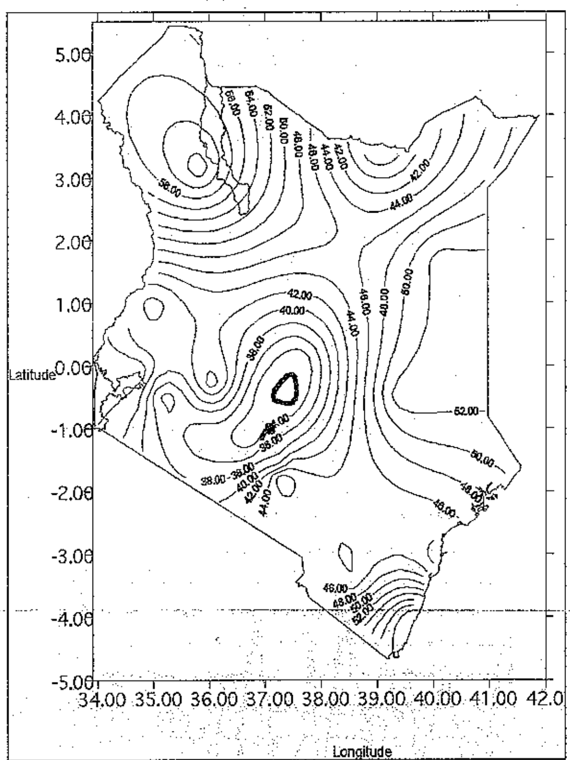


Figure 5.4(b): Distribution of Potential Evapotranspiration in Kenya



decades. For instance, Lake Victoria reached its lowest level in 1922, while Lake Naivasha showed a very sharp and sustained decrease after 1938. The sharp increase in rainfall in the 1960s significantly raised the lake levels by as much as 2.2m for Lake Victoria, 2.3 for Lake Nakuru, while Lake Turkana rose by about 4m.

Figure 5.4(a) presents the distribution of the mean annual rainfall over Kenya, while figure 5.4b present the distribution of the mean annual potential evapotranspiration over Kenya.

5.1.3 Baseline Climatological Records

A 30-year "normal" period of continuous recent climate data (e.g 1961-1990) is widely used for creating a baseline climate. This period is deemed to likely contain wet, dry, warm, and cool periods and is therefore considered to be sufficiently long to define a region's climate. This period had a more extensive network of observing stations and recorded more variables than earlier periods. However, the 1980s were, globally, the warmest decade this century, although in some regions the 1980s were not warmer than earlier decades. The period could, therefore introduce a warming trend into the baseline, which could bias the results of some impact assessments, particularly transient assessments that combine observed baseline climate with an underlying trend in climate variables.

5.1.4 Climate Change Scenarios Used Over Kenya

A number of GCM models were used to develop climate change scenarios (table 5.1). All models indicated increasing temperature changes at all locations with the doubling of carbon dioxide (table 5.1). Increases varied significantly not only from month to month, but also from location to location. The increases ranged from 0.5 to 3°C. Two GCMs namely, CCCM and GFDL3 were found to give reasonable results for the various locations in Kenya. Both models indicated increasing temperature trend with a maximum of about 3°C with the doubling of CO_2. A maximum change in rainfall of about 20% was observed. Table 5.2 presents the range of climate change scenarios used in the sectoral studies.

Table 5.1: The GCMs available for Climate Change Study

Climate Model	Model Resolution (Latitude - Longitude)		Levels	Temp. Change (°C)
GISS 1	7.83	10.0	9	4.2
GISS 2	3.90	5.00	12-18	-
GFDL 1	2.22	3.75	9	4.0
GFDL 2	2.22	3.75	14	3.2
UKMO 1	2.50	3.75	11	3.5
NCAR T42	2.81	2.81	18	-
CCC T32	3.75	3.75	10	3.5
GERMAN 1	5.63	5.63	19	2.6
UKMO 2	2.50	3.80	19	2.70
GERMAN 2	5.60	5.60	19	2.6
GDFL 3	4.44	7.50	9	4.0

Notation: ***GISS*** - *GORDAD Institute for Space Science*
UKMO - UK met Office
CCC - Canadian Climate Model
GDFL - Geophysical Fluid Dynamics Laboratory
NCAR - National Center for Atmospheric Research

Table 5.2. Range of climate change scenarios used in other sectoral studies

Variable	Climate change signal range
Temperature (°C)	-3.0 to 3.0
Rainfall (%)	-20 to 20

GCM-based future annual rainfall scenarios over Kenya for the year 2030 using the Canadian Climate Center Model (CCCM) is shown in figure 5.4(c). The GCM-based annual and seasonal rainfall scenarios seem to be controlled more strongly by large-scale mean earth-atmosphere-oceans causative factors.

The annual GCM rainfall projections in the region show that the region extending from Lake Victoria to the central highlands east of the Rift Valley will experience mild increases in the annual rainfall. The remainder of the country is expected to receive reduced annual rainfall amounts. The highest increments of the annual rainfall are seen in the vicinity of Mt. Elgon region.

The spatial patterns of the trend-based mean annual rainfall projections for the year 2030 show a strong spatial variability with no clear resemblance to the corresponding GCM-based projections in the region (figure 5.4(d)). The trend-based annual rainfall scenarios seem to be controlled mainly by local land-atmosphere causative factors.

Figure 5.4(c): GCM-based annual rainfall scenarios for the year 2030, expressed as percent increment of the annual rainfall above/below the 1990 baseline values

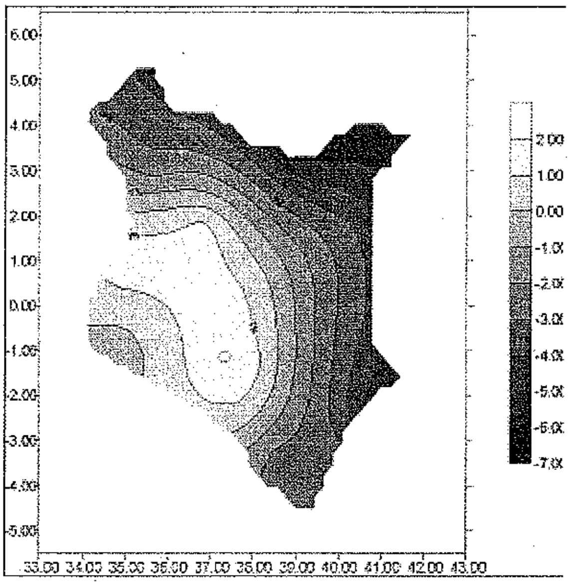
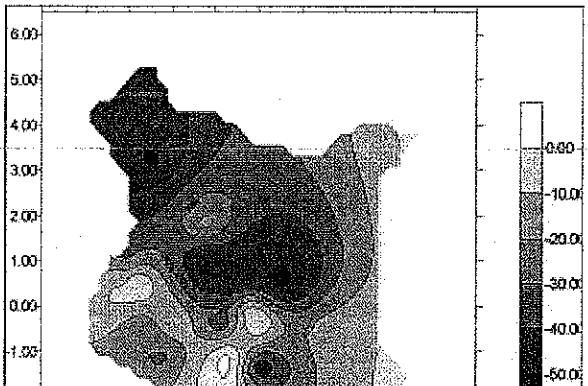


Figure 5.4(d): Trend-based annual rainfall scenarios for the year 2030, expressed as percent increment of the annual rainfall above/below the 1990 baseline values



5.2 Agricultural Sector

5.2.1 Introduction

Agriculture includes crop cultivation/farming, livestock farming and ranching, fishing and forestry. High to medium potential agricultural land forms 18% of the total land area of Kenya. About 60 % of this high and medium potential land is devoted to arable crops (maize, coffee, tea, horticulture, etc.) and livestock production. The rest of the land, which is classified as having low potential, is used for extensive livestock production, ranching and pastoralism and wild game in national parks and game reserves.

Agriculture accounts for over 60% of foreign exchange earnings and provides raw materials for Kenya's agro-industries, which account for about 70% of all national industrial production. Over 50% of export revenue is derived from primary agricultural products, notably tea, coffee, sisal, pyrethrum, sugar cane, wheat, and cotton. Exports of fruit, flowers, and vegetables also contribute to foreign exchange earnings. The primary food crops are maize, beans, cassava, potatoes and sorghum. In pastoral communities, livestock serve a multitude of purposes for their owners: transportation, milk, blood, meat, and wool or hair.

Kenya has varied land tenure systems ranging from freehold, leasehold to communal ownership. The farm sizes have been declining due to sub-division creating small uneconomic units.

There have been a number of significant changes in government policies governing land ownership since independence that have affected agriculture. Today, Kenya recognizes three broad types of land tenure: government land, trust land, and private land. Trust land makes up 73% of the total land area. The rights to make use of trust lands are held by individual families, but disposal rights are held by communities, whose elders must approve inheritance. Trust lands are gradually being converted into freehold lands under an adjudication and registration programme introduced in 1956.

There are on-going agricultural reform programmes geared towards a liberalized agricultural sector. These programmes are, however, hampered by poor support services.

Kenya is divided into seven agro-climatic zones using a moisture index based on annual rainfall expressed as a percentage of potential evaporation. Areas with an index greater than 50% have high potential for cropping, and are designated zones I, II, and III. These zones account for 12% of Kenya's land area. The semi-humid to arid regions (zones IV,V,VI, and VII) have indexes of less than 50% and a mean annual rainfall of less than 1100 mm. These zones are generally referred to as the Kenyan rangelands and account for 88% of the land area.

The seven agro-climatic zones are each sub-divided according to mean annual temperature to identify areas suitable for growing each of Kenya's major food and cash crops. Most of the high potential land areas are located above 1200 m above sea level and have mean annual temperatures of below 18° C, while 90% of the semi-arid and arid zones lies below 1260 m and has mean annual temperatures ranging from 10°C to 34.6°C.

5.2.2 Baseline Situation

Agriculture contributed 24.5% of real GDP in 1999 compared with 24.6% in 1998. Growth in agriculture was 1.2% in 1999 down from 1.5% in 1998. Growth in agriculture is estimated to have declined further to -2.4% in year 2000. The slowdown in growth of the agricultural sector in 1999 reflected structural bottlenecks on production and marketing, including poor infrastructure, low commodity prices, inadequate rainfall, particularly in major food crop areas, high cost of inputs and inefficiency in major marketing organisations.

5.2.2.1 Crop Production

a) Maize Production: Maize is the staple food for over 90% of Kenya's population, providing about 42% of the dietary energy intake. Over 1 million hectares of the crop are grown. About 70% of the crop is produced by small-scale farmers for subsistence. Large-scale farming of maize is practiced in parts of the Rift Valley.

b) Dry Bean Production: Grain legumes (pulses) are second only to maize in importance. Legumes are an important source of protein; they rank third after maize and milk. Beans are also important export crops. In 1990, beans (snap bean) comprised about 33% by volume and 25% by value of Kenya's horticultural exports. Production of beans in Kenya extends from high potential areas, which receive more than 1000 mm of rainfall to less than 700 mm of rainfall. Production is mainly by small-scale farmers, inter-cropped with maize, with little or no fertilizer application.

c) Coffee Production: Coffee is an important cash crop and a leading foreign exchange earner. It grows at altitudes between 1400m and 1800m above mean sea level. Production has been declining from 1,810,000 (60kg bags) in 1995/96 to 917,000 (60 kg bags) in 1998/99. The fall in production was due to unusually heavy rains caused by El Nino. The weather resulted in abnormal coffee tree flowering and cherry setting.

d) Tea Production: The Kenyan tea industry is made up of two distinct sectors: plantations and smallholders. Smallholders account for about half the total tea produced in the country. Currently, tea is the most important export crop. It grows best in humid wet climates with minimum and maximum temperatures of 13°C and 30° C, respectively. Production of tea declined by 15.5% from 294,200 tonnes in 1998 to 248,700 tonnes in 1999. The decline was attributed to lower precipitation in 1999, compared to 1998 when the El-Nino rains were experienced.

e) Sugar cane Production: Over 108,000 ha of land is under commercial sugarcane cultivation and produces an annual average of over 5.3 million tonnes of cane Production declined from 4.7 million tonnes in 1998 to 4.4 million tonnes in 1999. In contrast, sugar production went up by 4.7% in 1999 compared to 1998. Improved sugar production, despite less cane delivered, was attributed to improved sugar recovery from the cane due to the use of improved sugar varieties, improved cane husbandry, rehabilitation of sugar factories coupled with improved extension services.

f) Horticulture: In the period 1980-1991, exports of fresh fruits and vegetables trebled in volume from about 10,000 to 33,000 tonnes, while exports of cut flowers increased from 3,500 to 16,000 tonnes. By 1992 horticultural products, both fresh and processed were second to tea overtaking coffee in terms of export value. The horticultural sub-sector has continued to grow and is now the second leading foreign exchange earner after tea.

5.2.2.2. Irrigation

There are seven public owned and several individual irrigation schemes in Kenya. The crops grown under irrigation include rice, cotton, coffee, cut flowers, watermelon, onions, maize, beans, vegetables, paw-paw and chilies. Total paddy production from Mwea, Ahero, West Kano and Bunyala was 26,528 tonnes in 1994/95 and increased to 36,525 tonnes in 1998/99. Mwea paddy production was by far the most important – being 24,892 tonnes in 1994/95 and 31,876 tonnes in 1998/99. All the irrigation schemes recorded increases in paddy production in 1998/99 compared to 1997/98. Ahero recorded the highest (89.7%) followed by Mwea (49.3%). At Perkerra irrigation scheme, onion production increased by 85.4% in 1998/99 compared to 1997/98.

5.2.2.3 Livestock Production

Livestock contributes about 26% of the total national agricultural production. The total national cattle herd is about 12 million. Dairy cattle population is about 3 million, 40% of which are pure breed while 60% are crossbreeds. Dairy cattle are kept in areas receiving 800-1000 mm of rainfall per annum.

There are about 8.5 million head of beef cattle producing about 120,000 tonnes of beef per year, of which 50-60% come from the smallholder sector. Production has varied between 230,000 and 270,000 tonnes of beef and veal and between 2.2 and 2.5 million metric tonnes of milk in 1991 and 1997, respectively. Cattle are concentrated in medium to low potential areas where approximately 7 million sheep, 9.6 million goats and several thousand camels are also raised.

The livestock sub-sector is faced with various constraints. Smallholder farmers have limited access to credit. There is limited application of research findings because of the costs of adopting the new techniques. Currently, the primary objective is to promote increased investment in the livestock sub-sector, to ensure domestic self-sufficiency in livestock products and for export. Government efforts include provision of infrastructure, construction of cattle dips, sinking of boreholes, support for research and extension and development of markets.

Poor livestock nutrition is one of the most important constraints on increased livestock production, especially during dry season when forage quality and quantity is low. In this period, water is also limiting because most springs are seasonal. This affects all livestock feeding systems including cut and carry, tethered or free grazing systems. In beef production systems, over-stocking leads to over-grazing and land degradation especially in communal pastures. In many livestock systems, poor breeding results from inadequate artificial insemination (AI) and lack of improved breeding bulls. This is worsened by high calf mortality, long calving intervals and mastitis. Other constraints include diseases transmitted by ticks and tsetse flies, viral diseases, bacterial diseases, *endoparasites* and wildlife derived diseases, as over 70% of Kenya's wild game is found in range areas outside the national parks. Technologies on proper livestock management, disease control, production and livestock nutrition have been developed and are being extended to farmers by extension officers, in order to improve farmers' awareness and management skills.

5.2.3 Vulnerability and Impact Assessment

5.2.3.1. Climate Change Scenarios

GCMs studies projected for 2030 indicated that temperatures will increase at various locations in the country, with the doubling of carbon dioxide. The observed increase varied significantly not only from month to month, but also from location to location. The observed temperature increase ranged from 0.5 to 3°C. Some models had little temperature increase values above 3 °C at certain locations. Maximum change in rainfall was predicted at about 20%.

5.2.3.2 Impact Assessment

The most vulnerable areas to climate change are expected to be the arid and semi-arid lands (ASALs), where frequency and severity of both droughts and floods is expected to increase. In these areas, livestock production and subsistence farming are dominant and depend on rainfall. The major impact of drought on rural smallholders will be increased food insecurity: - food shortage, food poverty, and food deprivation.

a) Potential Impacts on Maize Production: Depending on planting dates, GCMs predicted, on average, an increase in grain yields by the year 2030. This is linked to the beneficial effects of increased carbon dioxide, and higher temperatures on the crop. From the climate change scenarios, positive shifts in rainfall are expected to occur in the months of January, March, May and September. The negative shifts in rainfall in the months of June and July would imply that earlier maturing maize varieties would be preferred.

b) Potential Impacts on Bean Production: The impact of climate change on bean yield was seen to vary significantly from one experimental site to another. High temperatures will encourage the bean crop to grow faster and reach maturation earlier. Consequently, the grain filling period will be shortened leading to substantial yield losses. The projected temperature increases will lead to increased potential evapotranspiration and loss of soil moisture. Therefore, although the two GCMs projected increases of precipitation, of up to 20% over the long rainy season, increase of available water to the crops might not be realized. Increase in rainfall in some regions may result in increased soil leaching and consequent reductions in fertility and crop yield.

c) Potential Impacts of Extreme Events: The overall adverse impacts of the extreme weather and climate events that could occur because of the projected climate change would be associated with mass migration, shortages of food, water and energy, famine, shortage of essential basic commodities, loss of life and property together with many other socio-economic disasters. It is therefore apparent that the space-time variability of rainfall could have far reaching socio-economic impacts in Kenya.

The two extreme climate events that would adversely impact on the agricultural sector are drought, which would result in crop water stress and hence yield reduction, and flooding resulting in water logging in both the ASALs and high potential areas. Detailed studies on the impacts of these extreme events on various crop varieties will be carried out. The impacts of these events need not be always negative. For example, during the excessive El-Nino rains of 1997/98, various positive and negative impacts were observed both in the crop and livestock sub-sectors. In the crop sub-sector, damage to food crops and some industrial crops, particularly coffee, occurred at different stages of growth in different regions of the country. In parts of western region, maize and wheat, which were already at maturity and harvesting stages, suffered due to rotting, molding and lack of proper sunshine.

In some parts of eastern region, food crops, which were at relatively younger stages of growth, suffered because of loss of nutrient, resulting from flooding, reduced soil temperatures, reduced sunshine hours, difficult weeding conditions, accelerated disease attack, particularly in legumes, and at much later stage, poor harvesting conditions.

In the Coast Province, El Nino rains continued into the normal long rains season of 1998, hampering farm operations and the performance of tree crops. Coffee performance on the other hand, was impaired by nutrient leaching and abnormal development of flowers, which led to decline in quality.

Irrigation systems in the country were also destroyed. Generally, there was extensive soil loss through erosion.

It was observed that production of some industrial crops improved during and immediately after El-Nino rains. For example, tea output went up by about 20% in 1997/98. In some agriculturally marginal areas of Eastern province, production of cereals, tubers and root crops were above average. El-Nino rains enhanced and prolonged the time and moisture availability for the biological soil and water conservation structures to take up. Tree planting was higher and survival rates generally increased to nearly 100%.

d) Impacts on Livestock:: Impacts on livestock during the 1997/98 El-Nino rains was mainly realised in arid and semi arid lands (ASALs) where livestock production is the predominant economic activity. Negative impacts on livestock and livestock infrastructure included:

i) Loss of livestock due to increased disease infection. Such diseases included east coast fever, pneumonia in calves and lambs, diarrhea, foot rot, contagious bovine pleura-pneumonia (CBPP) in cattle and contagious caprine pleura-pneumonia (CCPP) in goats. The diseases increased the cost of veterinary services and claimed lives of many animals.
ii) Loss of livestock, particularly small stock, due to drowning and starvation resulting from animals getting stuck in mud.
iii) Damage to livestock water facilities (dams, pans, boreholes, water troughs, crashes, etc).
iv) Loss of the young due to chilling effects.
v) Decline in body condition of livestock due to increased disease incidences.
vi) Disruption of livestock marketing services due to destroyed livestock marketing facilities (mainly holding grounds) and destroyed road network.
vii) After the El-Nino rains, the following were observed:

- Production of both fodder shrubs and

grasses improved tremendously. This resulted in improved livestock performance. Livestock prices went up due to favourable conditions. Water shortages, which is usually, a major problem in ASAL was for quite some time solved as water was available in excess quantities in most places.

- In medium and high agricultural potential zones, there was increased availability of pasture and other forage, which resulted in high milk production and improved livestock conditions.

With the predicted climate change scenarios, high frequency of flooding similar to that observed during the 1997-98 El Nino rains is expected and similar impacts in this sector as outlined above will be a common phenomena.

5.2.4 Adaptation Options

The predicted adverse impacts of climate change that could affect agricultural production in Kenya include droughts, floods, severe storms, hailstorms, frost and changes in soil structure. The following adaptations options have been proposed:

a) *Drought:* Introduction of drought-tolerant/ escaping crops irrigation and fertilizers; development of high yielding, more resistant, early maturing and disease and pest tolerant crops. Adaptation strategy will include disposing of stocks early before the onset of drought
b) *Floods* Introduction of flood control measures in the areas most prone; soil liming and application of organic fertilizers to mitigate soil leaching.
c) *Severe Storms and Hailstorms:* Planting of trees for windbreaks.
d) *Frost:* Protection methods, which modify the microclimate within the plant community, will be used. This will include the promotion of agro-forestry and application of mulching materials.
e) *Changes in Soil Structure:* Application of organic fertilizers, establishment of soil conservation structures and soil liming. Farmers will be discouraged from clearing vegetation on steep slopes and also in the ASAL.

5.2.5 Adaptation Strategies

Efforts will be made to:
a) Undertake studies on impacts of climate change on crop production, including a wider and closer network of experimental sites in each of the agro-ecological zones. Such studies will include the main food crops such as maize, potatoes, wheat, cassava, etc. and cash crops such as coffee, tea, cotton and sugar cane.
b) Undertake studies to determine appropriate planting dates in order to take advantage of moisture availability in a shortened crop-growing season.
c) Introduce drought-tolerant crops in regions where moisture is limiting.
d) Promote irrigation practices and use of fertilizer.
e) Develop crop varieties that are high yielding, more drought resistant, early maturing and disease and pest tolerant.
f) Compile and update data and information regularly including development of a database on on-going and past research on weather related activities.
g) Sensitize farmers and local leaders through extension services on implications of climate change, including the vulnerability of agriculture sector and the necessary adaptation strategies. On-farm demonstrations involving farmer participation will be intensified.

5.2.6 Conclusions

The major threats to Kenya as a result of climate change will be the increased frequency of drought, especially in the arid and semi-arid areas (ASALs). This will have significant implications on various sub sectors of agriculture and consequently the economy. The situation calls for development and implementation of strategies to mitigate the adverse impacts of climate change. Formulation of appropriate agricultural and livestock policies and action programmes will reduce vulnerability.

The government will support research, through increased budgetary allocations for development and promotion of drought tolerant crops. Development of irrigation systems to reduce susceptibility to drought will be given more attention by completing the formulation of the new national irrigation policy.

Priority will be given to development of smallholder irrigation schemes using both ground and surface water sources.

5.3 Water Resources

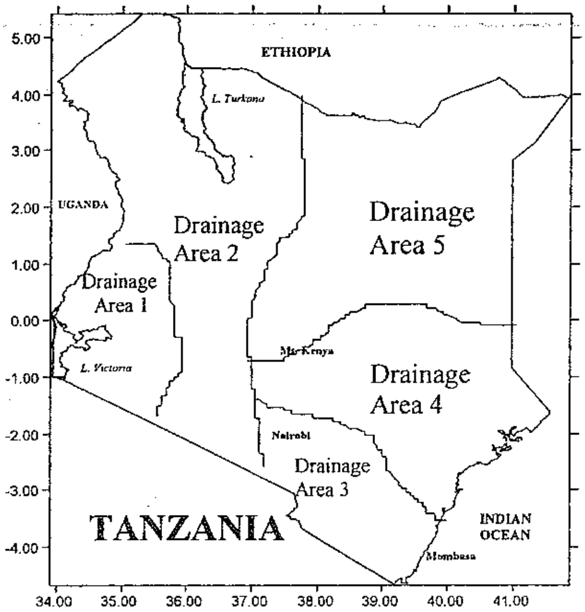
5.3.1 Introduction

Water is a basic need to all socio-economic developments and for maintaining healthy ecosystems. However, water availability is increasingly being limited by an ever-increasing demand, profligate use, and increased incidences of pollution.

There are several indicators of water resource stress, including the amount of water available per person and the ratio of the volume of water withdrawn to the volume of water potentially available. When withdrawals are between 20% and 40% of the total renewable resources, water stress is acknowledged to be a limiting factor on development. Withdrawals of 40% or more represent high stress. In 1990, approximately one third of the world's population lived in countries using more than 20% of their water resources, and by 2025 around 60% of a rather larger total (including Kenya), would be living in such stressed countries. Water stress is widely acknowledged to be a problem if a country or region has less than 1700 cubic metres /capita/year. Simple numerical indices, however, give only partial indications of water resources pressures in a country or region, as the consequences of "water stress" depend on how the water is managed.

Kenya is endowed with a large potential of water resources in terms of rainfall, groundwater, river flows, lakes and oceans. The surface water resources are contained within the five main drainage basins (figure 5.5). The hydrological characteristics of these basins are given in table 5.3.

Figure 5.5: Major drainage of Kenya



5.3.2 Climate Change Scenarios

Considerable effort has been expended to develop improved hydrological models for estimating the effects of climate change. Improved models have been developed to simulate water quantity and quality, with a focus on realistic representation of the physical processes involved. These models are often of general applicability, with no locally calibrated parameters, and are increasingly using remotely sensed data as input. Studies have also looked at the implications of parameter and model uncertainty on the estimated effects of climate change.

There have also been considerable advances in the understanding of the relationships between hydrological processes at the land surface and processes within the atmosphere above. These have largely come about through major field measurement

Table 5.3: Characteristics of the main drainage basins of Kenya

Drainage basin	Area (km^2)	Mean annual rainfall (mm)	Mean annual runoff (mm)	Climate
Lake Victoria (Area 1)	49,210	1000	270	Humid to sub-humid
Rift Valley (Area 2)	126,910	600	120	Arid to semi-arid
Athi River (Area 3)	69,930	650	200	Semi-arid
Tana River (Area 4)	132,090	520	170	Semi-humid (headlands), semi-arid to arid
Ewaso Nyiro (Area 5)	204,610	400	80	Arid to semi arid

and modeling projects in different geographical environments. The goal of such studies is improved assessments of the hydrological effects of climate change.

5.3.2.1 Influences of Rainfall on Water Resources

Rainfall is a major source of water in Kenya. Rainfall largely determines the extent of water availability in space and time. Changes in precipitation have far-reaching implications on hydrology and water resources. Flood freq uency is affected by changes in the year-to-year variability in precipitation, but also by changes in short-term rainfall properties (such as rainfall storm intensity). The frequency of low or drought flows are affected primarily by changes in the seasonal distribution of precipitation, year-to-year variability and the occurrence of prolonged droughts.

The mean annual rainfall over Kenya is estimated to be 621 mm, which is equivalent to about 360,000 million cubic meters of water. However, not all this amount of water is available for use. According to the National Water Master Plan of 1992, the national annual freshwater potential is estimated at about 20,000 million cubic meters, consisting of both surface (about 85%) and ground water (about 15%). This freshwater resource can sustain most of the demands of the whole population of Kenya. However, the poor distribution and unreliability of rainfall over most parts of Kenya results in water shortages, which frequently range from mild to severe, especially in the ASALs (figure 5.6).

Annual rainfall ranges from about 200mm in northwestern and eastern parts of Kenya to 1200-2000 mm in areas bordering Lake Victoria and central highlands east of the Rift Valley. The temporal variability is presented in terms of the spatial distribution of the coefficient of variation (Cv) given by the ratio (standard deviation to mean). The coefficient of variation is higher in areas over which there is a large year-to-year rainfall variability and therefore low rainfall reliability than over areas with a low year-to-year rainfall variability and therefore high rainfall reliability. Generally, areas of low rainfall reliability (high coefficient of variation) suffer form frequent droughts. On the other hand, areas of high rainfall reliability (low coefficient of variation) experience few incidences of drought.

The temporal rainfall variability is lowest in the more humid areas of the country. The highest annual rainfall variability is experienced in arid areas of northwestern and eastern Kenya. Moderate rainfall variability is experienced mainly in the semi-arid parts of Kenya.

The trends of the annual, March to May (MAM) and October to December (OND) rainfall time series vary in magnitude from one station to another. This spatial non-uniform trend for two typical stations is illustrated in figure 5.7. The distribution of annual and seasonal rainfall show that vast areas experience negative trends of differing magnitudes. Each zone has a unique trend pattern.

Figure 5.6: Distribution of mean annual rainfall and the coefficient of variation of annual rainfall in Kenya.

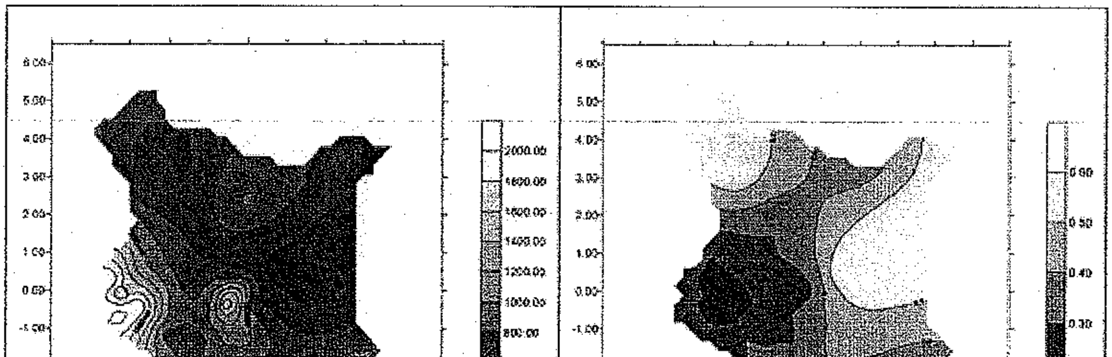
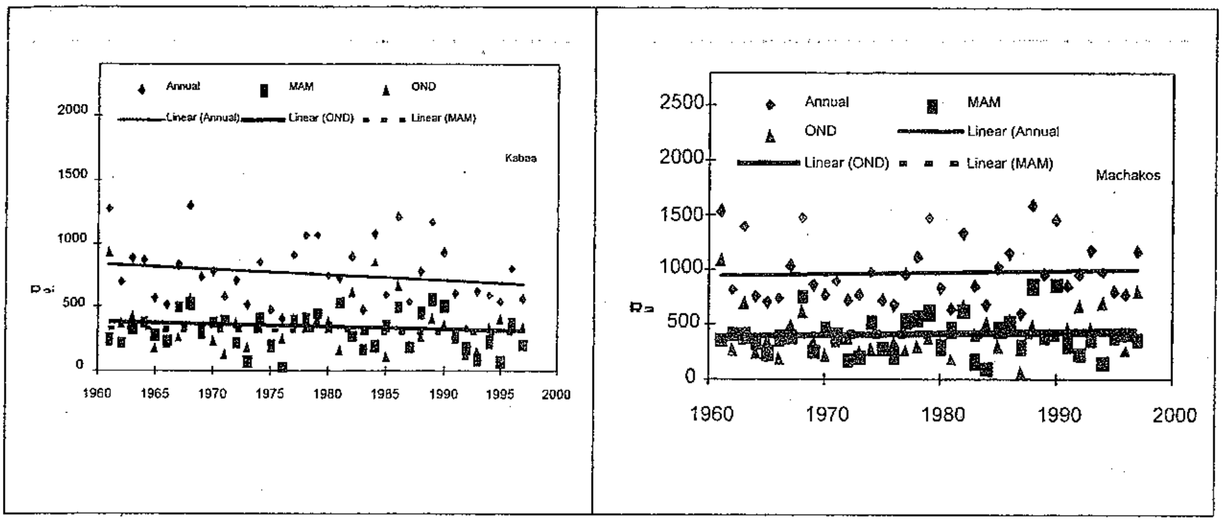


Figure 5.7: The annual and seasonal rainfall trend patterns for rainfall stations in the vicinity of Nairobi



5.3.2.2 Trend and GCM-Based Future Rainfall Scenarios

Figure 5.8 shows the spatial distribution of the GCM-based (using the Canadian Climate Center Model) annual rainfall scenarios in Kenya, for the year 2030. These GCM-based annual and seasonal rainfall scenarios seem to be controlled more strongly by large-scale mean earth-atmosphere-oceans causative factors.

The annual GCM rainfall projections in the region show not only the lowest magnitudes of the relative adjustments of the rainfall, but also relatively smooth spatial variability. These projections indicate that the region from Lake Victoria to the central highlands east of the Rift Valley will experience mild increases in annual rainfall. The rest of the country is expected to receive reduced annual rainfall amounts.

Figure 5.9 shows the real patterns of the trend-based mean annual rainfall projections for the year 2030. These patterns show a strong spatial variability with no clear resemblance to the corresponding GCM-based projections in the region. Unlike the case in the GCM-based projections, the trend-based annual rainfall scenarios seem to be controlled mainly by local land-atmosphere causative factors.

Figure 5.8: GCM-based annual rainfall scenarios for the year 2030, expressed as percent increment of the annual rainfall above/below the 1990 baseline values

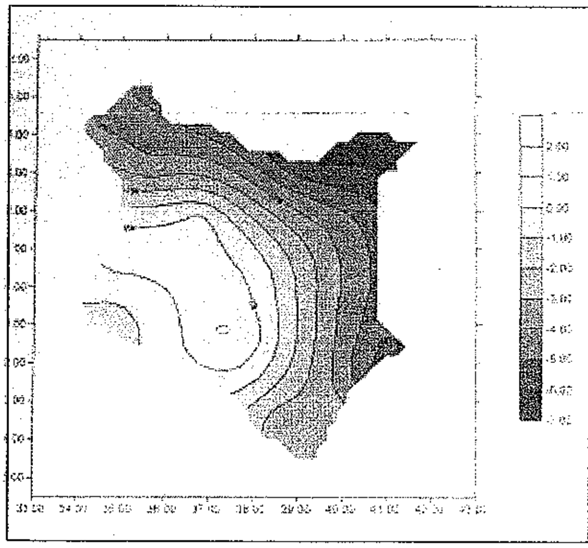
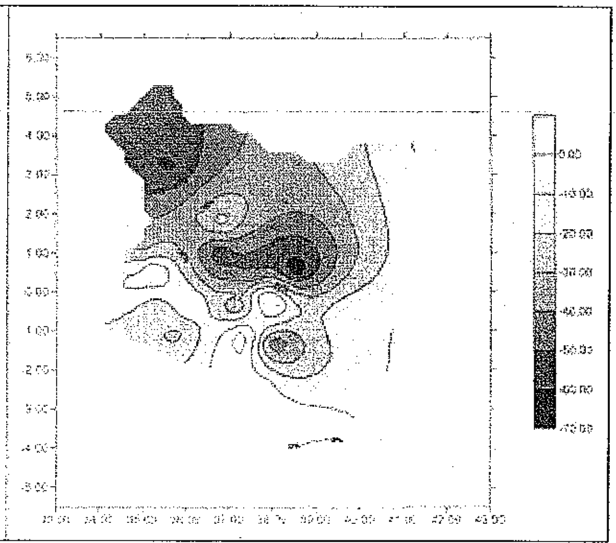


Figure 5.9: Trend-based annual rainfall scenarios for the year 2030, expressed as percent increment of the annual rainfall above/below the 1990 baseline values.



The spatial distribution patterns of the relative adjustments of the mean annual rainfall indicate that only a few areas in the country will experience positive adjustments. Such areas are found in the vicinity of the City of Nairobi only. All other parts of the country will experience negative mean annual rainfall adjustments with the lowest relative adjustments found in central and northwestern parts of Kenya.

5.3.2.3 Influence of Evaporation on Water Resources

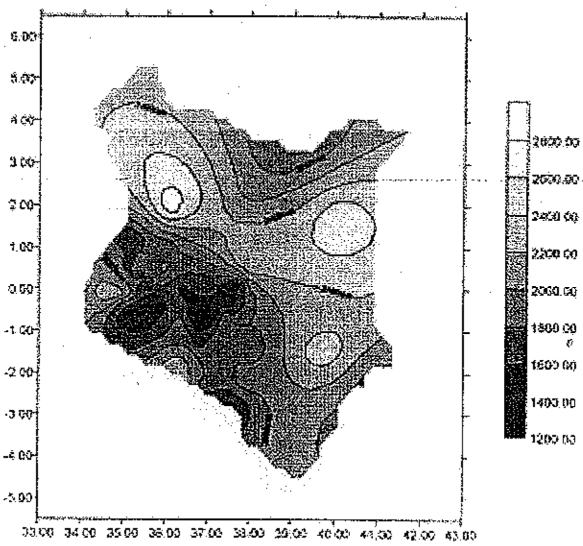
The rate of evaporation from the land surface is controlled by meteorological factors, and influenced by vegetation and soil characteristics, and amount of available water. Climate change has the potential to affect all these factors, in a combined way, which is not yet clearly understood.

The primary meteorological controls on the rate of evaporation are the amount of energy available (characterised by net radiation), the moisture content of the air (humidity: a function of water vapour content and air temperature), and the rate of movement of air across the surface (a function of wind speed). Increasing temperature generally results in an increase in evaporation, largely because the water-holding capacity of air is increased. Changes in the other meteorological controls may exaggerate or offset the rise in temperature. It is possible that increased water vapour content and lower net radiation could lead to lower evaporative demands. The relative importance of the different meteorological controls, however, varies geographically. In dry regions, for example, evaporation is driven by energy and not constrained by atmospheric moisture contents, so changes in humidity here are relatively unimportant. In humid regions, however, atmospheric moisture content is a major limitation to evaporation and changes in humidity here have a very big effect on the rate of evaporation.

Vegetation cover, type and properties play a very important role in evaporation. Interception of precipitation is greatly influenced by vegetation type (as indexed by the canopy storage capacity). Different vegetation types have different rates of transpiration and produce different amounts of turbulence above the canopy: the greater the turbulence, the greater the evaporation. A change in catchment vegetation - directly or indirectly due to climate change - may therefore affect the catchment water balance. A number of studies have assessed changes in biome type under climate change, but the hydrological effects of such changes - and indeed changes in agricultural land use - have not yet been explored.

Plant physiological properties are affected by the concentration of CO_2. Increased CO_2 concentrations reduce stomatal conductance in many plants, although the effects vary considerably between species. Plant water use efficiency (WUE) may therefore increase substantially implying a reduction in transpiration. However, higher CO_2 concentrations may also be associated with increased plant growth, compensating for the increased WUE, and plants may acclimatise to the higher CO_2 concentrations. Most empirical evidence so far is at the plant scale, and it is difficult to generalise to the catchment or regional scale. Free-air $C0_2$ enrichment (FACE) experiments, however, have allowed extrapolation at least to the 20m-plot scale. Experiments show no detectable change in water use per unit land area when $C0_2$ concentrations are increased to 55Oppmv, as the 40% increase in biomass offset the increased WUE. Experiments with wheat, however, indicated that increased growth did not offset increased WUE, and evaporation reduced by around 7% (although still less than implied by the change in stomatal conductance). High potential evapotranspiration values are observed in the hot and coincidentally dry areas of Kenya (figure 5.10).

Figure 5.10. Distribution of the mean annual potential evapotranspiration in Kenya



Globally, the potential evapotranspiration of the dry and hot regions, which are generally devoid of substantial cloud cover, will increase. This increased evaporative power will impact negatively on the limited water resources in such regions. Nevertheless, the increased cloud cover in the semi-humid and humid regions may moderate the greenhouse (induced) increased evaporative power. This therefore implies that the drier regions in Kenya may become drier and vice versa.

5.3.2.4 Influence of soil Moisture on Water Resources

The amount of water stored in the soil is fundamentally important to agriculture, and is also an influence on the rate of actual evaporation, groundwater recharge and the generation of runoff. Global climate models directly simulate soil moisture contents, albeit over a very coarse spatial resolution. Outputs from these models give an indication of possible directions of change. Doubling of CO_2 could reduce soil moisture in the arid and semi-arid lands, and increase soil moisture in the more moist areas. The local effects of climate change on soil moisture, however, will vary not only with the degree of climate change but also with soil properties. The water holding capacity of soil will affect possible changes in soil moisture deficits and the lower the capacity the greater the vulnerability to climate change. Climate change may also affect soil properties, perhaps through changes in water logging or cracking, which may in turn affect soil moisture storage properties. Notwithstanding, socio-economic factors may enhance or moderate the negative impacts of climate change in both the moist and dry areas of the country, mainly through land use and management practices which are prevalent in such areas.

Furthermore, during dry spells and with raised temperature, perched-aquifer can be depleted through capillarity effect. This usually leads to evaporation of water from perched aquifers, leaving salt precipitate on the soil surface. The salt precipitate increases salinity of the soil.

5.3.2.5 Groundwater Recharge and Resources

The potential of ground water in Kenya is extremely variable, both spatially and seasonally, in quality and quantity and the depth of the groundwater table. Recharge varies from about 5% in ASALs where evaporation losses are high to about 30% in areas of deep sandy soils and unconsolidated rocks where evaporation losses are low. In the humid and sub-humid regions where evapotranspiration losses are also low, the soils are fairly permeable and the slopes are low, the recharge rates are about 10%.

The highest groundwater capacities are found in the areas east of the central rift valley and around Lake Victoria and at the coastal strip with a maximum around the Malindi region and around Moyale and Mandera. Generally, the broad belt extending from north western to the central eastern parts of the country, are characterized by low groundwater storage capacities. The quality of the groundwater resources is generally influenced by the geological formations in which the aquifer occurs. In central and western Kenya, the water is generally soft with moderate alkalinity. Chemically, this water is satisfactory for domestic purposes. In most parts of the coast, eastern and north-eastern regions, the groundwater is generally saline and of poor quality. The major problems arise from salinity and high fluoride levels. In the case of fluoride, the concentration generally exceeds the WHO drinking water guidelines of a minimum concentration of 1.5 mg/l. However, the trend now is that the groundwater is being used extensively for irrigation, livestock and industrial purposes.

Deep aquifers are generally replenished by the excess of rainfall over evaporation. This water may reach the aquifer either rapidly through macro-pores or fissures, or more slowly by infiltrating through saturated soils overlying the aquifer. Recharge from saturated soils is, largely confined to those times of the year when soils are saturated. A change in the amount of effective rainfall will alter recharge, but so too will change in the duration of the recharge season. Decreased rainfall - as projected under most climate change scenarios in Kenya - is generally likely to result in decreased groundwater recharge. Further, higher evaporation may mean that water deficits persist for longer periods and commence earlier, offsetting an increase in total effective rainfall. Macro-pore and fissure recharge is most common in porous and aggregated forest soils and less common in poorly structured soils. It also occurs where the underlying geology is highly fractured with, for example, numerous sinkholes: such recharge can be very important in some semi-arid areas. "Rapid" recharge can occur whenever it rains; it will be affected more by changes in rainfall amount than the seasonal cycle of soil moisture variability.

Studies using GCMs and groundwater models in other parts of the world show that small negative changes in rainfall could lead to large negative changes in recharge and hence impact very negatively on the groundwater resources. On the other hand, shallow floodplain aquifers - most common in semi-arid environments - are recharged by flooding, and can be depleted directly by evaporation. Changes in recharge will therefore be determined by changes in the frequency of flooding - which may locally increase or decrease - but increased evaporative demands lead to lower groundwater storage. In the semi-arid areas of Kenya the flood aquifers have been improved by construction of sub surface weirs across the river valleys, hence forming sub-surface dams from which water is tapped by shallow wells. The thick layer of sands substantially reduces the impact of evaporation. The wells have become perennial water supply sources even during prolonged droughts.

Sea level rise will cause saline intrusion into coastal aquifers, with the amount of intrusion depending on local groundwater gradients. Shallow coastal aquifers are at greatest risk. The thin wedge of fresh groundwater in the coastal areas, which sits on top of the salt-water lenses, is generally sustained by rainfall. A reduction in rainfall coupled with sea level rise would not only cause a diminution of the harvestable volume of water, but would also reduce the size of the narrow fresh water lens.

5.3.2.6 River Runoff

A water balance (WATBAL) conceptual hydrologic model was used to assess the vulnerability of the river flows to climate change in the upper Tana River basin and the upper Ewaso Nyiro River basin. The same approach was used for the Nyando and Nzoia river basins (both within the Lake Victoria basin). The Ewaso Nyiro basin is located in a generally arid to semi-arid zone, while the Tana basin is basically semi-arid although a small area constituting the headlands of the basin (slopes of Mt Kenya and Aberdares) is humid. The simulated impacts of reduced rainfall and/or increased temperatures are more drastic in the river runoff of the Ewaso Nyiro basin than for the upper Tana basin. On the other hand, the simulated impacts of reduced rainfall and/ or increased temperatures for the Nyando and Nzoia basins (located in semi-humid to humid zones) showed similar results. In general, temperature increments will be accompanied by correspondingly positive changes in rainfall. However, a decrease in rainfall accompanied by an increase in rainfall always impacts negatively on the river flows.

It is expected that river runoff trends should be consistent with those identified for precipitation: runoff tends to increase where precipitation has increased, and decrease where it has fallen. Variations in runoff are more strongly related to precipitation changes than to temperature changes.

5.3.2.6 Lakes and Wetlands

Most of Kenya's lakes are saline and/or alkaline with a pH of over 9.55 and with dissolved solids greater than 5,000 mg/l being mainly contributed by sodium, carbonates, fluoride and chloride. There exists large seasonal variations in the lake water quality due to variations in the balance between evaporation, river inflows and inflows from the seasonal rains. Changes in water quality are contributed by sediments, but also by industrial and agricultural pollutants as well as by domestic wastes collected from the catchment by runoff.

Lakes and wetlands are potentially more vulnerable to changes in climate parameters than rivers. Variations in air temperature, precipitation and other meteorological components directly cause change in evaporation, water balance, lake level, ice events, hydro-chemical and hydro-biological regimes. There are many different types of lakes, classified according to lake formation and origin, the amount of water exchange, hydrochemistry, etc. An important distinction is between closed (endorheic) lakes, with no outflow, and exorheic lakes, which are drained, by out-flowing rivers. Endorheic lakes are very dependent and sensitive to changes in inflows and evaporation. This also means that they are very important indicators of climate change and can provide records of past hydro-climatic variability over a large area. Small endorheic lakes are the most vulnerable to a change in climate, and there are indications that even relatively small changes in inputs can produce large fluctuations in water level (and also salinity) in small closed lakes. Exorheric lakes too may also be sensitive to changes in the amount of inflow and the volume of evaporation. Evidence from Lake Victoria, for example, indicates that lake levels may be increased for several years following a short-duration increase in precipitation and inflows; Studies have shown the vulnerability of levels in the great lakes to changes in inflows and evaporation. Climate change is also likely to have an effect on exorheic lake water quality, through changes in water temperature.

5.3.2.7 Changes in Flood Frequency

Observations indicate that the frequency of extreme rainfall has increased in most parts of the world and a greater proportion of precipitation is currently falling in large episodic events than in earlier decades. Although a change in flood risk is frequently cited as one of the potential effects of climate change, there have still been relatively few studies since the early 1990s, which have looked explicitly at possible changes in high flows. Current global climate models cannot simulate with accuracy short-duration, high intensity, localised heavy rainfall; a change in mean monthly rainfall may not be representative of a change in short-duration rainfall.

5.3.2.8 Changes in Drought Frequency

The effect of a drought depends on dimensions such as its duration and intensity. The impact of drought on water resources depends critically on how the drought is managed: drought "impact" is therefore not necessarily a simple function of a water deficit. Notwithstanding, the climate change projections of both rainfall and river flows indicate significant falling trends in most parts of the country, especially in the arid and semi-arid lands.

5.3.2.9 Water Quality

The deterioration of water quality threatens aquatic ecosystems and water use. Major water pollutants are organic compounds, which cause oxygen deficiency in water bodies and nutrients, but cause excessive growth of algae in lakes and coastal areas, known as eutrophication (leading to algal blooms, which may be toxic and which consume large amounts of oxygen when decaying). The intensity of pollutants and the assimilation capacity of receiving water bodies govern severity of water pollution, which depends on the physical, chemical and biological conditions. Socio-economic factors have significant impact by increasing pollutants and decreasing available water for its assimilation.

River water quality is a function of the chemical load applied to the river, water temperature and the volume of flow. The load is determined by catchment geological and land use activities. Agricultural inputs are most likely to be affected by climate change, as a changing climate might alter agricultural practices. A changing climate may also alter chemical processes in the soil, including chemical weathering. Warmer, drier conditions, for example, promote the mineralisation of organic nitrogen, and thus increase the potential supply to the river or groundwater. The processes by which water reaches the river channel also influence load. Nitrates, for example, are frequently flushed into rivers in intense storms following prolonged dry periods.

River water temperature depends not only on atmospheric temperature but also wind and solar radiation. River water temperature will increase by a slightly lesser amount than air temperature, with the smallest increases in catchments with large contributions from groundwater, such as the Lake Victoria Basin Rivers. Biological and chemical processes in river water are dependent on water temperature: higher temperatures alone would lead to increases in concentrations of some chemicals and decreases in others. Dissolved oxygen concentrations are lower in warmer water. Higher temperatures would encourage the growth of algal blooms, which consume oxygen on decomposition. Stream flow volumes, affecting both concentrations and total loads, however, will also affect stream-water quality.

Water temperature in lakes respond to climate change in more complicated ways because of the interplay of thermal stratification in the lakes. Nevertheless, increases in temperature would deteriorate water quality in most of the polluted water bodies by increasing the oxygen-consuming biological activities and by decreasing the saturation concentration of dissolved oxygen.

5.3.2.10 Mountain Glaciers

In Kenya, mountain glaciers represent a water resource, which affects the river flows in the Tana and Nzoia rivers over long time scales. The state of a glacier is characterised by the relationship between the rate of accumulation of ice and the rate of melts. The effect of future climate change on mountain glaciers depends on the extent to which melting is enhanced by increased temperatures.

Glacier retreat has implications for downstream river flows. In rivers fed by glaciers, dry-season flows are supported by glacier melt. If the glacier is in equilibrium, the amount of precipitation stored during the rainy season is matched by melt during the dry season. However, as the glacier melts due to global warming, then flows would be expected to increase generally, a process, which may compensate for a reduction in precipitation. As the glacier gets smaller and the volume of melt reduces, then dry season flows will no longer be supported and will decline to below present levels. The duration of the period of increased flows will depend on glacier size and the rate at which the glacier melts: the smaller the glacier, the shorter-lived the increase in flows and the sooner the onset of the reduction in summer flow.

5.3.3 Vulnerability of Water Resources

Possible changes in hydrology and demand for the water resources in Kenya have implications on water supply, flood risk, power generation, navigation, pollution control, recreation, and habitats and ecosystems services. Climate change can directly influence water resources system through: soil moisture, storage in lakes and reservoirs, extent and potential of wetlands, water quality, mountain glaciers, and groundwater recharge. Further, climate change can also indirectly influence a water resources system through: drought frequency, flood frequency, and sea level.

The factors/parameters, which can be affected directly by climate change, are herein referred to as Category-A parameters, while those, which can be affected indirectly, are referred to as Category-B parameters. Table 5.4 summarises the impacts of different climate scenarios on the dependent factors (Category-A and category-B parameters) of a water resources system. A positive impact on either of the categories is represented by (+), while a negative impact is represented by (-) and no impact by (0).

On the basis of the GCM and rainfall trends analyses given earlier, it seems logical to adopt a general water resources scenario that the temperatures in the country may either remain unchanged (0) or will increase slightly (+), while the rainfall may remain unchanged (0) or decrease slightly (-). Under this scenario, we note from table 5.10 that Category a parameters (direct) will decrease (-), while Category B parameters (indirect) will increase (+). In general, this implies that the water resources base in the country, which is currently stressed, will become scarce by the year 2030. Below is a detailed assessment of the various water resources components in the country due to the projected climate change.

5.3.3.1 Vulnerability of Water Demands

The increasing population and changing land tenure policies have increased demand on water. In addition, the poor land-use and water resources management practices have reduced water resources quality and quantity. This situation could deteriorate further if there is a general reduction in rainfall over the country.

Climate change is a potential influence on the demand for water. The vulnerability of municipal demand to climate change depends on the uses to which the water is put. The most sensitive areas are increased domestic use and, more increased use of water in the garden and particularly on the lawn.

Industrial use for processing purposes is insensitive to climate change. Demands for cooling water, however, may be affected by climate change. Increased water temperatures will reduce the efficiency of cooling, perhaps necessitating increased abstraction.

Agricultural demand, particularly for irrigation water, is considerably more sensitive to climate-change. There are two potential effects. First, a change in field-level climate may alter the need for and timing of irrigation. Second, increased dryness may lead to increased demands, but demands cannot

Table 5.4: Impacts of climate change scenarios on the two categories of factors in a water resources system

	Rainfall		
Temperature	**No change (0)**	**Decrease (-)**	**Increase (-)**
No change (0)	Category-A (0) Category-B (0)	Category-A (-) Category-B (+)	Category-A (+) Category-B (+)
Increase (+)	Category-A (-) Category-B (+)	Category-A (-) Category-B (+)	Category-A (+/-) Category-B (+)

be reduced if soil moisture contents rise at critical times of the year.

The future demand for water is sensitive to many controlling influences, many of which - such as population growth and rates of economic development - are inherently uncertain. A few studies have considered the additional effect of climate change, and have shown that climate change effects in most sectors are small relative to underlying trends and, more importantly, the uncertain effects of different future water conservation policies.

5.3.3.2 *Vulnerability of Storage, Recharge and Quality of Water Resources*

In general, impacts of climate change on water resources in Kenya, depend not only on the biophysical changes in the storage, recharge, and quality of the resource, but also on the characteristics of the water management system and the magnitude of sea level rise for the water resources at the coastal areas. In practice, incremental or autonomous adaptations to change will depend on adaptation costs and residual impacts. Many past studies in Kenya have not been accounting for non-climatic changes in the way water resources are managed or systems are operated, and have applied the future climate to the present management system. It is important therefore to assess future impacts in the context of the water management systems that will exist then.

The vulnerability of a water resource system to climate change is a function of a number of physical features and social characteristics. The physical features, which are associated with maximum vulnerability of the water resources in a country, include:

a) A current hydrological and climatic regime that is marginal for agriculture and livestock;
b) Highly seasonal hydrology due either to seasonal precipitation or dependence on snowmelt;
c) High rates of sedimentation leading to reduction of reservoir storage;
d) Topography and land-use practices that promote soil erosion and flash flooding conditions;
e) Sea-level rise; and
f) Lack of variety of climatic conditions across the territory of the nation state, leading to inability to relocate activities in response to climate change.

On the other hand, the social characteristics that would increase vulnerability of water resources include:

- Poverty and low income levels;
- Inadequate water control infrastructures;
- Inadequate maintenance and deterioration of existing infrastructure;
- Inadequate human capital skills for system planning and management;
- Lack of appropriate and empowered institutions;
- Absence of appropriate land-use planning and management;
- High population densities and other factors that inhibit population mobility;
- Increasing demand for water because of rapid population growth; and
- Unwillingness to live with some risks as a trade-off against more goods and services.

The degree of vulnerability varies from place to place because of the way the physical and social factors of vulnerability inherently combine in a given area to produce a unique degree of vulnerability over that region. In general, the surface water resources in the country are and will continue to be most vulnerable in the arid and semi-arid areas, while ground water resources in the coastal regions will be most vulnerable in the future.

5.3.4 Adaptation Options and Implementation Strategies

A wide range of adaptation techniques have been developed and applied in the water resources sector in different parts of the world. Broad distinctions can be made between "supply-side" adaptive techniques (changing structures, operating rules and institutional arrangements) and "demand side" techniques (which change the demand for water or protection against risk and include institutional changes too). Examples of supply-side adaptations include increasing flood defences, building weirs and locks to manage water levels for navigation, and modifying or extending infrastructure to collect and distribute water to consumers. Demand-side techniques include water demand management (such as encouraging water-efficient irrigation and also through water pricing). Distinctions can also be made between anticipatory and reactive actions. The former is taken in advance of some change, while the latter is a response to a change. Reactive actions include both short-term operational adaptations, such as the temporary exploitation of new sources and longer-term measures. A major flood or drought, for example, often triggers a change in water management. However, whilst many reactive options do exist in Kenya, anticipatory options have not been implemented satisfactorily in many situations.

The ability to adapt to climate variability and climate change (anticipatory options) is affected by a range of institutional, technological and cultural features at the international, national, regional and local levels in addition to specific dimensions of the change being experienced. Among the most important features are the following:

a) The capacity of water-related institutions to act, skilled personnel, the capability and authority to consider a wide range of alternatives (including but not limited to supply-side and demand-side interventions) in adapting to changed conditions, the capability and authority to use multi-objective planning and evaluation procedures in the assessment of policy alternatives, procedures for conflict resolution, and the incentives to undertake serious post analysis of policies and projects to learn what has and has not really worked in the past.
b) The legal framework for water administration that always constrains, for better and for worse, the options that is open to water management. Naturally, laws change as needs change, but the changes is slow and greatly lag behind changing needs. In Kenya, the legal framework for water management is moving in a direction towards increasing environmental protection. Such a direction on the one hand poses further constraints on options to address climate change, but if the move reflects an increasing concern with sustainable water management, then the opportunities for considering adaptation to climate change are increased.
c) The wealth of nations in terms of natural resources and ecosystems, human-made capital (especially in the form of water control systems), and human capital (including trained personnel) that determines what nations can "afford to commit" to adaptation. This should include the ability and willingness to transfer wealth among population groups and regions within a country and among nations. This is the major constraint on adaptation to climate change in poor countries such as Kenya.
d) The state of technology and the framework for the dissemination (or monopolisation) of technology, especially in the fields of bioengineering of drought resistant and salt resistant varieties of plants and techniques for the desalination of seawater.
e) The mobility of human populations to change residential and work locations in response to severe climate events or climate change.
f) The speed of climate change is crucial in determining the capabilities of societies to adapt and change water management practices. Speed of change and the cumulative extent of change affect the impacts on society in non-linear fashions.
g) The complexity of management arrangements may also be a factor in response. In principle, the fewer the number of agencies involved in water management, the easier it will be to implement adaptation strategies. If there are many stakeholders to involve - perhaps with conflicting requirements, management goals and perceptions, and each with some management control over part of the water system - then it may be more difficult to adapt to changing circumstances. There is evidence that in some mature infrastructure systems there may be substantial opportunities for increasing the resilience of water resource systems through institutional changes as well.

Over the years, a wide range of adaptive techniques and water resources management policies have been developed in Kenya, largely in response to the need to meet increased demands. Sessional Paper No. 1 of 1999 on Water Resources Management and Development identifies four areas of major concern in water resources management. The elements considered in each of the four broad areas are: water resources management, water and sewerage development, institutional framework, and financing of the water sector (Table 5.5).

The management of existing water supply systems is constrained by many factors especially,

a) Shortage of funds for development, operation and maintenance of water supplies and management of water resources.
b) Institutional weaknesses, especially the scarcity of qualified manpower and inadequate skills among users to properly operate and maintain water supplies.
c) Institutional weaknesses to deal with climate extremes.

Table 5.5: Summary of the Policies and Strategies given in the Sessional Paper No. 1 of 1999 on Water Resources Development, Supply and Management

Policy Option On:	Strategy
1. Water Availability	Formulate a National Water Conservation Programme to promote water conservation, with an in-built mechanism for payment of fees and levies for water utilisation to avail finance for water conservation activities which will, include but not limited to, the following: - i. Water catchment and source protection and conservation. ii. Construction of reservoirs for impounding surface run-off and for regulating river flows to synchronise them with the water demand patterns. iii. Artificial ground water recharge as a means of conserving surface run-off. iv. Identification and development of retarding basin, where possible, for the control and management of floodwaters.
2. Roles and functions at different management levels	Setting up and or strengthening of the existing institutions at the national, basin and catchment levels with clearly defined roles to promote and implement agreed water resources management principles at the national, basin and catchment levels. The results of the recently concluded Water Sector Actors Survey will be a major input towards this end. The following is a breakdown of the stepwise approach to the decentralisation process. i. Setting up/strengthening national institutions. ii. Setting up/strengthening basin level institutions. iii. Setting up/strengthening sub-basin/catchment level institutions. iv. Decentralise decision making to basin level institutions. v. Decentralise decision making to sub-basin/ catchment level institutions. vi. Gazettement of all vital water catchments
3. Integrated water resources Management	Set up a National Standing Committee to deal with water related cross-sectoral issues and, among other issues, to spearhead the formulation of a consolidated policy on Land, Water and Forests.
4. Legal Framework	i. Review of the Water Act Cap 372 in view of this policy and harmonise it with other acts. This review to cover also existing treaties on international shared water resources. ii. Enhance the Ministry's capacity to enforce the Act by reviewing the water user fees as A.I.A.
5. Impact of water resources development on environment	Develop environmental guidelines for water sector, which integrate environmental impact assessment with water development planning process taking into account the requirements of initiatives by other ministries aimed at ensuring environmental harmony.
6. Water quality issues	Formulate standards and guidelines for the disposal of undesirable elements in water and introduce legislation to ban/regulate their discharge into water bodies with appropriate fines/tariffs. The national water quality-monitoring Programme to be strengthened for monitoring performance.
7. Water resources assessment, monitoring and information systems	i. Develop/strengthen a national water resources assessment and monitoring system that is connected to basin/sub-basin systems with appropriate data and information dissemination system. Updated Databases to be established and maintained at the national, basin and sub-basin levels ii. Initiate an annual publication of key water resources data and information for public consumption.
8. Water research and technology	i. Initiate contacts and collaboration with relevant research institutes both locally and abroad as a means of sharing research experiences and results. ii. Carry out a study to determine the most appropriate system/mechanism to be adopted for identifying the research needs for the water sector iii. Implement the accepted recommendations of the above study and publish the first edition of the water sector research needs and priorities. iv. Support the development of the applied water research branch to a fully-fledged research institute for water matters.
9. Development to meet water demands	i. The Government to review water undertakership rules in order to encourage other actors to apply for the water undertakership and hereafter progressively withdraws from operational and management activities and only retains intervention capacity. The Government to intensify regulatory and monitoring Roles of Water Undertakers and encourage enhanced participation in development activities by other stakeholders.

Table 5.5: (Cntd.)

Policy Option On:	Strategy
	ii. The Government sets collaborative mechanism between donors, civil society, private sector and communities for the purpose of mobilising resources for the sector Development with particular reference to rural and disadvantaged areas. iii. Publish a manual on the development and management of appropriate water and sanitation facilities in the rural areas involving communities in order to stimulate rural development. iv. Publish a manual on water harvesting (surface run off water) techniques as part of the national initiative to promote water conservation for use in agricultural development. v. Link up hydropower production with the National Water Conservation Programme .
10. Development for poverty Alleviation	i. Rehabilitate water supplies schemes and ensure sound community based management. ii. Identify appropriate sites and construct dams and pans for irrigation and other uses. iii. Carry out groundwater exploration and drill bore-holes/wells in ASAL areas. Impound rivers to provide reservoirs.
11. Technology	Set up a national technology vetting mechanism to vet incoming technologies and publish a journal on appropriate technology on a regular yearly basis. This will also include water treatment chemicals
12. Monitoring system	The Ministry sets up a comprehensive water sector monitoring system that includes country level collaboration within the region.
13. Operation and maintenance	i. Develop a criterion for selection of projects for hand-over to beneficiaries and stakeholders. ii. Assist communities to form water users associations. iii. Initiate an intensive capacity building at the district/ community/local levels and within the private sector for eventual take-over of all currently government run schemes.
14. Waste water disposal systems	Review of water undertakership to incorporate sewerage systems to encourage the concurrent development and management of water supply and sewerage/wastewater utilities.
15. Institutional set-up	i. Strengthen the ministry's core functions of regulatory and monitoring roles. ii. Re-organise key institutions in the water sector in line with the new roles necessitated by this policy
16. Co-ordination	i. Carry out a water sector actors survey. ii. Define the roles of the actors based on the results of the survey. iii. Define mechanism for registration of water sector actors with the ministry in charge of water affairs.
17. Legislation	i. Provide the necessary information for the review of the Water Act to include the legal aspects of transfer of the management of water facilities. ii. Enact appropriate Legislation to give institutions the necessary legal mandate for performing their roles.
18. Community Participation	i. Prepare curriculum for community training courses to equip them with knowledge on project management. ii. Institutionalise community training at KEWI. iii. Commence training courses for communities. iv. Form community based water committees at the local level.
19. Gender Concerns	i. Carry out a study to determine key gender aspects of water use and management and thereafter make recommendations on how best gender concerns can be incorporated in water development and management at the community level. ii. Develop a manual on the application of gender concerns in the management of water utilities.
20. Handing Over Water Supplies	i. Assess capability of local authorities to run urban water supply and sewerage communities to run rural water supplies. ii. Develop a capacity building programme for potential water undertakers both in urban and rural areas and initiate training at KEWI. iii. Commence progressive handing over process.

Table 5.5: (Cntd.)

Policy Option On:	Strategy
21. Financial Resources	i. Hold a workshop to deliberate on ways and means of mobilising Local Resources for the water sector development and prepare a report on appropriate financial mechanism. ii. Implement recommendation on mobilisation of local financial resources for water sector development. iii. Identify areas of deficiency that will require external donor funding for the government to take appropriate action
22. Revenue base	i. Gazettement of all water supplies and liberalising tariff setting. ii. Introduce a water-resources tariff for all water uses for funding water resources assessment, monitoring and research. iii. Develop a mechanism for channelling water resources tariff to monitoring, conservation and research activities. iv. Introduce an effluent discharge levy.
23. Management of Financial Resources	i. Develop guidelines for assisting donor agencies and civil society organisations in channelling their funds to the needy areas and to ensure that their efforts are complimentary. ii. Develop appropriate tariff for bottled water and water vending operations and set a unit to monitor the same.

d) Water resources unavailability due to its uneven distribution both in time and space.

e) Poor choice of technology in water supply and sewerage development, and inconsistent project selection criteria which has resulted in adoption of technologies and delivery mechanisms which are not well suited for the sector development.

f) Inadequate co-ordination of the various actors in the sector.

g) Inadequate inter-linkages with other water related sectors.

The water-sector policy as outlined in the Session Paper No. 1 of 1999 does not adequately incorporate issues that are important for adaptation to climate change. The following are some of the factors, which need to be considered and probably added into the existing water policy for ease of adaptation to climate change.

i) Changing operating rules for existing structures and systems.

ii) Poverty eradication measures.

iii) Increasing protection against drought and flood hazards through:
   - Continuous maintenance of infrastructure;
   - Introduction of an effective flood and drought disaster management strategies;
   - Limitations on sand harvesting in river channels;
   - Introduction of a settlement and land tenure policy in coastal zones 1, 2 and 3; near river banks; around major reservoirs and forests and other state reserves; and
   - Investing in alternative power sources.

iv) Reduction of the number of agencies involved in water management: The fewer the number, the easier it will be to implement adaptation.

v) Introduction and implementation of policies to encourage the use of groundwater through:
   - Subsidies for community efforts to sink boreholes;
   - Financing of research into cheaper bore-sinking technologies; and
   - Enhancing groundwater protection.

vi) Development of cheap technologies for desalination of seawater for use in the coastal areas especially for ships, sanitation (hotels, domestic) and industries.

vii) Review the land tenure policies to encourage large-scale land developments and discourage land subdivisions which often lead to migration of people and the creation of sedentary settlements and lifestyles based on poor land use and management practices which in turn adversely affect the hydrological systems.

viii) Develop and implement strategies which would ensures that small water supplies projects (including low-cost rainwater harvesting) are distributed uniformly over wide areas and therefore spreads out the settlements against the creation of large water supply projects, which encourage dense settlements around such projects.

ix) The capacity of water-related institutions must have the capability and authority to consider a wide range of alternatives that include not only the supply and demand interventions but also the adaptation to climate changed conditions.

x) Sustainable development and expansion of urban centres.

xi) Public awareness to prepare communities to learn how to live in a sustainable manner with any uncontrolled risks arising from climate change.

In recognition of the limitations posed by the absence of the above factors in the water policy, the government has initiated efforts to revise the existing water policy. A new draft water policy includes options encompassing the above factors. The government has also initiated efforts to develop and institute a disaster policy, which includes, among others, disasters, which are either directly or indirectly related to the water resources in the country.

The implementation of the new water and disaster policies in Kenya will greatly ease the burden of the water managers to plan adaptation strategies to reduce the vulnerability of the water resources in the country as a result of climate change. However, whether these steps towards adaptation take place or not may be heavily influenced by the occurrence of extreme events in the future. Such events are often the catalyst for change, and may serve two roles. First, they may expose failings in the implementation strategies of both the water and disaster policies in relation to the water management system. The failings often reflect weaknesses in development control, planning guidance, public education and fiscal incentives. Secondly, they may raise the perception amongst decision-makers of the possibility and dangers of climate change - even if they cannot be directly attributed to climate change.

The government has also identified other factors, which are important in reducing vulnerability of water resources to climate change, and is putting in place the relevant measures to minimise the limitations due to these factors. These other factors include:

a) *Data for monitoring:* Adaptive water management needs reliable data for use in making decisions, calibrating models and developing projections for the future. These data should cover not just hydrological characteristics, but also indicators of water use.

b) *Understanding patterns of variability:* An understanding of patterns of variability - and in particular the stability of a "baseline" climate - is important for medium-term water management. It is increasingly recognised that even in the absence of climate change, the recent past may not be a reliable guide to the hydrological resource base of the near future.

The impact of climate change in the water sector is a function of the biophysical change in water quantity and composition, the use to which the water is put, and the way in which those uses are managed.

The implications of climate change on water resources must therefore be seen in the context of the many other pressures on water resources and their management. These pressures, and the management responses to them, are evolving rapidly, and the water management system (infrastructural, legal and institutional) in the future may be very different from that pertaining today. Considerable efforts are under way in many international agencies and organisations to improve the way water is used and managed, and these actions will have very significant consequences not only for economies, access to safe water and the environment, but also for the impacts of climate change. Adaptation to climate change in the water sector must be seen in the context of these other changes and, of course, climate change must be considered as a factor in the development of improved management techniques. These other sectors are: ecosystems, coastal and marine zones, settlements, financial services, health, energy, and water and conflict.

5.3.5 Conclusions

Kenya has a wide spectrum of the water resources base, which consists of both surface and groundwater resources (fossil and rechargeable). The terrestrial-surface-water resources systems are strongly influenced by rainfall. Most projections of future climate change in Kenya indicate that rainfall will either increase or remain unchanged in the humid areas, but will decrease in the arid and semi-arid areas. All these imply that, terrestrial surface water resources are very vulnerable to the impacts of climate change.

Further, the surface water resources in the country have been utilized differently and at various degrees of exploitation. Nevertheless, there is still a large and untapped surface-water resources potential. However, more than 25% of the existing surface water resources in the humid and sub-humid areas are currently being utilized. In the arid and semi-arid areas, estimates show that more than 40% of the existing surface water resources are being used for different purposes, mainly in horticulture. This implies that the current surface water resources are stressed and in fact a water shortage exists in the arid and semi-arid areas. This is compounded by factors related to population pressure and migration, poor resource use and management and other socio-economic factors mainly poverty and inappropriate land tenure practices. The factors increase the vulnerability of water to the impacts of climate change.

On the other hand, the groundwater resources in Kenya also vary spatially, because of the complex geology in the different parts of the country. Nevertheless, this resource is in sufficient amounts in many parts of the country. However, groundwater resources are currently under-utilised. Perhaps, this is due to the fact that the medium to large-scale groundwater projects requires considerable investments. Thus, most communities, groups and individuals prefer to develop and utilise surface water resources for domestic, irrigation and livestock farming requirements to groundwater. This is unfortunate because groundwater resources are less sensitive to climate variability than surface water resources. Research also indicates that the groundwater resources may be less vulnerable (except in the arid, semi-arid and coastal areas) to the impacts of climate change. It is anticipated that the impacts of climate change on the groundwater resources will be more gradual than in the case with surface water resources. This is a good attribute of the ground water resources in terms of adaptation to the impacts, which may be caused by climate change. The government is therefore encouraging individuals, groups and communities, through development of appropriate policies and provision of financial assistance to utilise groundwater more substantively but simultaneously, wherever possible, with surface water resources. However, great care should be exercised in the exploitation of the groundwater resources in the arid and semi-arid areas where the recharge processes may be negatively impacted on by climate change and also in coastal areas where salt intrusion, compounded by sea-level rise could be a serious set-back.

The government is currently reviewing not only the Water Act but also the Policies on water, disasters settlement and land tenure with the aim to discourage migration and settlements in environmentally fragile areas. The reviews when completed and implemented will form important tools for reducing the vulnerability of the surface water resources.

5.4 Aquatic And Coastal Resources

5.4.1 Introduction

Kenya is endowed with a variety of ecosystems, a rich heritage of diverse natural resources that include aquatic resources found in both oceanic and inland water systems. The inland water systems include rivers, swamps, freshwater and alkaline lakes and impoundments. The marine resources are characterized by shallow biophysically interactive coastal systems like mangrove forests, sea grass meadows and coral reef besides the oceanic water resources. They host a rich diversity of flora and fauna some of which are of high economic value. They also provide invaluable ecological functions to coastal areas.

Freshwater ecosystems provide significant resources; most important of which are fisheries. Other resources include aquatic macrophytes such as papyrus and reeds. These resources have diverse utilities. Some of the macrophytes in the wetlands in Lake Victoria basin are inhabited by many endemic bird species. Alkaline lakes like Elementaita and Magadi are important mining sites for soda ash and salt. Climate change might cause significant changes to these important resources.

The coastal environment and habitats represent the boundary between land, sea and air. It supports some of the most diverse and productive resources in the country. The resources include mangrove forests, coral reefs, sea grass beds, as well as rocky, sandy and muddy shores together with their unique species.

5.4.2 Baseline Situation

The fisheries activities create considerable employment opportunities, especially to riparian communities. The industry also has a myriad of aesthetic values, which jointly contribute significantly to the country's foreign exchange. About 0.3 % of Kenya's Gross Domestic Product in 1996 emanated from the sector.

5.4.2.1 Freshwater (Inland Fisheries)

The bulk of the country's fish resources come from inland fisheries with L. Victoria producing about 95 % of total fish yields from an area of about 11, 200 km^2 (figure 5.11) Currently, fish production fluctuates between 160,000 mt and 200, 000 mt per year (figure 5.12). Aquaculture, though concentrated along the Lake Victoria basin and Central province, significantly supplements capture fisheries in the country.

Fig. 5.11. Freshwater fish production from 1980 to 1998; other areas*: Lakes Jipe, Chala, Rivers and Dams

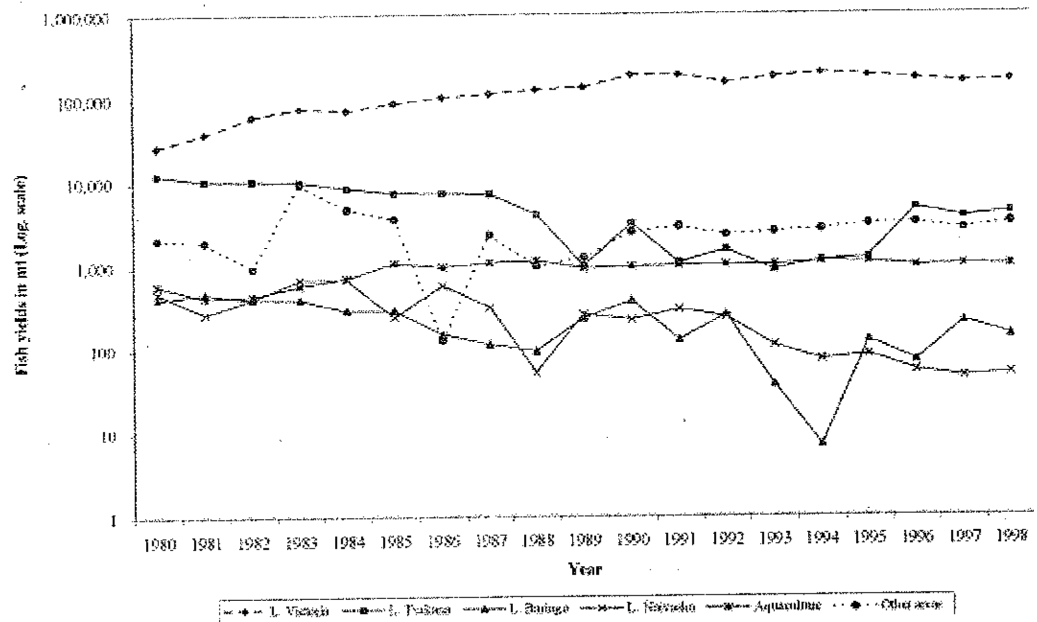
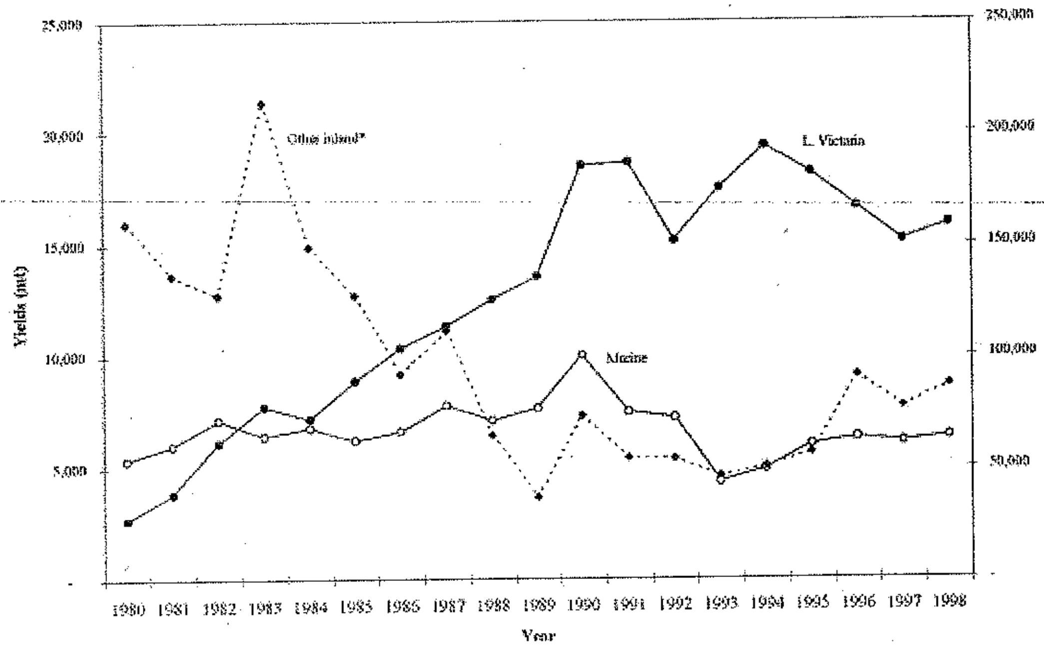


Fig. 5.12 Total fish production from 1980 to 1998, Others*: Lakes Turkana, Naivasha, Baringo, Jipe, Chala, Aquaculture, Rivers and Dams



The fisheries sector contributes fluctuating revenue of Kshs. 5-6 billion annually. This is about 1.5 % of the country's GNP. The most commercially important fresh water fish species in Kenya include: Nile Perch *Lates niloticus* Nile Tilapia *Oreochromis niloticus* Lake Victoria Sardine *Rastrineobola argentia,* Large mouth bass *Micropterus salmoides,* African sharp tooth catfish *Clarias gariepinus,* Rainbow trout *Oncorhynchus mykiss,* Barbs and Labeos among others. Cray fish, *Procambrus clarkii* that is densely stocked in Lake Naivasha is the only economically important crustacean fishery in the inland waters.

Impact of climate change on freshwater fishery was assessed in 1998. A simulated relationship between fish yields in lakes Naivasha and Victoria with mean temperature and morphoedaphic index (MEI) i.e. ratio of Total Dissolved Solids (TDS) to mean depth, as an environmental index was used. The empirical regression models for Lake Naivasha fish yields gave too low goodness of fit (i.e. $r^2 = 0.01$ and $r^2 = 0.48$ for mean temperature and MEI respectively). The goodness of fit was better for lake Victoria (i.e. $r^2 = 0.803$ and $r^2 = 0.933$ respectively). These results showed that in L. Victoria, mean annual temperature has a greater impact on fish yields than MEI. The opposite was true in the case of L. Naivasha. In the latter case, temperature accounted for only 10 % of the yield variability, while MEI accounted for 46.7 %. On the other hand, mean annual temperature (as a climate index) accounted for slightly over 80 % variability of the yields in L. Victoria, while MEI accounted for an additional 13 %. The simulated models indicated that changes in temperature and precipitation could impact significantly on fresh water fisheries.

5.4.2.2 Marine Fisheries

Climate change is expected to affect the biological, biochemical and physical characteristics of the marine systems in Kenya. A number of changes have been predicted on climate conditions and these include increased air temperatures, regional shifts in precipitation, alteration on precipitation timing, retreating icecaps and sea level rise.

All the Kenyan marine fisheries concentrate in the inshore reefs, creeks, lagoons and bays. The economically important marine fishes can primarily be categorized as demersal, pelagic, sharks and rays, crustaceans, molluscs and other finfishes. Fig. 5.13. The contribution of marine fisheries to the total national yields is however, extremely low (3.1 %) despite its enormous area of 157,500 km^2.

Studies on ecosystem response to climate change have based their predictions on possible scenarios of climate change. Studies carried out on Kenya's

Fig.5.13 Marine fish production from 1980 to 1997

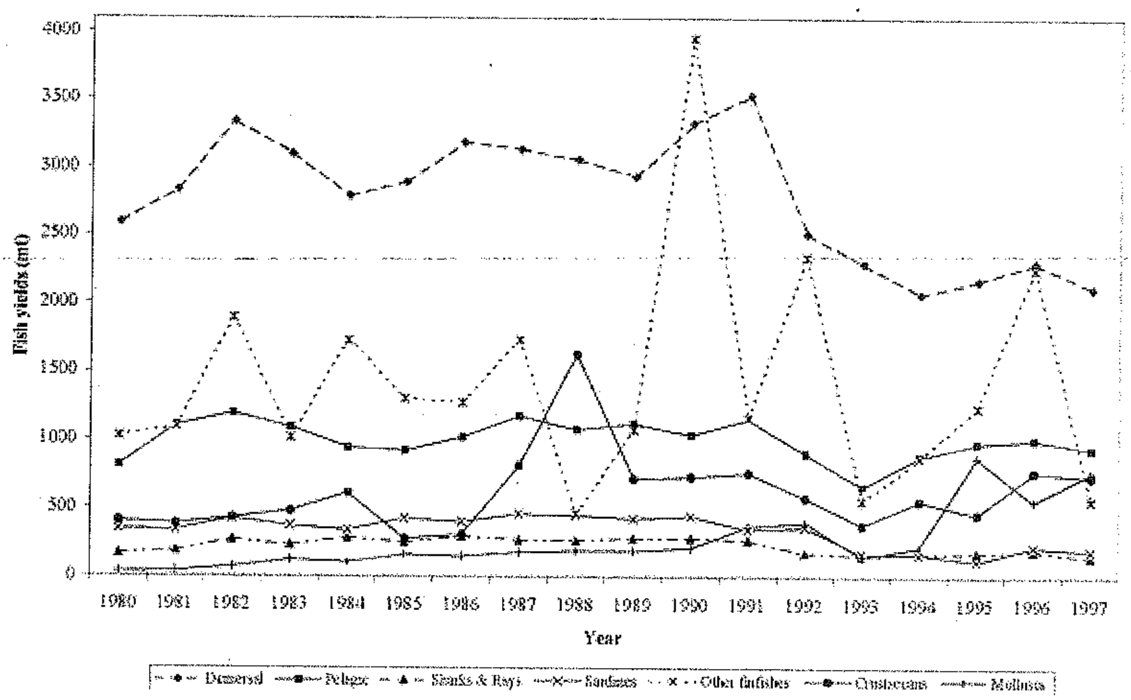


Table 5.6. Correlation coefficients between landings and meteorological parameters				
Environmental parameters	Total landings	Demersal landings	Pelagic landings	Crustacean landings
Mean SST	0.485**	0.540**	0.467*	0.460*
Rainfall	0.194	0.058	0.235	-0.081
Mean air temp	-0.007	0.054	0.074	0.107
Wind speed	0.045	0.374	0.465*	0.277

*** highly significant ($p < 0.01$); * significant ($p < 0.05$); unmarked- not significant ($p>0.05$)*

fishery resources have indicated that climate change might have direct and/or indirect impacts on inland and marine fisheries.

A preliminary assessment on impact of climate change on marine fisheries based on multiple regression showed that except for the mean annual sea surface temperature (SST), other factors such as wind speed, precipitation and other physical and meteorological parameters did not show any significant impact on marine fish landings (table 5.6). It is predicted that without climate change, the Kenyan marine fisheries will continue to increase till maximum sustainable yield (MSY) is attained. Regression models predict that increase in SST will have a positive impact on marine fish landings, whereas a decrease will impact negatively on the fishery (table 5.7). However, an increase in temperature by 3 °C and above will have a drastic negative effect on fish yields.

This impact will be stronger on demersal and pelagic fish species as wells as crustaceans. However, long-term change in precipitation might also impact significantly on the pelagic fishes and crustaceans, especially mangrove dwellers. Anthropogenic impacts such as fishing effort, sand mining, mangrove deforestation, tourism industry among others, could exacerbate the impact of climate change on aquatic resources. However, lack of reliable long term data on the same for further analysis, are impediments to determining vulnerability of the resources to climate change.

5.4.2.3. Population

A total of 1,829,191 people lived in the coastal area in 1990. The city of Mombasa had a population of about 461,753. Other small towns; Lamu, Malindi, Kilifi, Kikambala, Watamu, Bamburi, and Diani areas, are significant population centres. The population has been growing at a rate of about 4.6 % per year and therefore, poses a lot of pressure to the coastal resources. The well being of the people at the coast is also supported by systems and infrastructure such as transportation facilities, energy, supply systems and resorts in the coastal area, all of which directly and indirectly impact on the coastal resources.

5.4.2.4 Sea Level Rise (SLR)

Global SLR is one of the consequences of climate change, which is already taking place. The key impacts of SLR have been identified as: lowland inundation and wetland displacement; shoreline erosion; salt water intrusion into estuaries and freshwater aquifers; altered tidal range in rivers and bays; changes in sediment pattern and budget; and decreased light penetration to benthic organisms.

Table 5.7. Annual fish landings under temperature change only									
	Mean annual SST change scenarios (°C)								
	<-3	-3 to -2	-2 to -1	-1 to -.5	-.5 to .5	0.5 to 1	1 to 2	2 to 3	>3
Total	-	-	942	2984	2025	7067	9109	11831	>13192
Demersal	-	-	818	188	2558	3428	4298	5458	>6038
Pelagics	-	-	-	313	828	1344	1859	2546	>2889
Crustacea	-	-	-	26	362	698	1034	1482	>1706

Significant impacts of SLR as a consequence of climate change are expected to have serious repercussions along the Kenyan Coast. Mombasa Port is a facility that is of great economic value to both Kenya and landlocked countries such as Uganda, Rwanda and Burundi, whose goods pass through the port.

The Kenyan coast is one of the most vulnerable to sea level rise in the world. The most vulnerable aspects are developments on low-lying areas including agriculture, infrastructure and tourism. About 4,600 ha (17 % of Mombasa district) will be submerged with the 0.3 m increase in sea level rise. Another 70,500 ha of the district will be made uninhabitable or agriculturally unexploitable. In Kilifi District, an estimated 0.5 % of the total land will be submerged when the sea level rise by the same magnitude. The 1m rise predicted for the year 2100 will submerge 1 % of the district posing a lot of threat especially to agricultural activities in the district. The most vulnerable industries at the coast include oil refineries, fuel storage tanks and harbour facilities. The Bamburi Cement Factory will also loose the source of their raw materials. The saline water might cause shortage of fresh water for domestic use and hotel industry. It will also corrode metal pipes.

The expected scenario of 1m sea level rise by 2100 is bound to inundate low lying coastal areas thereby affecting coastal ecosystems. These low lying areas are covered by mangroves, sea grass beds and coral reefs which serve as feeding, breeding and nursery grounds to most of the marine fish communities, besides functioning as sinks and sediment traps.

If enhanced by storm inundation it could exacerbarate coastal erosion and intrusion of seawater into fresh water aquifers, including increased salinities in estuaries of rivers such as Sabaki and Tana. It will also affect agricultural diversity in the two estuaries in Lamu archipelago. The predicted rise in sea level will adversely affect food security especially the production of sugarcane, maize, rice, potatoes, coconuts, cashew nuts, mangoes and citrus fruits in low lying regions and islands. Tourism industry in the Kenyan Coast is highly supported by a network of coastal infrastructure, which is likely to be affected by the predicted sea level rise.

5.4.3 Vulnerability Assessment

5.4.3.1 Freshwater Fishery

Most inland fisheries are based on lakes and rivers. In most cases fluctuation of river and to some extent, lake levels alters breeding ecology of not only permanent populations, but also of anadromous fishes e.g. the eel, *Anguilla bengalensis labiata* (Peters 1852). Such fluctuations have a deleterious consequence on the overall fish production in the country. Climate change is predicted to alter hydrological regimes, which in turn would influence biological, biogeochemical and hydrological functions of wetlands. Owing to the heterogeneity of the wetlands, such impacts might be site specific. Where these wetlands form important nursery grounds for fishery resources, changes in their functions would impact on the fishery.

5.4.3.2 Marine Fisheries

Changes in ocean circulation as a result of climate change is predicted to lead to loss of certain fish populations or establishment of new ones, besides other impacts. Temperature change may also result to changes of upwelling patterns, which might impact on fish spawning period and success of larvae thereby altering the entire life cycle and size of fish population. Exposure of egg, larvae, phytoplankton, zooplanktons, corals and other organisms to UV as a result of increased temperature, could cause abnormalities (e.g. expulsion of zooxanthelae leading to bleaching of the corals) or even deaths thereby indirectly affecting fisheries.

5.4.3.3 Coastal Zone

Records of coral bleaching in Kenya were made in 1982 and 1988, while the most disastrous episode was observed in 1998 when over 80 % of the country's coral reef was affected. Studies along the Kenyan coast indicate that heavy siltation on the coral reefs is an additional factor in the bleaching. National ability to adequately project and thus mitigate the impact of global warming on: coral reefs ecosystems is limited by lack of adequate information on taxonomic, genetic and spatial temporal factors governing the response of coral systems to increases in sea surface temperatures.

There is an overwhelming evidence of coastal erosion in Kenya, especially along Diani, Nyali, Bamburi and

Shanzu areas where properties constructed in erosion prone areas are faced with the danger of retreating shoreline (Plate 1.1). Erosion is seen as an encroachment by the sea on coastal infrastructure. There is therefore, a tendency by beach property owners to construct seawalls to protect their properties against strong storms (Plate 1.2). More often than not, the structures offer only short-term solutions whereas in the long term, they exacerbate or transfer the problem to adjoining localities. The walls also result in loss of natural beach profile thereby restricting beach-nesting fauna, such as turtles, from accessing their breeding grounds. Aesthetic value of the beaches is also reduced by the seawalls.

Other effects of coastal erosion include degradation of mangrove forests, sea grass beds and coral reefs. Tourism development, salt pan constructions and/or poorly planned and managed aquaculture activities, only compound coastal erosion impacts.

5.4.4 Vulnerability of Aquatic and Coastal Resources

5.4.4.1 Freshwater Fishery

Lake Turkana fishery is the second largest fresh water inland fishery in the country. It currently contributes about 1.8 % of the total inland fish production. The major economically important fish species of the lake are Nile perch *Lates niloticus* and Nile tilapia *Oreochromis niloticus*. Others include *Citharinus* sp, catfishes and labeos. Despite the fact that the lake's fishes fetch very low market prices, it significantly contributes to about 0.61 % of the inland fishery revenue. However, it is predicted that climate change might impact the lake's fishery significantly. This study indicates that the rainfall pattern of the lake is changing and is feared to be declining by as far as 23.105 mm per year by the year 2050.

Even though the correlation is not significant (i.e. $p = 0.157$), the long-term impact of the amount of rainfall might adversely affect the fisheries (figure 5.14). Deduced from the mean annual rainfall of 200.013 ± 132.510 mm S.D, the optimal fish yields of L. Turkana was calculated to be 6222.640 mt per year. With the persistent decline in rainfall by the year 2050, the production is expected to decline to 4636.96 mt. The impact might even be more adverse by the year 2100. Table 5.8 shows the impact on fish yields when the amount of rainfall declines at an interval of 20 mm. The estimated decline of rainfall will cause a loss of about Kshs 81.51 million (0.04 % GNP) by the year 2050. The loss will be even more serious (0.12 % GNP) by the year 2100 (table 5.9.).

Plate 1.1. Coastal erosion on a section of Diani beach. Debris on the foreground are dead seaweeds deposited by the monsoon winds (Photo by Dalmas, July 2000)

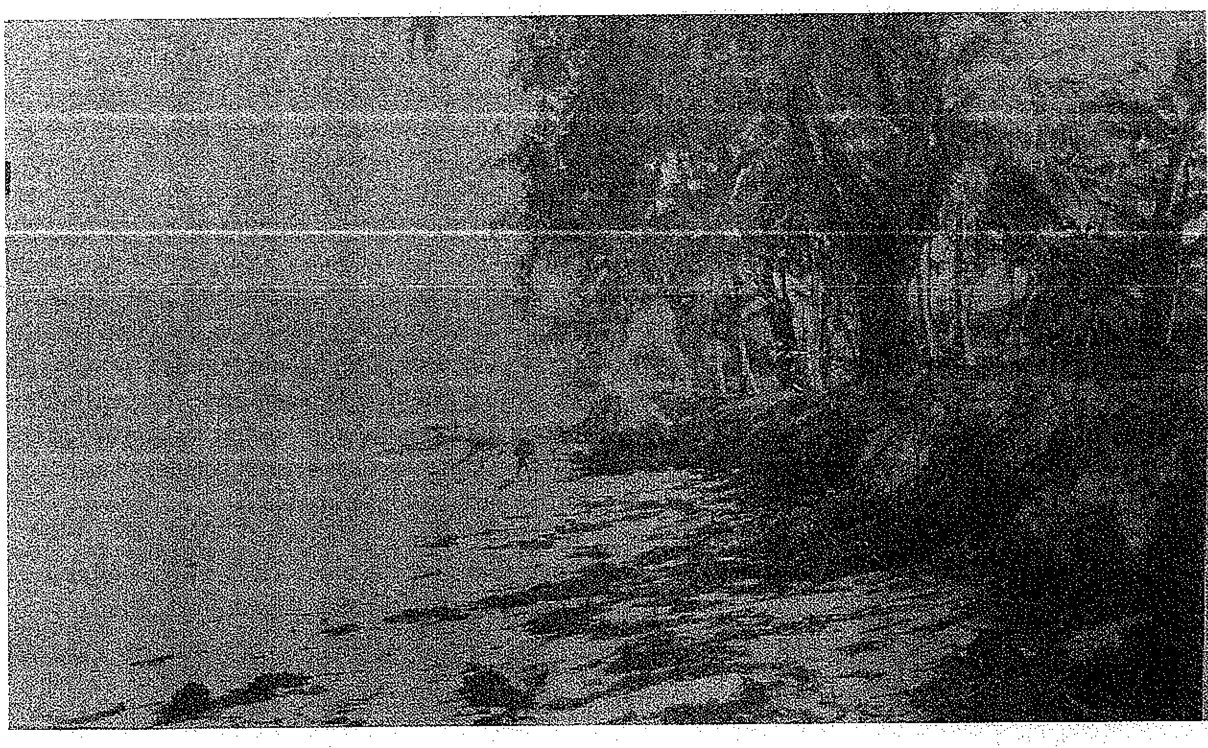


Plate 1.2. A concrete barrier constructed to protect beach infrastructures against heavy storms. Its long-term impact might be even more disastrous (Photo by Dalmas, July 2000)

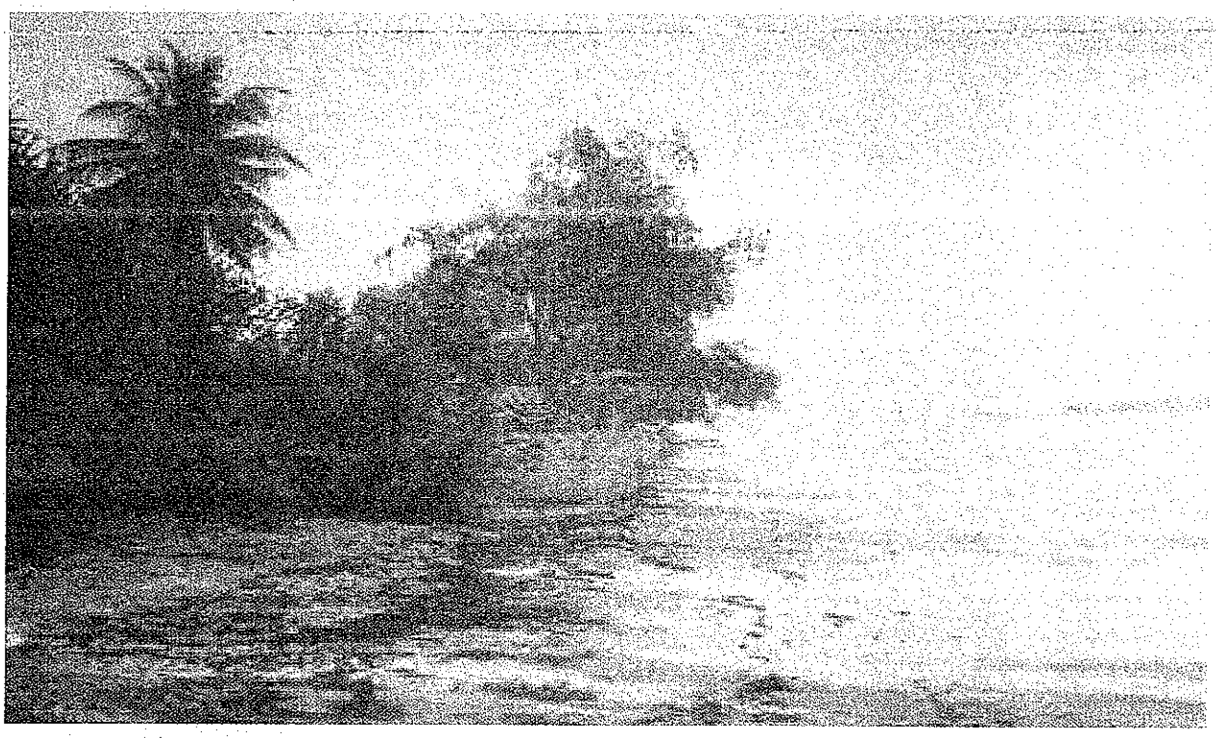
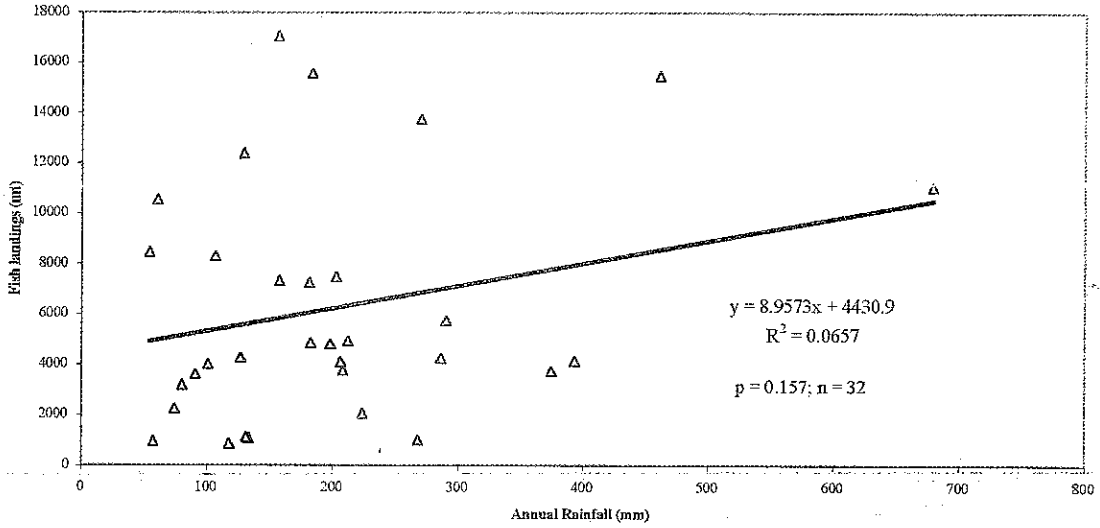


Fig. 5.14. Correlation of fish landings and annual rainfall from Lake Turkana (rainfall data source: Meteorological Department



The lake does not only rely on the Kenyan catchments but gets a significant amount of its water from the Abyssinian highlands in Ethiopia through River Omo. Damming of the river and poor agricultural activities upstream is likely to affect the productivity of the lake. At the same time, over-exploitation of the lake's fishery resources might also contribute significantly to the decline of the fish yields. As has also been seen in the model above, the rainfall around the lake plays a less significant role on the lake's fisheries. Correlation of fish landings and annual mean temperature was not feasible owing to lack of consistent data. But it is certain that temperature might regulate the lake's fishery. In making any possible mitigation options for the lake's fishery sustainability, a regional framework especially involving both Ethiopia and Kenya is inevitable.

Table 5.8. Probable impact of the decline of amount of rainfall on Lake Turkana fishery			
Year Scenario	Δ Rainfall (mm)	Rainfall (mm)	Fish yields (mt)
	0.00	200.0313	6222.64
-	-20.00	180.0313	6043.49
-	-40.00	160.0313	5864.35
-	-60.00	140.0313	5685.20
-	-80.00	120.0313	5506.06
-	-100.00	100.0313	5326.91
-	-120.00	80.0313	5147.76
-	-140.00	60.0313	4968.62
-	-160.00	40.0313	4789.47
2050	-176.93	23.105	4636.96
-	-180.00	20.03132	4610.33
-	-200.00	0.0313	4431.18

Table. 5.9. Estimated impact of climate change on fisheries of Lake Turkana (Rainfall data source: Meteorological Department						
Year scenario	Rainfall (mm)	Yields (mt)	Loss (mt)	Price/ tonne (Kshs)	Loss (Kshs (m))	% GNP
1990	178.09	6026.06	196.58	16970.00	3.34	0.002
2050	23.11	4636.96	1585.68	51401.00	81.51	0.04
2100	-106.05	3480.12	2742.50	89609.90	245.76	0.12
Mean annual rainfall: 200.03 ± 132.51 mm; Optimal yields: 6222.640 mt)						

Lake Baringo also contributes significantly to the country's fish landings. It is famous for its Tilapine *Oreochromis niloticus baringoensis* production and the African sharp-tooth catfish *C. gariepinus*. Despite its perennial problem of siltation, the lake still produces about 0.07 % of the total inland fish landings, earning about 0.06 % of the inland fisheries revenue. No previous study had been done on the probable impact of climate change on the fisheries of this lake.

The rainfall of the area correlates weakly with time. The mean average amount of rainfall in Baringo is about 643.9579 ± 168.1824 mm S.D. This is predicted to increase to 1192.474 mm by the year 2050. It will even be more (1634.824 mm) by the year 2100. A striking aspect on the lake's case study is that the amount of annual rainfall correlates negatively with the amount of fish (fig. 5.15).

Table 5.10 shows that the yields will decrease as a result of progressively increasing amount of rain at an interval of 20 mm. The optimal fish production of Lake Baringo was estimated to be 222.294 mt. By the year 1990 the increase in rainfall had reduced the yield to 219.76 mt and this will decrease consequently to only 143.86 mt by 2050. With the increasing amount of rainfall, the fish production might continue to decline and it is feared that by the year 2100, it will only be 80.6 mt. This will cause a loss of Kshs 22.551 million (0.011 % GNP) (table 5.11).

The problem of siltation in Lake Baringo is a phenomenon, which is likely to perpetuate continued decline in fish production in the lake unless serious action is taken. The issue of heavy grazing in Baringo district, not only destroys the vegetation, but also loosens the top soil, thus exposing it to soil erosion. The eroded topsoil finally gets deposited into the lake through small streams and galleys. This causes high turbidity and siltation in the lake consequently reducing the depth of the lake.

Survival of fish in the lake is likely to be restricted to species like *C. gariepinus* and *O. nilotictus baringoensis*, whose physiology allows for adaptation to living under heavy siltation. Feasible adaptation options for the lake, especially addressing livestock and environment should be given an immediate consideration. The correlation study suggests that for the lake's fishery, local dry spell favours the

Fig. 5.15 Correlation of fish landings and annual rainfall in Lake Baringo
(Rainfall data source: Meteorological Department)

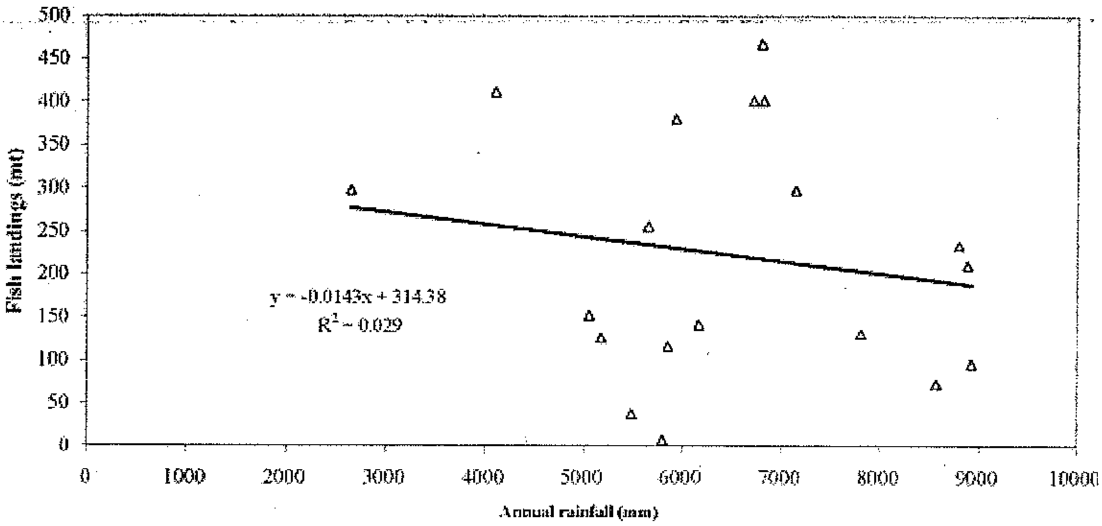


Table 5.10. The probable impact of increase of rainfall on L. Baringo fishery		
D Rainfall (mm)	*Rainfall (mm)*	*Fish yields (mt)*
0.00	6439.579	222.294
20.00	6459.579	222.008
40.00	6479.579	221.772
60.00	6499.579	221.436
80.00	6519.579	221.150
100.00	6539.579	220.864
120.00	6559.579	220.578
140.00	6561.579	220.549
160.00	6581.579	220.263

Table. 5.11. Estimated impact of climate change on fisheries, a case study of Lake Baringo (Rainfall data source: Meteorological Department)

Year scenario	Rainfall (mm)	Yields (mt)	Loss (mt)	Price/ tonne (Kshs)	Loss (Kshs (m))	%
GNP						
1990	6616.54	219.76	2.53	11271.20	0.03	0.00001
2050	11924.74	143.86	78.43	90690.60	7.11	0.004
2100	16348.24	80.60	141.69	159155.00	22.55	0.011

Mean annual Rainfall: 6439.58 ± 168.182 mm; Optimal yields: 222.29 mt)

productivity than local rains as long as distant catchments are not encroached into by destructive practices.

5.4.4.1 Lake Levels and Fisheries

The high amount of rainfall in the early 1960s (commonly referred to as *Uhuru* rains) elevated the level of Lake Victoria by about 2 m resulting into an increase of surface area from 68,800 km^2 to about 75,000 km^2. The flood submerged most of the vegetation, especially papyrus some of which died. This consequently created more breeding grounds for species like *Oreochromis esculentus,* which formed the mainstay of L. Victoria fisheries. The stamps left became nursery grounds for the fry. Consequently, the decline of the vegetation improved accessibility to the lake for many fishermen who then caused more harm to the *O. esculentus* fishery than the papyrus. The pressure currently exerted by water hyacinth has further complicated the lake's fisheries. However, the long-term impact of climate change, especially with regard to lake levels is yet to be assessed.

5.4.4.2 Marine Fisheries

The high diversity and interrelationships between fisheries and other marine resources such as mangroves, sea grass meadows, coral reefs, etc. make it extremely difficult to effectively assess the impact of climate change on the marine resources. Sea level rise will inundate coastal lowlands. This will create additional breeding, nursery and feeding grounds for many fish species. However, this prediction has not been validated for the Kenyan systems. The response of coastal zone to climate change can be highly variable being greatly influenced by local geomorphological configuration and ecological factors.

Studies have shown that extended habitats due to sea level rise are likely to impact positively on growth, recruitment and consequent annual fisheries. If sea level rises at a rate that exceeds the capacity of the coral to grow upwards and remain in the photic zone they may perish. The estuarine fisheries (especially shrimp fishery) are the most vulnerable to sea level rise. Mangroves are also very vulnerable to sea level rise and since 70 % of marine fishes depend on such near shore ecosystems feeding or nursery grounds, an event of sea level rise will significantly affect the fisheries.

5.4.4.3 Sea Level Rise

Kilifi District is one of the most vulnerable areas to sea level rise in the Kenyan coastal region. An analytical review indicates that in the event of the sea level rising by 0.3 m by the year 2050, about 0.5 % (6, 205 ha) of the district will be inundated. This is about 6 % of the total high potential land (coastal strip) of the district. The 1 m scenario by the year 2100 will inundate about 12,410 ha (12 %) of the high potential land. There is need therefore for a comprehensive study on possible impact of the sea level rise not only in Kilifi District, but also in other low-lying coastal areas.

This inundation is likely to result in a loss at current prices and production levels of Kshs 4.964 billion from three cash crops (i.e. mangoes: Kshs1.862 billion, cashew nuts: Kshs 1.862 billion, coconuts: Kshs1.241 billion). These are the chief cash crops of the district. The general agricultural loss would therefore be enormous. The 1 m SLR scenario will elevate the losses to about Kshs 9.928 billion (i.e. mangoes: Kshs 3.723 billion; cashew Kshs 3.723 billion and coconuts Kshs 2.482 billion). These losses (i.e. due to the 0.3 m sea level rise) will be about 2.41 % of the country's GNP.

About 90 % of employment opportunities in the district come from agriculture, while subsistence in the district also heavily relies on the agricultural sector. The 0.3 m sea level rise scenario will also displace about 21,023 people of the district. This is about 3.6 % of the district's total population. To acquire land to resettle this population requires an estimated Kshs 1.551 billion (0.75 % of the country's GNP).

About 50 beach hotels (on the first and second rows of the beach plots), which are currently operational in Kilifi District, will be impacted directly or indirectly by sea level rise. They currently yield a turn over of about Kshs 1.299 billion per year (i.e. 0.63 % of the county's GNP). The predicted sea level rise scenario is therefore a great threat to the country's economy.

5.4.5 Adaptation Options and Strategies

a) There is scarcity of information on impact of climate change on fisheries and other aquatic resources. No study has been done on effects of climate change on species diversity, predator-prey relationship, parasitology or other ecological factors, or even on faunal community. Some species based on their physiology might be more vulnerable to climate change than others. This therefore requires *Weight of Evidence* approach to evaluate vulnerability of each fishery. Such study also requires data on historical environmental parameters, species-specific physiology and life history. Attempts will therefore be made by aquatic research institutions to assess the impact of climate change on individual species, especially those of high economic and ecological importance.

b) Long-term data collection on lower aquatic fauna has been identified as deficient and efforts will be made to strengthen existing capacity.

Most of these fauna play important role in the food chain of various fishery resources.

c) Inadequate funding for research activities and information dissemination is a contributing factor to the gaps in knowledge identified above and therefore requires urgent attention. Furthermore, inadequate institutional networking has been a bottleneck in information exchange to facilitate the use of research results in mitigating the impact of climate change on aquatic resources. Efforts will be made to create more effective institutional networking and collaboration, especially among those whose activities complement one another.

d) Development and improvement of aquaculture countrywide is an area identified as needing strengthening. This would release some pressure from capture fisheries. Proper mechanisms for impact assessment for aquaculture have been put in place through the Environmental Management and Co-ordination Act, especially identification of suitable sites for aquacultural activities and enforcing appropriate regulations for the sector.

e) The Fisheries Department is mandated to collect and store fish yield and value data for management purposes. Accurate and comprehensive data would be necessary to develop yield models to simulate future fish landings with respect to climate change. Inconsistency of such data hampers such studies, especially when addressing seasonality processes. As an adaptive measure, efforts will be made to collect and store such data more efficiently.

f) Lack of appropriate fishing technology has confined fishing efforts on the already over-fished inshore resources making them more vulnerable to climate change. Efforts will be made to enhance offshore fishery.

g) Three basic responses are predicted for sea level rise; retreat landwards to create room for ecosystem shifting inland, accommodating the changes e.g. changing from agriculture to fishery when engulfed in water and protecting properties against storms by erecting protective barriers. Of these adaptive measures, landward retreat and adapting appropriate living conditions would be the most appropriate measure. However, given the current land tenure system at the coast where most local communities do not own the land they live in, there will be efforts towards development of appropriate land tenure policies that will facilitate such retreats.

h) Coral reefs play an important role in dissipating energy from storms, waves and currents, which would otherwise contribute significantly to coastal erosion. Regulations that would ensure conservation and rehabilitation of these important ecosystems will therefore be paramount.

i) Effective education and creation of public awareness on the consequences of coastal erosion and sea level rise is important and will be promoted. The public's preparedness to recognize the changes that are taking place due to these phenomena will enhance their willingness and vigilance to embrace new adaptive measures.

j) Capacity for research and documentation for climate change and sea level rise data is currently weak and needs to be strengthened. Proper databases on coastal erosion, sea level rise, response strategies and any other relevant information are necessary. Currently, sea level data available at the Kenya Marine and Fisheries Research Institute stations are for 1986-1998 for Mombasa and for 1996-1998 for Lamu station. Certainly the period, for which the data is available, is inadequate for any meaningful analysis. In an effort to develop a sea level observing network, three other stations are planned to complete the network. All efforts will be made, therefore, to develop capacity to install and maintain tide gauges, to conduct data analysis and quality control, and to address social aspects of sea level rise. Studies on predictive modeling will be promoted.

k) Extensive consultations between government departments, private sector, civil society organisations and community groups is an effective tool for identifying and implementing appropriate adaptive measures for changes occurring at the coastal zone due to sea level rise and/or erosion. Such multi-disciplinary approach on matters concerning the fisheries management, research and monitoring, tourism and coastal development as a whole is more likely to create a window for early warning and preparedness for any adverse coastal changes. An Integrated Coastal Zone Management (ICZM) pilot study has been successfully completed in Bamburi-Shanzu area in the North coast region. It is envisaged that this study will pave way for the development of a national ICZM Action Plan to address the management of the whole coastal zone.

5.4.6 Conclusion

a) Materials and Equipment: There are financial implications to implementing the above stated adaptive options and strategies. Lack of powerful research vessels and gears for offshore fishing and research, has led to over-reliance on the continental fisheries. Acquiring such vessels and gears has very high cost implications. The existing infrastructural capacity for research in the relevant institutions would also have to be strengthened to generate appropriate long-term data for analytical and predictive studies. Enhanced institutional net-working and collaboration would go a long way in sharing resources and expertise.

b) Land and Aquaculture Facilities: Inundation due to sea level rise will imply relocating settlement areas, agricultural land and other establishments from affected areas. This would require substantial funds. Furthermore, acquisition of land for the promotion of aquaculture, especially where suitable land is on private property is also envisaged to be an added cost to the government.

c) Fisheries Management and Surveillance of Protected Areas: Strengthening of aquatic resources management structures and law enforcement mechanisms within relevant government departments will have an added cost.

d) Capacity Building and Institutional Networking: Serious aquatic research work requires competent research personnel supported by enabling financial resources. Capacity building, in terms of infrastructural development and training will form an integral component of any aquatic research programme.

e) Integrated Management of Aquatic Resources: Results of pilot studies on integrated coastal zone management integrated coastal zone (ICZM) have been quite effective in the management of coastal aquatic resources. Substantial amount of funds would have to be set aside to develop and implement ICZM for the whole of the Kenyan coast. Coast Development Authority (CDA) has embarked on plans to develop ICZM for the south coast and finally for the whole of the Kenyan coast.

5.5 Human Health

5.5.1 Introduction

Climatic factors play a major role in human health. Climatic factors normally affect weather patterns, which in turn interfere with life-supporting natural processes, including the health of people. Several climatic factors have influenced the health sector in Kenya. The anticipated climate change – resulting in temperature and rainfall changes – will affect, among others, the incidence of vector- and water-borne diseases, the incidence of respiratory diseases, cases of stress and stress related disease conditions, nutritional health status, and public health infrastructure. The biology and health of human populations is affected by climatic conditions (temperature, rainfall, wind speed and humidity). Sudden changes in weather conditions could cause severe health problems. In the view of the above factors, it is important to consider vulnerability and adaptation of the health factor to climate.

5.5.2 Baseline Situation

During the year 2000 there were 481 hospitals, 601 health centres and 3,273 dispensaries in the country that represented an increase of 7.1%, 1.3% and 2.5% respectively compared to 1999. The increase in hospitals was attributed to an increase in the number of new private nursing homes. Hospital beds and cots increased by 5.6% from 54,378 to 57, 416 due to investment by private and non-governmental organizations. The number of registered nurses and public health officers per 1000 people improved slightly from 30.2 and 2.7 in 1999 to 31.2 and 3.1 in 2000 respectively. The number of doctors in the country increased from 4,411 in 1999 to 4,506 in 2000 maintaining the current number of doctors per 100,000 people at 15.4. The ratio of doctors to people in the country is still very low.

5.5.2.1 Health and Disease

Climate change is expected to have a wide range of health impacts, both positive and negative. Negative impacts are likely to outweigh the positive. The effects of climate change on health can be direct (heat, drought and floods) or indirect, (effects on ecological and social systems which result in changes in infectious diseases, food production and nutritional status). Most human health problems are caused by several factors that interact together in varied socio-economic and geographic backgrounds.

Infectious and parasitic diseases dominate the health sector. Malaria continues to be the most important parasitic disease and also the leading cause of morbidity accounting for about 30% of total outpatient diagnoses (table 5. 12).

Table 5.12 Leading causes of morbidity in Kenya

Disease	% Of cases
Malaria	32.62
Respiratory diseases	22.52
Skin diseases	6.94
Diarrheal diseases	4.65
Intestinal worms	4.52
Accidents	2.80
Pneumonia	2.34
Urinary tract infections	2.26
Eye infections	2.02
Rheumatism	1.80
Ear infections	1.30
Others	16.23

Source: Central Bureau of Statistics (2000)

Kenya has a variety of tropical diseases that are either vector or waterborne. Vector and water borne diseases are particularly sensitive to changes in meteorological parameters such as rainfall, temperature and humidity. Certain geographical areas and human populations are particularly vulnerable to outbreaks of malaria, cholera and Rift valley Fever, while others are vulnerable to drought and famine.

5.5.2.2: Vector-Borne Diseases

The prevalence and spread of some diseases is directly and indirectly dependent on weather and climate. High temperatures and humidity will favour a higher rate of multiplication of both the vectors and the parasites. The important vector-borne diseases in Kenya are malaria, African trypanosomiasis, schistosomiasis and leishmaniasis.

a) Malaria: Malaria is caused by the parasite *Plasmodium.* The development and survival of both the mosquito and the *Plasmodium* parasite are dependent on temperature, rainfall and humidity, which affect the geographical distribution of malaria. The direction and speed of wind will also contribute to the passive dispersal of anopheline mosquitoes -, which can be dispersed hundreds of kilometers from their original area. Distribution also depends on the major vectors (*An. gambiae* and *An. funestus*). Whereas *An. funestus* is important during dry seasons when breeding of mosquitoes is restricted to large bodies of water such as lakes, swamps and dam. The *gambiae* is responsible for many malaria transmissions during the rainy season.

Most cases of malaria in Kenya are due to *P. falciparum*, which will not develop in the *Anopheles* mosquito at temperatures of more than 38∞C and less than 16∞C but has an optimum temperature (21°C – 27°C) for development. In the dry parts of Kenya where humidity is less than 60% and temperatures are high, the life span of mosquitoes is greatly reduced from the 30-day average. The few mosquitoes that survive between two rainy seasons will multiply during a subsequent rainy season, leading to an increase in the incidence of malaria, which is otherwise low during the dry season.

b) African Trypanosomiasis: Human African trypanosomiasis (sleeping sickness) is transmitted by the blood-sucking tsetse flies *Glossina.* The main parasite that causes trypanosomiasis in Kenya is *Trypanosoma rhodesience.* It is transmitted by *G. fuscipes and G. pallidipes.* Endemic areas of African trypanosomiasis in Kenya are the Lambwe Valley in Nyanza Province and Samia in Busia District. The tsetse flies are dependent on shrubs and trees.

c) Leishmaniasis: The two principal clinical types of leishmaniasis are visceral leishmaniasis (*kala-azar*) and cutaneous leishmaniasis. The former type is caused by the parasite *Leishmania donovani* and the later one by *L. tropica.* These parasites are transmitted by sand flies of the genus *Phlebotomus. Phlebotomus* is sensitive to sudden temperature changes and prefers areas with small differences between minimum and maximum temperatures. The sand fly, *P. martini,* which transmits cutaneous leishmaniasis in Kenya, is mainly found below 900m above sea level. The fly inhabits hot and dry areas with a vegetation of *Acacia* thorn bush and little grass where the termite *Macrotermes bellicosus* builds huge termite hills with ventilation shafts where the fly hides. Transmission of the parasite to man takes place when the fly comes out of the resting sites - usually on warm windless evenings when humidity is high and at the start and end of the rainy season.

d) Schistosomiasis (Bilharzia): Schistosomiasis is caused by the trematode (flatworm) *Schistosoma*. The two species of the genus present in Kenya are *S. haematobium and S. mansoni*. Snails are vectors of these trematodes. The snail of the genus *Bulinus* is the principal vector for *S. haematobium* in Kenya. This snail is found in areas below 1,800m above sea level in dams, irrigation canals, drainage systems, reservoirs and pools of water due to flooding as a result of heavy rains. The immature forms of *S. haematobium* can survive in the snails for months during aestivation (dormant state in warm conditions). The snail is found in most parts of Kenya.

The intermediate snail host for *S. mansoni (Biomphalaria)* is found over most of Kenya except along the coastal strip. *B. pfeifferi,* an important species of *Biomphalaria,* is found in nearly all districts of Kenya and breeds in a variety of habitats from small pools to dams but rarely in swamps.

Expansion of irrigation schemes in the hot parts of Kenya where viable snail populations can find human parasite carriers of the disease has led to the spread of schistosomiasis. Climate change will affect the snail to man cycle as temperature influences snail reproduction and growth, schistosome mortality, infectivity and development in the snail, and human-water contact. Climate change that causes water shortage will result in greater need for irrigation which might in turn lead to higher snail populations leading to greater risk of infection by the parasite.

5.5.2.3 Water-borne Diseases

Water availability and sanitation have a major effect on the transmission of water-borne diseases. Reduced water availability for drinking and other uses lowers the efficiency of sewerage systems (leading to increased concentration of pathogens in raw water supplies). Water scarcity also leads to use of poorer sources of water, such as rivers, which may sometimes be contaminated. Heavy rains can lead to contamination of water sources, blockage of sewers due to siltation, open drains and raised ground water table causing collapse and overflow of pit latrines. These conditions could lead to an increase in the incidences of water-borne diseases.

A number of diseases are associated with the interrelated problems of water quality, availability, sanitation and hygiene. Cholera and diarrhea diseases due to *Shigella, Salmonella* and Enteropathogenic *Escherichia coli* accounted for 4% of medical cases in 1995.

a) Cholera: Cholera, a water and food-borne disease are caused by *Vibrio cholerae.* It has a faecal-oral transmission pathway. Cholera outbreaks have been seen during times of droughts and heavy rains that have resulted in flooding and also during mass migrations. Seasonality of cholera epidemics is linked to the seasonality of algal blooms and marine food chain. Sea level rise is likely to lead to transmission of cholera in low/lying coastal areas in Kenya.

a) Diarrheal Diseases: Bacterial diarrhoeal diseases in Kenya are caused by, among others, the enterobacteriaceae group of *Salmonellae, Shigellae* and enteropathogenic *Escherichia coli.* Bacterial diarrhoea increases during hot and wet seasons. During the hot weather when water is more scarce and sanitation poorer, levels of water and food contamination are greater. Heavy rains lead to floods and water overflow, which can transport terrestrial microorganisms into drinking water sources. The seasonal nature of diarrhoea in children can also be due to early weaning and bottle-feeding resulting in deprivation of maternal antibodies (for protection) normally gained from breast milk.

5.5.3 Climatic Change Scenarios

Synthetic climate change scenarios were used, were based on incremental changes of the maximum/ minimum temperatures and rainfall scenarios. These were applied in cases of the vector-borne and water-borne diseases. The effect of climate change on vulnerability and adaptation was assessed in terms of increase or decrease in incidence (including geographical spread or decline) of the diseases based on the Canadian Climate Centre Model and GFDL, which indicate a maximum change in temperature, and rainfall of 3∞C and 20% respectively. Since the climate of Kenya varies regionally, the effects of the climate scenarios, singly or combined, will have different effects on vector and water-borne diseases.

Sudden changes according to these scenarios could result in severe changes in the environment that could impact negatively on the health sector as opposed to gradual changes that will result in adaptive responses. A temperature rise accompanied by reduced rainfall could severely impair agricultural food production, which could have adverse effects on the health sector by increasing cases of mortality due to starvation and increased susceptibility to disease as a result of malnutrition. Increases in temperature and rainfall could increase the spread of malaria to high altitude areas and an accompanying decrease in rainfall could result in a decrease in the incidence of the disease in dry areas as well as reduction in vector-borne diseases. Rainfall storms, apart from causing damage to infrastructure, can result in an increase in cases of water-borne diseases due to contamination of water sources by surface run-off. Reduced rainfall accompanied by an increase in temperature can result in higher cases of respiratory diseases .

5.5.3.1 Vulnerability and Impacts

Classical epidemiological models and integrated mathematical models have been used to quantitatively predict climate-related changes in the potential distribution of disease. These models have limitations since they do not consider the complex relations that exist between climate variables, vector, pathogen and human host. The classical epidemiological model deals with a simple linear relation between a climatic variable, for example, temperature and disease rate. A vector may spread without a consequent increase in disease incident. On the other hand, a small increase in temperature may produce a marked increase in disease incidence. Although an integrated mathematical model improves on the quantitative prediction of climate-related changes in the potential distribution of a disease, for example the effect of temperature rise on mosquito populations-development, feeding-frequency and longevity and the incubation of the malarial parasite inside the mosquito, it does not take into account all the possible determinants of a disease transmission potential.

A conceptual model that describes the interactions among the various factors contributing to the severity of the problem should be developed for infectious diseases. The model will assist in solving the initial qualitative assessment of climate impacts on health, the quantitative analysis of regional relations between climate factors and disease and the identification of possible intermediate endpoints that can be used for monitoring surveillance. The initial phase characterises the essential elements of the system stressors. Climate stressors involve the complex climate-ecosystem interactions. The rate of change, frequency of events and climate variability may have a much greater effect on ecosystems than the magnitude of change. The level of analysis here is complex and is beyond the capacity of the current GCM models, which agree on average temperature projections but differ greatly on estimates of regional precipitation and extreme weather events. These models have been applied to malaria, African trypanosomiasis and cholera. These models have been applied to malaria, African trypanosomiasis and cholera.

5.5.3.2 Malaria

The number of malarial cases has continued to increase as has the proportion of the population since the 1950s . In 1952, the proportion of reported cases was 1 to 10000. It increased to 5 to 1000 in 1958; 8 to 1000 in 1963; 387 to 1000 in 1981; 229 to 1000 in 1986; and 128 to 1000 in 1994. This could be due to several factors, which include:

a) The warm weather conditions and high humidity.
b) Increased awareness of the disease resulting in reporting of cases.
c) Increased movement of people due to trade and improved communication.
d) Introduction of free outpatient treatment for all at public health facilities and free in-patient treatment for children by the government greatly increased attendance at all units.

Agricultural development projects such as aforestation, irrigation and creation of dams have changed ecological conditions that have increased mosquito contact with humans. Rainfall, temperature and humidity greatly determine the prevalence of malaria in an area. The incubation cycle of *Plasmodium* in the mosquito is sensitive to temperature. This factor is very important in the transmission of malaria. The optimum temperatures for the sexual development of three of the species of *Plasmodium* that cause malaria in Kenya are *P. vivax* (25∞C), *P. falciparum* (30∞C), *P. malariae* (22∞C).

Transmission of malaria occurs throughout the year in endemic regions where the disease is stable. Such areas experience high rainfall, are hot and humid.

Mosquito survival becomes more sensitive to relative humidity at higher temperature. Warming without increased humidity tends to shorten the longevity of the mosquito.

The distribution of the anopheline mosquito and its ability to transmit *Plasmodium* as a result of climate change will vary in different parts of Kenya depending on the prevailing climatic conditions:

a) A slight increase in temperature will increase the vertical spread of the disease in the highland areas and decrease the prevalence of the disease in the dry parts of northeastern Kenya (if humidity does not increase).
b) An increase in the amount of rainfall will increase the humidity and longevity and mosquito population in the dry parts of Kenya. An increase in floods will lead to an increase in the population of the anopheline mosquito, especially *An. gambiae.*

5.5.3.3 African Human Trypanosomiasis

Tsetse fly distribution is mainly dependent on climate factors. For example, since 1953, when the meteorological conditions of the Sahel have become drier and harsher, the northern boundaries of tsetse distribution have shifted 50-100km southward. Since a very small difference in mean temperature has been observed between areas where *G. morsitans* occurs and does not occur in Kenya, a small change in temperature may significantly affect its distribution boundaries. Land use changes can also affect the suitability of environmental conditions for tsetse fly survival through their impacts on the temperature: humidity ratio which can lead to changes in patterns of tsetse disease transmission.

5.5.3.4 Cholera

Rising temperature, changing precipitation patterns, increased storms, floods and sea level rise are expected to lead to an increase in the incidence of cholera. The most affected communities will be those that lack adequate drinking-water supplies and sanitation systems. Urban communities are likely to be at greater risk than rural communities. Water management practices, demand for water and socio-economic factors related to access to clean and safe water supply are taken into consideration when predicting the potential impacts of climate change on cholera.

Since the prolonged survival of the dormant spore-like vibrio is associated with marine phytoplankton, seaweed, macro-algae, water hyacinths and zooplankton, adverse conditions that affect the environment such as shifts in temperature, pH, salinity and nutrient levels lead to "hibernation" of the organism. When water temperature increases, the cholera bacillus re-emerges and infects people. The transmission of cholera can thus result from climate factors such as increase in sea surface temperatures and from human-induced factors such as discharge of urban effluents consisting of high concentrations of pollutants, which will result in marine eutrophication.

5.5.3.5 Respiratory Diseases

Respiratory diseases (mainly pneumonia and tuberculosis) accounted for 24% of all diseases in Kenya. Adverse weather conditions such as drought that lead to low agricultural productivity and malnutrition or factors that will favour an increase in vector- and water-borne diseases could further compound the problem in affected individuals.

5.5.3.6 Extreme Climate Events

Natural disasters such as droughts and floods cause physical injury and death, diminish nutritional status especially in children, increase respiratory diseases in overcrowded areas, increased cases of diarrhoea diseases due to inadequate portable water or contamination of water sources, and increase mental health cases. The El Nino phenomenon of 1997/98, which resulted in heavy rains for a prolonged period affected more than 300,000 families in Kenya. The health resources in the affected parts of the country were stretched beyond manageable levels. The eight most affected districts in Kenya were Mandera, Wajir, Garissa, Marsabit, Moyale, Isiolo, Tana River and Busia. There was an upsurge of vector- and water-borne diseases such as malaria, rift valley fever, cholera, typhoid fever and dysentery. By the middle of July 1998, 472,528 cases of malaria with 2,705 deaths and 44,833 cases of cholera with 2,525 deaths had been reported.

Droughts, as experienced in Kenya in 2000 (La Ñina phenomenon) had severe effects in the arid and semi-arid lands. People lost their animals to the drought, pastoral communities moved hundreds of kilometres in search of pasture. Many animals in poor health died, while others contracted fatal diseases because of their already poor health. This resulted in great loss of income to the affected communities. There were also conflicts between the resident communities and the immigrant pastoralists in search of pasture.

Droughts reduce food production, which leads to famine and deaths due to malnutrition or disease as a result of reduced immunity. Signs of protein-energy malnutrition such as weakness, weight loss, cachexia and reduced mobility will be experienced. The affected population will be less productive. There are likely to be cases of food toxicity since starving people are tempted to eat unfamiliar foods without taking the necessary precautions. Young children are mainly affected since their energy needs are greater. Cases of marasmus and kwashiorkor will be prevalent.

5.5.4 Adaptation Options and Strategies

Policy options that could contribute to monitoring and responding to increases in incidences of vector and water-borne diseases due to climate change are in place. However, there is inadequate capacity for early warning preparedness and limited financial resources for use in responding to disease outbreaks. For example, the health services could not respond adequately to the effects of the 1997/98 El Nino phenomenon, especially increased incidences of vector and water-borne diseases, especially malaria and cholera which killed 2,705 and 2,525 people respectively by middle of July 1998.

The establishment of a National (Disaster) Operations Centre (NOC) in January 1998 by the government to coordinate activities related to disasters, including disease outbreaks as related to sudden weather changes will help mitigate effects of sudden climate change on human health.

Existing policy options for controlling vector- and water-borne diseases are covered under the general government policy of increasing personnel at the peripheral level to ease access to health care services. The overall government policy is to create an enabling environment for the provision of sustainable quality health care service that is acceptable, affordable and accessible to all. In this regard, the government is decentralizing the decision-making organs, resource allocation and management of health services to district levels to allow greater participation of the communities in the management and delivery of health care services.

The government emphasizes prevention rather than cure of the water- and vector-borne diseases. However, implementation of this policy is severely constrained by inadequate funds.

5.5.5 Strategies/ Way Forward

Several response strategies have been recommended for vector- and water-borne diseases with regard to climate change, including the following:

a) Intensification of public health campaigns including prevention of vector-and water-borne diseases targeting the vector or the organism that causes the disease.

b) Continued surveillance for other diseases other than those expected to occur with weather and climate changes. Critical ecosystem indicators will be monitored so that timely intervention can be instituted as disease progression changes. Early indicators identified in developing models and disease incidence will be used. Field data on diseases will be gathered to give a picture of the seasonal and interseasonal variation of climatic factors and the diseases.

c) Public awareness campaigns and public participation will be enhanced with the aim of being sensitized and educated on the correct measures to take when a severe weather condition and the resultant effects are anticipated. Local health centres will be equipped with appropriate drugs and facilities.

d) The National Operations (Disaster) Centre, will be strengthened with both relevant and trained personnel, sound equipment and finance to cope with emergencies as a result of weather changes. The operations centre will be decentralized to areas that are prone to disasters to ensure swift action. Other measures will include:

   - Setting up of early warning systems for disasters.
   - Equipping medical laboratories with appropriate diagnostic kits.
   - Training of personnel in new techniques of handling humanitarian relief.
   - Provision of adequate drugs and chemicals to treat diseases and to control vectors.

e) The Ministry of Heath will improve its production of annual medical reports of various diseases and medical conditions, which can be a major source of valuable data for prediction of weather, related cases.

The proposed adaptation options and strategies may be constrained by inadequate funds, personnel and equipment. Cultural beliefs will be taken into consideration as they are essential for pubic acceptance and success of the policies. The following studies are proposed.

i) The effects of extreme weather conditions on health.
ii) Impact of climatic and weather conditions on zoonotic diseases (diseases transmissible between man and animals).
iii) Effect of climate and weather on domestic animals and people.
iv) Relationship between climate parameters and the incidence of tropical diseases.

5.6. Terrestrial Ecosystems

5.6.1 Introduction

Terrestrial ecosystems contribute immensely to Kenya's economy, through timber products, tourism, pastoral industries and recreation. They are also important catchment areas of major river systems upon which hydroelectric power generation is based. Further, forests and rangelands modulate climate by acting as vital sinks for carbon dioxide.

5.6.2 Rangeland Ecosystems

Rangelands generally support grazing and browsing animals. They are primarily arid and semi arid lands where arable agriculture is not economically feasible. Rangeland ecosystems in Kenya fall mainly under ecological zones IV to VII (fig.5.16). They cover about 80% (approximately 470,320 km_) of the country's area, and supporting 50% of cattle, 75% of sheep and goats, 100% of camels, 25% of human population and more than 70% of Kenya's large wildlife population.

The semi–arid rangelands constitute 28% of the country. They support mixed farming where drought–tolerant crops and /or quick maturing types, and livestock are raised together. Arid rangelands on the other hand constitute 52% (305,708 km^2) of the country, and predominantly occur in the northern part of the country. The areas are too dry to support rain-fed cultivation, and under the current economic and technological conditions, they are most suited to extensive livestock production based on natural vegetation.

5.6.3 Wildlife Conservation

Kenya's rangelands form important habitats for wildlife. Currently, about 8% of Kenya's land is under some form of protection (Fig 5.17). These protected areas include marine, mountain, savanna and wetland ecosystems. Additionally, there are several private and communal sanctuaries established for the conservation of wildlife and promotion of eco-tourism activities.

Most of the parks and reserves are found in the arid and semi-arid rangelands. The wildlife populations in the rangelands have greatly diminished over the last 30 years in both number and distribution. Illegal hunting has been a major factor in reducing wildlife populations. However, the greatest overall threat to wildlife is the loss of habitat. In Kenya, the growth of human settlements and cultivation is displacing wildlife, and closing migratory routes as well as access to wet season dispersal areas. The result is reduced wildlife numbers and confining of wildlife (especially elephants) within parks, thus placing severe pressure on natural resources.

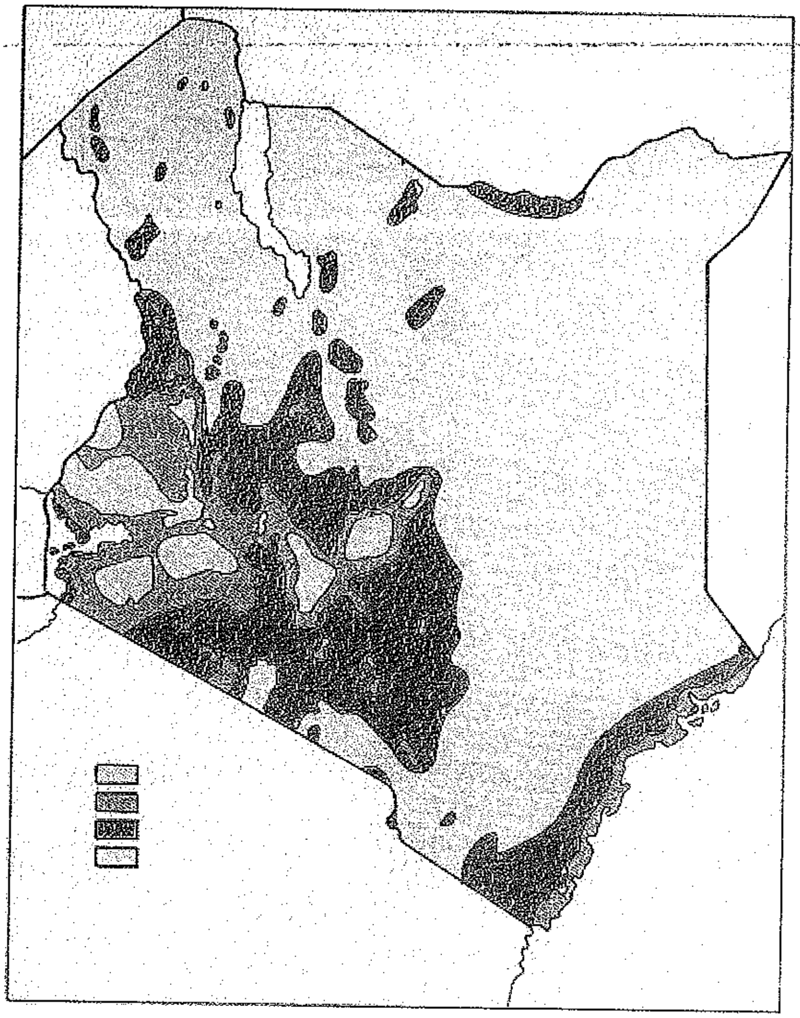
Wildlife has the potential to significantly contribute to both local and national economies. Wildlife management is an attractive land use in the rangelands because of its potential of increasing income without placing undue pressure on the environment and because wildlife species are better adapted to their environment than domestic livestock.

5.6.4 Forest Ecosystem

About 90% of Kenya's population depends on wood energy. Besides, forests are crucial in the conservation of soil and water, especially in regulation of water flow, control of floods and erosion and conservation of biodiversity.

Most forests are distributed in the central highlands where human population and agricultural settlement are also concentrated. Within the rangelands, forests are found on hilltops and in narrow bands along permanent or seasonal rivers.

Figure 5.16: Ecological zonation of Kenya



Source: Pratt & Gwynne, 1977; GoK, 1992.

Legend explanation:

Zone I: *Afro-alpine moorland and grassland or barren land above forest line.*

Zone II: *Forests and derived grasslands and bush lands.*

Zone III: *Land of high agricultural value (intensive livestock and crop production), low forest potential.*

Zone IV: *Semi-humid, annual rainfall: 700 – 850 mm.*

Zone V: *Semi-arid, annual rainfall: 550 – 700 mm.*

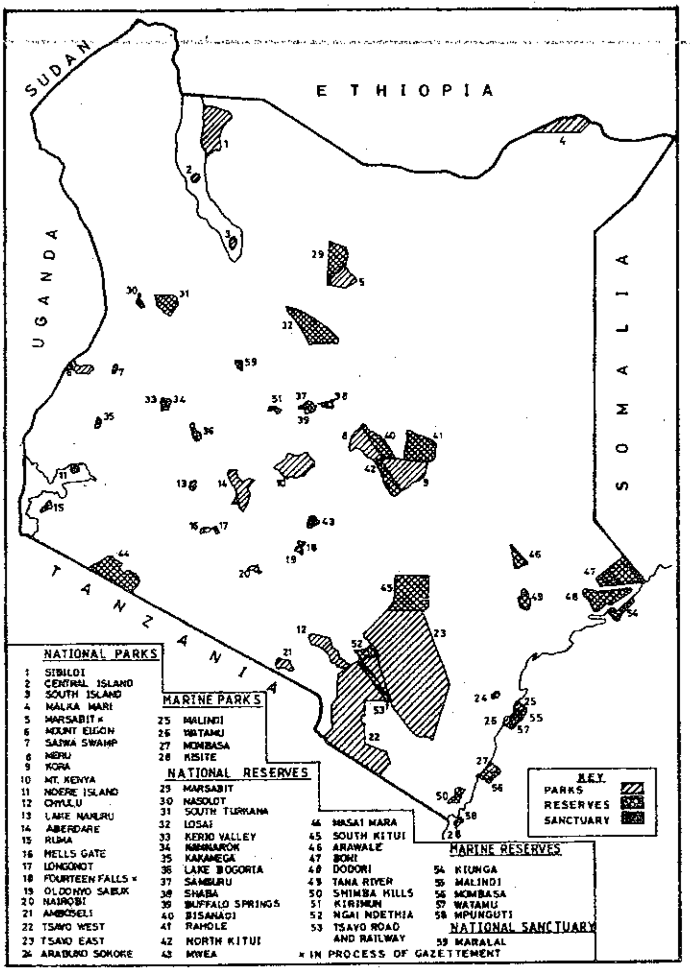
Zone VI: *Arid, annual rainfall: 300 – 500 mm.*

Zone VII: *Very arid, annual rainfall: 200 – 300 mm.*

Kenya's forests are determined mainly by rainfall, altitude, and soil type and consist of many tree species interspersed in places with bush and grassland. Large areas of bamboo are common in some highland forests. About 39 forest dependent tree species have been confirmed as rare, while 379 species of mammals have been recorded as forest dependent.

Presently, the rate of forest loss, degradation and encroachment is unsustainable. This is primarily due to clearing for agriculture, grazing, and settlement. The major factor contributing to loss of forest estate is continuing legal excisions, poaching and illegal encroachment. Excisions are currently occurring without adequate consultation. The 1999 Environmental Management and Coordination Act now provides for impact assessment and transparent procedures before alienations take place. It also gives Kenyans the right to litigate against projects that might have adverse impact on the environment.

Fig. 5.17 Protected Areas in Kenya



5.6.5 Vulnerability of Rangelands to Climate Change

Climate change represents an important additional stress on those ecosystems already affected by increasing resource demands and unsustainable management practices. This additional stress can be expected to challenge the ability of terrestrial ecosystems to provide, on a sustained basis, key goods and services needed for successful economic and social development.

Rangelands are vulnerable to land use changes. Agriculture, livestock production and fuel wood/ timber collection alter land surface characteristics and biosphere-atmosphere interaction. These land uses affect soil carbon storage, soil fertility, soil erosion rates, and dust loading into the atmosphere, trace gas exchange, and water and energy balances. These changes have also influenced local climate patterns, associated with changes in evapo-transpiration rates and land surface energy exchange relative to estimated values from undisturbed land cover. These land use changes modify biological constraints (for example, plant nutrients and grazing) and they will change at different time scale from the abiotic controls (e.g. light and water), thus leading to a hierarchical scheme of limiting factors and subsequent feedback to the atmosphere system. This inter-dependence of short-term regulation is vital to understanding how ecosystem components and processes will respond to changing climatic conditions during transient periods of environmental change.

5.6.6 Response to Shocks and Stresses

a) Pastoral Systems

Kenya's rangelands have experienced several droughts and flood-related shocks and stresses

Table 5.13: Mean herd size per climatic phase and per cent reduction in herd size (ASARECA, 2000)								
Location	Prod. System	Pre-drought	Peak drought	Peak El Ninõ Rains	La Nina Dry	% Reduction Pre-drought to start of minor rains	% Reduction minor rains to La Nina dry	% Cumulative Reduction
S. Ethiopia	PP	34	31	7	8	78	-3	77
N. Kenya	PP	11	10	8	8	34	-8	29
S. Kenya	AP	34	29	32	30	30	-23	12
S. Kenya	PP	149	125	98	79	35	19	47
N. Tanzania	PP	125	99	95	88	25	6	29
N. Tanzania	PP	56	46	40	52	23	-23	6
C. Tanzania	AP	58	53	52	53	9	-1	9

Key: PP - pure pastoral; AP - agro-pastoral

between 1992 and 2002. Two severe droughts were recorded in the decade ending 1999. These were in 1991/92 and again in 1996/97. In late 1997 and early 1998, the country experienced heavy rains associated with the *El Ninõ* phenomenon. Floods devastated pastoral areas as the diseases associated with it killed large numbers of livestock. Table 5.13 shows livestock herd dynamics during different climatic phases in East Africa.

The effect of the 1996/97 droughts and 1997/98 floods in pastoral production systems was a major reason for the acute food shortage and associated human suffering experienced in these areas. The agro-pastoral croplands lost over 80% of maize production. The long rains in 1999 were sub-normal. This successive scarcity of rain resulted in a degeneration of vegetation that subsequently lead to severe declines in rangeland grazing capacity. This resulted in a negative effect not only on livestock production but also on their market prices. This domino effect was a major concern in most purely pastoral districts, because it eliminated the peoples' ability to purchase foodstuffs.

During the floods, pans and dams were silted up. Those that were de-silted quickly dried up in 1999. As a result, a few functional boreholes and hand-dug wells formed the major source of water. Therefore in the absence of any form of intervention, the distances covered in search of water increases. For example, in Obbu division, Moyale, 35 km was recorded as the maximum distance traveled to water due to the presence of only one functional water point. In Machakos, the 1999 daily household water collection period averaged 8-10 hours.

b) Predicted Changes in Forest Types under Altered Climate

Analysis of the simulations show that on a broad scale, Coast and Meru forests are less vulnerable to changed climate, whereas Ngong and Kakamega forests are more vulnerable to predictable changes in climate (tables 5.14. and 5.15).

At the current temperatures and a 10% to 20% decrease in precipitation, Ngong forest is predicted to change from a premontane dry forest to a premontane very dry forest. A rise in temperature, in combination with 20% less precipitation would lead to a change of forest to tropical thorn woodland. An increase in temperature above +2°C is predicted to result in change of the forest to tropical thorn woodland at 10% to 20% less precipitation.

Kakamega forest is predicted to remain as a moist tropical forest with a 10% decrease in precipitation in combination with a temperature rise of up to + 6°C. However, a 20% increase in precipitation would result in a shift of the forest to a tropical wet forest for the whole range of temperature used.

Meru forest is predicted to change from a lower montane moist forest to a lower montane dry forest with a 20% decrease in precipitation at the current temperature and up to +2°C rise. The forest type changed successively with increasing temperature combinations with 20% and 10% decrease in precipitation.

5.6.7 Potential Impacts of Climate Change

Almost all sectors will be affected by climate change, either directly or indirectly. The possible impacts of

Table 5.14. Holdridge life zone classifications of four forest regions under three equilibrium GCM scenarios for the current climate ($1xCO_2$) and under changed climate ($2xCO_2$)			
Forest Region (Type of forest at $1xCO_2$).	CCCM ($2xCO_2$)	GFDL ($2xCO_2$)	GISS ($2xCO_2$)
Mombasa (Tropical dry forest)	Tropical dry forest	Tropical dry forest	Tropical dry forest
Ngong (Premontane dry forest)	Premontane dry forest	Premontane moist forest	Premontane moist forest
Kakamega (Tropical moist forest)	Tropical moist forest	Tropical wet forest	Tropical wet forest
Meru (L/Montane moist forest)	L/Montane moist forest	L/Montane moist forest	L/Montane moist forest
Key: CCCM, GFDL, GISS are General Circulation Models (GCMs) (see Omenda et al., 1998)			

Table 5.15. Holdridge life zone classification of four forest regions in Kenya and shifts in the life zones predicted under GFDL transient scenario

Forest region	Year (decade)	Forest type
Mombasa	1985 (1)- Current	Tropical dry forest
	2015 (4)	Tropical dry forest
	2045 (7)	Tropical dry forest
	2075 (10)	Tropical dry forest
Ngong	1985 (1)- Current	Premontane dry forest
	2015 (4)	Premontane moist forest
	2045 (7)	Premontane moist forest
	2075 (10)	Premontane moist forest
Kakamega	1985 (1)- Current	Tropical moist forest
	2015 (4)	Tropical moist forest
	2045 (7)	Tropical moist forest
	2075 (10)	Tropical wet forest
Meru	1985 (1)- Current	Lower montane moist forest
	2015 (4)	Lower montane moist forest
	2045 (7)	Lower montane moist Forest
	2075 (10)	Lower montane moist Forest

climate change on Kenya's terrestrial ecosystems will emanate from changes in weather elements such as rainfall, temperature, humidity, winds and evapotranspiration. The potential impacts include:

a) Changes in terrestrial vegetation structure and boundaries due to species reactions to climate changes, changes in species interactions, changes in vegetation use by man.
b) Changes in forage quality and quantity – there is close relationship between rainfall and forage types both in terms of quality (especially for livestock) and quantity (especially in the drier terrestrial ecosystems.)
c) Changes in livestock and wildlife productivity due to responses/changes in vegetation on which they depend for food, shelter, breeding, territory, etc.
d) Changes in water quality and quantity – a change in climate, and the associated components will affect the hydrologic cycle, and the pathway taken. Quality and amount of water will change differently in different places.
e) Changes in distribution of disease and parasites. These usually closely correlate with the distribution of moisture and temperature. Therefore any changes in the weather elements will results in redistribution of diseases and

parasites, be they human, plant or animal (domestic and wild).

f) Alteration in carbon storage capacity of the ecosystem due to changes in plant production, grass: tree ratios, and plant distribution.

g) Disturbances in ecosystem functions, e.g., biogeochemical cycling, incidences of fire, etc. that will lead to changes in soil quality and productivity, further affecting ecosystem productivity.

h) Change in weather elements, species interactions, land use, etc. This has been an international concern, leading to the Convention on Biological Diversity.

i) Changes in land use – the potential of land in terms of utility to man will change due to the anticipated changes in land components. This will bring about changes in the mechanisms of food production and livelihoods security.

j) Changes in scenic quality of the ecosystems due to changes in ecosystems components e.g. vegetation, animals, habitats, communities, etc.

k) The relative economic, ecological and cultural importance of the various goods and services from these ecosystems will change due to the change in the characteristics of the goods and services themselves.

5.6.8 Vulnerability of Forests

Vulnerability of the different forests on a broad scale has been derived from interpretations of predictions of equilibrium and transient models use was made of synthetic scenarios. For coastal forests, no changes in forest type were predicted under all GCM scenarios, thus suggesting the forests to be fairly stable. Similarly for Meru, no changes were predicted under all GCM scenarios, including GFDL transient. These results suggest the two ecosystems to be less vulnerable to changes in climatic conditions. The relative stability of the coastal forests is probably because they occur in a region with high temperatures and a rise of the temperature of the magnitude predicted by the GCMs may not have a significant effect on the forest type. Meru forest, on the other hand is found in a high altitude region with low temperatures and a rise in temperatures by about 2°C does not have an effect on the forest type. Precipitation is also fairly high and an increase or decrease may not affect the forest type on a broad scale. Kakamega and Ngong forests were the more vulnerable. Kakamega forest is at the upper limits of precipitation of tropical moist rain forest type hence vulnerable to modest increases in precipitation. Ngong on the other hand is a transition zone type of forest, hence could be more vulnerable due to ecotonal 'buffer' effect. Table 5.16 gives a summary classification of Kenya forests for vulnerability to climate change.

Table 5.16. Classification of Kenyan forests for vulnerability to climate change

Forest type	Vulnerability
Coastal lowland forest	Less vulnerable
Dry upland forest	Vulnerable
Western tropical forest	Moderately vulnerable
Montane forests	Less vulnerable

Generally, conclusions on forest vulnerability include:

a) About 40% of all closed forests will change in species composition, which will affect the vegetation composition and thus biodiversity. These changes may constitute threats to the ecosystems.

b) An alteration in the tree-insect/pest relationships that may alter the natural balance of the relationship; susceptibility to infestations may increase.

c) Increased proportion of moist forests compared to other forest types and possible successive shifts in vegetation types e.g. grassland to woodlands.

d) Expansion of climatic limits of current forests may increase the land area potentially suitable for forest establishment. However, due to soil type and competing land uses, this may not translate into more forests.

5.6.9 Adaptation Options

Current climate change models are unable to predict ecosystem changes to very fine details. This limitation calls for a refined long-term research geared towards a better understanding of tropical terrestrial ecosystems, in terms of their structural and functional dynamics. Consequently, there is need to conduct holistic research into the ecosystems. Key adaptation options include strategies to:

a) Conserve water, protect watershed areas, and promote community water harvesting methods, e.g., rock catchments, and deepen impoundments.

b) Develop and maintain infrastructure to connect different sectors of the country/economy. This will ease the flow of goods and services, technology, information, etc.
c) Develop early warning signals within the systems, using both scientific and indigenous knowledge.
d) Expand the range of options for livelihoods in order to ameliorate the impacts of adverse whether/climate, e.g., extended droughts and/or floods.
e) Implement terrestrial resources rehabilitation policies.
f) Develop land and land use conflict mechanisms in order to maintain or increase range / space of flexible operation.
g) Strengthen linkages and promote partnerships.
h) Implement climate change programmes in national development plans.
i) Involve communities in the implementation of climate change programmes.
j) Provide financial resources to climate change activities.

5.6.10 Policy Options

Policy options that would ameliorate the adverse climate changes in the terrestrial ecosystems include:

a) Promotion of energy efficiency and renewable energy sources.
b) Enhance and intensify rehabilitation measures such as aforestation programmes in degraded dry lands in Kenya, given their spatial extent and importance.
c) Promote activities/actions aimed at combating desertification and restoring the ecological quality of dry lands.
d) Increase funds for combating desertification.

5.6.11 Conclusion

Currently, there exist wide gaps in knowledge regarding structural and functional characteristics of Kenya's terrestrial ecosystems and their ultimate relationship to climate. Research efforts should therefore be directed towards narrowing the gaps in knowledge. Once the knowledge is refined, impact and vulnerability predictions can be conducted with some degree of precision, and system areas vulnerable to a change in climate can be identified. Further, precise impact studies may reveal new or different opportunities for the Kenyan economy and society brought about by climate change. Currently, the interactions of humans and energy flow in natural ecosystems remain only casually understood. However, it is well appreciated that the determination of the effects of climate change on terrestrial ecosystem elements and dynamism is imperative. This will enable resource managers and the government to make informed decisions regarding sustainable management of the ecosystems with the overall aim of reducing their vulnerability to climate change.

5.7 Human Settlements And Socio-economic Setting

5.7.1 Introduction

Kenya's human population has grown rapid since independence in 1963. In 1969, it was 8.6 million, but had increased to 28.7 million in 1999. The fastest growth rates were experienced in the 1970s and 1980s. At the current growth rate of 2.4 % per annum, the projection for 2008 is 35 million. About 44% of the current population of 30.4 million, are children between 0 and 15 years, while those aged 65 years and above number one million.

Most Kenyans (60%) live in the medium to high potential agricultural areas. These areas receive on average about 1200mm annually. Only a small proportion (20%) live in the arid and semi arid lands (ASAL), which cover about 84% of the total land area. The Urban population, although relatively low is growing very rapidly. It has grown from 3.8 in 1989 to 9.9 million in 1999 (34% of the total population) and is projected to reach 16 million by 2005.

Owing to population pressure in the high-to-medium potential areas, semi arid areas and protected lands are being encroached by human settlements. The government is concerned with the decline in the areas of indigenous forests and degradation of biodiversity resources.

5.7.2 Baseline Situation

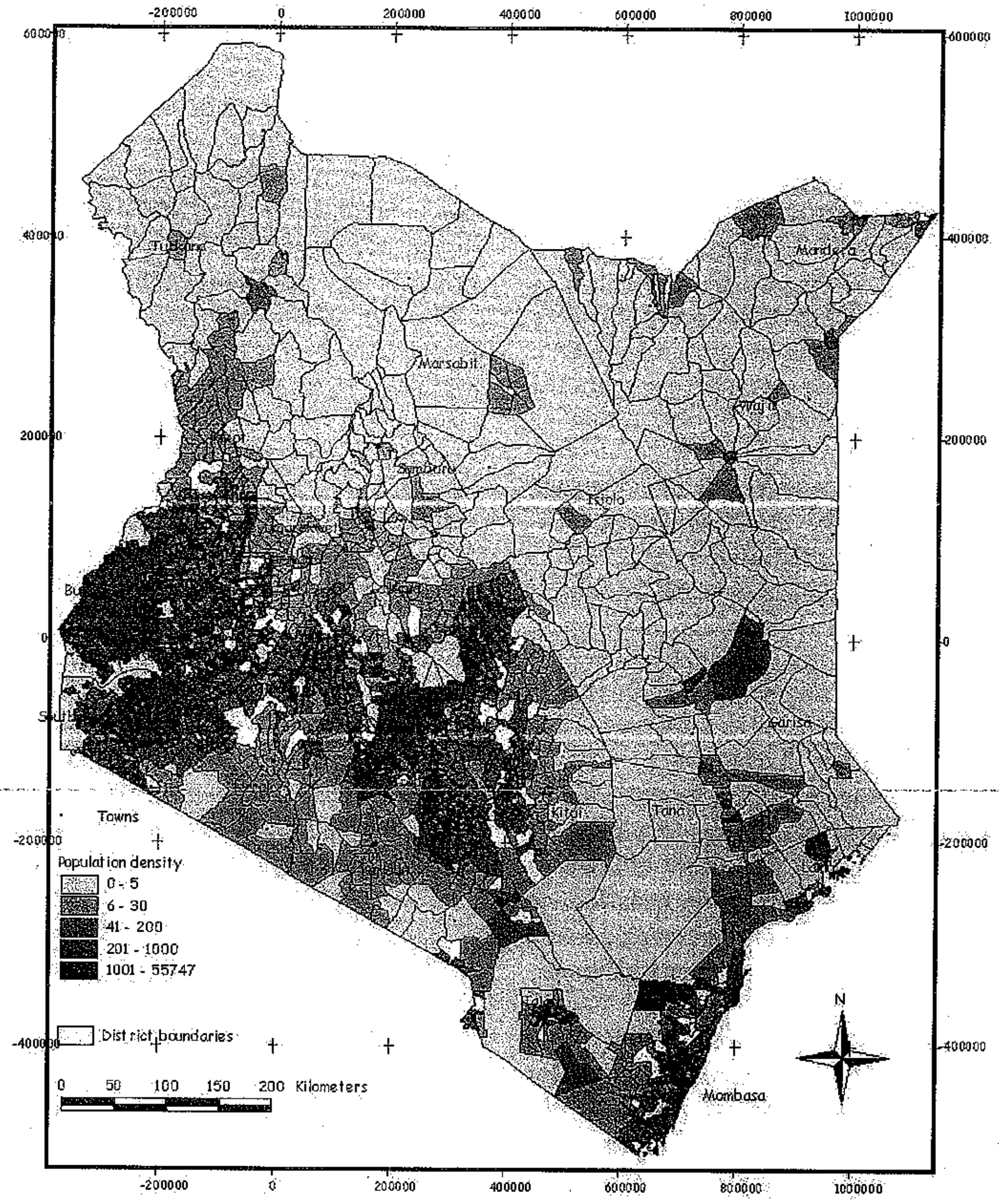
5.7.2.1. Types of Settlements

a) Rural: Socio-economic/cultural factors together with climate strongly influence the type of human settlements. About 60% of the population (18 million) lives in rural areas, with 6 million living in the semi-arid southwestern, eastern and northern parts of the country, most of them being nomadic and semi-nomadic pastoralist communities.

b) Refugee Camps: The latest, albeit regrettable, addition to the Kenyan settlement types is refugee camps. Most of them are based in northern Kenya. They are home to communities from strife-stricken neighbouring countries, viz, Somalia, Ethiopia, Sudan and Uganda. They constitute high-density settlements with scant infrastructure. Heavy reliance on wood fuel for energy needs by the refugee communities has accelerated land degradation in the already fragile semi-arid environment.

c) Urban: Urban population increased from 3.8 million in 1989 to 9.9 million in 1999. Currently, 34% of the total population lives in urban centres. It is estimated that by 2005, 16 million Kenyans will be living in urban centres. Urban planning and provision of social services by local government authorities has not kept place with population growth. Rapid urbanization has led to proliferation of urban informal settlements (generally referred to as slums), which currently accommodate about 70% of urban dwellers. These settlements lack basic infrastructure such as clean water, sanitation, communication facilities, electricity, schools and hospitals. Generally, there is lack of security and crime is a major problem. Environmental degradation and deteriorating public health standards is also a common feature.

Figure 5.18. Kenyan Population density (1989)



5.7.2.2. Infrastructure

a) Water: In general, rural infrastructure is poor as compared to urban. Only about 50% of the rural population has access to portable water. The current government policy places responsibility for water supply on communities. However, rural poverty limits ability of rural communities to initiate development projects in this sub-sector. Furthermore, increased human population and shifts in land tenure policies have increased demand for water and degraded water resources. This situation could deteriorate further if the climate change resulted in a general reduction of rainfall in the country

b) Health: Health is a basic human right irrespective of ones race, social class, locality and residence. Good human health can be guaranteed by a sound health care delivery system, good human nutrition status, good security and absence of morbidity and mortality. Advances in health care delivery have been adversely affected by limited budgetary allocations. Increased incidences of malaria, reduced food security and declining incomes have contributed to increased mortality. The emergence of HIV/AIDS and other disasters further complicates health planning and delivery. Currently, government budgetary allocation to health is about 8%. Of this, 67% goes to curative health, 13% to rural health, 6% to preventive health, and the remaining 6% is used for general administration and planning.

Mortality in children under five and infants in rural areas are 109 and 74 per thousand, respectively. Urban areas have relatively lower rates at 88 for under five years old and 55 per thousand for infants. Health facilities in urban areas are better than those in rural areas. Similarly, urban areas have more access to information and higher literacy, then rural areas.

There exist regional inequalities in health. Central Province has the lowest mortality rates with 27 for infants and 34 for under five years old. North Eastern, Nyanza and Western provinces have high mortality rates due mainly to low incomes, poverty, food shortage and generally poor living conditions.

c) Schools: Education is key to human development. It facilitates overall socioeconomic development through higher labour productivity and improved health and nutrition. Distribution of schools in the country is biased towards high potential agricultural areas. North Eastern Province has the lowest primary and secondary school enrolment (9.8% and 4.8%, respectively) due mainly to poverty, remoteness, insecurity and transhumance. A similar situation prevails at the Coast province due to the same causes as well as child labour in tourism. Low literacy in Rift Valley and Eastern provinces is due to spillover effects of poverty.

d) Energy: Energy has a critical role in human development. It is a domestic necessity and a major factor in production. There are huge disparities in energy availability in the country. About 80% of the population is dependent on wood fuel for its domestic energy needs. This has led to deforestation and degradation of biodiversity. Rural electrification projects have been limited to high potential areas, especially within the coffee and tea sub-sectors. Solar energy has emerged as an alternative source of energy in rural households. It is environmentally friendly and does not contribute to global warming phenomenon. Other sources of energy that need promotional investment from the government are biogas and wind energy.

Climate change will have serious impacts on energy supply. For example, temperature increase will have a negative effect on power generation from both steam and gas turbines, which rely heavily on availability of cooling water. High temperatures will also lead to an increase in evaporation of water resulting in a decrease in the reservoir levels.

e) Transport and Communication: Transport and communication are crucial to development activities, especially the movement of people and goods. Communication technology facilitates exchange of information with the same objective. Most government expenditure on roads is used in urban areas. Low expenditure on roads in rural areas could explain the low agricultural productivity, high incidences of rural poverty, and low level of investment. Poor rural roads also make it difficult for people to access health care and education services.

5.7.2.3. Household Incomes

The major sources of household incomes in rural areas are through sale of farm produce and livestock. These range from cereal and pulse grains to beef animals. Incomes are low in ASAL due to low levels of production. Formal employment in the rural areas is only available in agro-based industries such as sugar factories.

There is great variation in the household incomes of urban dwellers. The high-income bracket earners are found in the private industrial and commercial sector, while the lowest earners are in the informal (jua kali) sector. Commercial activities in the urban areas also contribute significantly to income generation. Levels of household incomes have a significant influence on the types of settlements sought by people. The unemployed or those who work in the informal sector often seek residence in the informal and unplanned settlements where they can afford rent.

There is significant rural-urban disparity in economic development in Kenya. Development strategies have generally been focused to the urban areas, with the notion that gains made here will trickle to the rural areas. As a result rural areas have been left behind in virtually all spheres of development. This is exemplified by the disparity between rural and urban wages and earnings. Although agriculture provides employment for an estimated 75% of Kenya's labour force and about 90% of rural incomes, it accounts for 9% of the total private and public sector earnings in the country. The mean monthly incomes from wages, salaries and profits are much higher in the urban areas than in the rural areas. With the majority of the population living in the rural areas, such disparity is indicative of poor overall access to basic services such as health, education, security and the general living standards of the population.

Kenya's HDI which measures the socio-economic development progress is estimated at 0.53%, but with variations across provinces and districts in Kenya (table 1.2). Such disparities are reflected in differences in regional resource basis, infrastructure development and life opportunities. Provision of education and life-prolonging services such as good health care are crucial in human development in the country.

Kenya's HPI value has steadily risen from 26.1% in 1997 to 34.5% in 2001. Table 1.3 has components of the HPI index.

5.7.3 Climate Scenarios

Synthetic climatic scenarios were based on an incremental change of the maximum/minimum temperatures and rainfall scenarios and sea level rise. The changes could result in frequent droughts, flooding and land degradation. These will affect large human populations leading to the incidence of "environmental refugees." At the coast, sea level rise would reduce the land under cultivation, and degrade tourism infrastructure. Most vulnerable areas at the coast include: settlements close to the beaches and those along the estuaries of Tana and Sabaki rivers. It is predicted that the islands of Watamu and Lamu as well as the Malindi municipality would lose their coastline. Scarcity of suitable land for human habitation in both rural and urban areas would increase competitive land use interests among communities leading to enhanced human conflicts and social strife. Under such circumstances, homelessness, overcrowding, squatting and increased migrations would be inevitable, exacerbating socio-ecological stress.

Flooding would further stress existing drainage system, especially the capacity of sewerage systems, solid waste disposal, and other infrastructural services and facilities. The result would be land degradation and air and water pollution. Flooding would also necessitate relocation of human settlements as well as industrial sites. Conversely, limited or reduced rainfall would lead to drought, which would seriously affect agricultural communities engaged in crop cultivation and/or animal husbandry. Drought would lead to crop failure and famine, which normally devastate the wellbeing of human beings, especially the health, nutrition and overall sustenance.

Since agriculture is the mainstay of Kenya's economy, drought often implies increase in the incidence and magnitude/depth of poverty, which would reduce the people's ability to cope with future environmental and other crises. Rain failure and the concomitant scarcity of water and pasture have negative implications for animal health and survival. In the event of drought, animals would die in great numbers. For pastoral communities, who occupy over 60% of Kenya's landmass, animal death would lead to human misery and suffering since livestock are the main form of socio-economic, cultural and political capital. The tendency for people in areas stricken by drought is to migrate, thereby contributing to socio-economic, health and other pressures on the destination areas, in addition to ecological imbalances.

Temperature change in form of global warming would affect the urban more than the rural areas, since the former are already exposed to a lot of heat as a result of removal of vegetation and the associated construction of building, roads and pavements. In addition, human activities related to urban commerce, transport and the overall industrialization process tend to raise temperatures in the towns and cities above those of the surrounding rural areas. Yet urbanization is increasing in Kenya, making urban areas more exposed to relatively higher temperatures in relation to rural areas. Global warming would increase exposure to excessive heat, cause discomfort and probably increase of skin diseases. The costs incurred in curing skin diseases, and purchasing and installing cooling systems are enormous and inevitably increase the range of human consumption items.

5.7.4 Vulnerability Assessment and Indicators

Vulnerability is the extent to which climate change may damage or harm a system/country. It depends largely on the system's ability to adapt to new conditions, but also on its sensitivity, i.e. the degree to which the system will respond to changes in climatic conditions. Vulnerability of human settlements to climate change would be manifested in socio-economic factors. However, vulnerability would be influenced or moderated by technology (technology choice and habitat management) and government policy (including but not limited to land, development and population distribution policies). An understanding of each of these components is crucial for analysis of vulnerability.

Studies on climate change in Kenya are quite few and based on specific localities, mainly Nairobi, Laikipia and the Coast. More studies should, therefore, be carried out to identify indicators and impacts of climate change for each locality in the country. Available data shows that:

a) Sea level rise changes would inundate the coastal belt, mainly Mombasa, Lamu, Pate and Wagiri, and settlements close to the beaches as well as settlements along river valleys and river estuaries. This would adversely affect the tourist industry, resulting in a multiplicity of socio-economic ramifications, e.g. increased poverty, unemployment and crime.

b) Abnormal rains such as occurred during the El Nino phenomenon and floods would destroy houses, especially in urban areas. These rains and floods would severely hampered physical mobility.

c) Global warming would make arid and semi-arid lands (ASAL) drier, thereby adversely affecting both plants and animals. Food production in these areas would most likely be adversely affected, leading to increased malnutrition.

d) Increased occurrence of extreme climatic events such as droughts, heavy and prolonged rains and floods.

e) Nighttime warming would lead to decreasing diurnal temperature range and increasing mean temperature. Meteorological statistics indicate that three weather stations in Nairobi (Dagoretti, Wilson and Jomo Kenyatta airports) are becoming drier and warmer.

5.7.5 Specific Impacts

The effects of the foregoing climatic changes, coupled with those of the non-climatic factors, would be:

a) Population displacement as a result of sea level rise and flooding or drought, Displaced people would become squatters, most probably living in abject poverty.

b) Rural-urban migrants would come mainly from places adversely affected by climate variability. Previously, rural people who have lost their crops and animals to drought and floods have migrated to nearby towns in search of relief and better opportunities. Immigrants are often stressed infrastructural facilities and services.

c) Increased energy consumption for air conditioning and socio-economic activity.

d) During the period 1999-2001, Kenya underwent an unprecedented period of hydroelectric power and water rationing, which cost the nation millions of shillings as well as socio-psychological suffering. These shortages were due to low water levels at the dams, which are the major sources of electricity and water. Power and water shortages are partly to blame for the negative economic growth in the year 2000. The latter led to more poverty and social disorder.

e) Water pollution resulting from poor drainage.

f) Damage to infrastructure by floods, especially roads, bridges, culverts, and drains resulting in huge repair or reinstallation costs as was witnessed in the El Nino Emergency Project.

Extreme and costly effects, e.g. floods, especially in plains as occasionally witnessed in Kano plains of Nyanza Province and Budalangi Division of Busia District, landslides as seen in Meru and Murang'a and droughts as seen in Turkana and the dry areas of Eastern and North Eastern provinces. The costs related to human suffering or even life, as well as crop and animal health, can be disastrous.

g) Changes in water quality and availability, which may affect people's health and basic survival. Bursts sewers and pipes during heavy rains often lead to water shortages, and contamination due to contact with raw sewerage.

5.7.6 Adaptation Options and Strategies

Potential adaptation options to cope with adverse capacity of climate change on human settlements could include:

a) Support to multidisciplinary and continuous action-oriented studies on climate change as well as clear models of its effects on human settlements. Participatory studies regarding the expected climate changes and sea level rise are necessary in dealing with the challenges. Such studies have to address climate aspects of an area or locality.

b) Incorporation of climate change should in the poverty reduction strategy, especially the following aspects:

- Environmental protection within urban development, sanitation, housing, and other land uses, including industrial sites.
- Strengthening disaster preparedness in terms of equipment, knowledge and skills at all levels within the areas expected to suffer from climate changes.
- Supporting community-based activities related to mitigation against depletion of ozone layer, global warming, sea level rise and pollution of natural resources. Putting in place integrated strategies for the development of ASAL focusing on water resources, Pastoralism, food security, and environmental conservation.
- Enhancing the legal framework related to the protection of fragile ecologies, including the promotion and enforcement of environmentally safe technologies.

c) Strengthening the decentralized development planning process by involving all population groups, including those in the remotest rural parts of the country. Civil society organizations and the private sector should be encouraged to work with government in these endeavours.

d) Building capacities in disaster preparedness through training and acquisition of facilities/ equipment for disaster management.

e) Enhancement of energy-saving measures: Encouraging tree planting in place of air conditioning; have buildings with better ventilation; encourage non-motorized transportation; and use of energy-saving cookers. Efforts emphasizing the foregoing have been put in place, but there should be enhanced community involvement in the programmes.

f) Waste Disposal: Continuously monitor and evaluate urban waste disposal practices to ensure that decisions are arrived at and acted on in good time.

g) Environmental safety and impact assessment: The Environmental Management and Coordination Act provides for impact assessment. The Act, however, needs to be rigorously implemented.

h) Reuse of sewerage and wastes: Sewerage water could be reused in industrial services, while solid wastes could be sorted out and recycled and where possible converted to energy civil society organization and the private sector have the potential to effectively contribute to re-use of waste.

i) Codes and standards for infrastructure: This is an important government responsibility but needs active support of professional bodies.

j) Education and public awareness creation: Enormous effort and resources are needed to develop clear information, education and communication strategies for education and public awareness creation regarding environmental risks, especially as they relate to impacts of expected climate changes. Awareness should be created in the public, while education is required for development planners and implementers. This would ensure that policy makers and planners are able to incorporate environmental issues in their work.

k) Encourage population management programmes to check growth rates. Although the 1999 population census indicates decline in population annual growth rate to about 2.4%, it is clear that Kenya's population is still increasing at an unsustainable rate, well above the rate of gross domestic product.

5.7.7 Conclusions

Climate change impacts will vary across localities. This necessitates encouragement of locality-specific foci, supported by all stakeholders, with the communities in those areas as the primary participants.

Since human settlements and the socio-economic sector is closely related to other aspects of people's lives, adaptation options in this sector should be integrated with those of other sectors, especially water and sanitation, health, agriculture, energy, terrestrial ecosystems and aquatic resources. Indeed, integration of these sectors fits well within the on-going efforts of many government and civil society organisations working to improve human settlements.

5.8 Energy

5.8.1 Introduction

Energy in Kenya is harnessed from a variety of resources including hydropower, biomass, solar and wind power, petroleum and geothermal power. The inputs required for the development of all but biomass are capital intensive and require long-term investment and planning. The effects of climate change can therefore be viewed from the financial implications for generation and production of energy to balance the prevailing supply and demand trends. It would therefore be important to estimate changes in energy use due to climate variability and forecast the implications based on current status, so as to formulate policies that may prevent, reduce, or more equitably share or harmonize losses accruing from the climate change effects.

5.8.2 Biomass

a) Wood Fuel Resources

Biomass energy is harnessed from a variety of sources including wood, crop residuals, briquettes of combustible products (such as coffee husks), and animal and secondary fuels derived from biomass (such as biogas and industrial spirit ethanol). Electricity and petroleum oil as sources of energy are not accessible in most rural areas. Over 74% of the people in the rural areas rely on biomass energy for cooking and heating. Consequently, such biomass will continue to be the major source of energy in the foreseeable future. Wood fuel provides the bulk of total primary energy consumption of about 70% and provides 93% of the rural household energy requirements.

During the past two decades, demand for fuel wood alone has exceeded supply, rising from 18.7 million tons in 1980 to 38.6 million tons in 1995. Demand is expected to continue to increase. Supply shortfall trend for the period 1980 – 2000 is shown in table 5.17.

Table 5.17: Demand and supply of fuel wood in Kenya during the period1980 – 2000 (Million tons)

	1980	1985	1990	1995	2000+
Demand	18.7	24.5	30.3	38.6	47.1
Supply Total from yields from stocks	18.7 13.1 5.6	19.1 12.6 6.5	20.5 10.7 9.8	20.6 7.8 18.8	16.5 5.2 11.3
Supply Shortfall	0.0	5.4	9.8	12.0	30.6
Standing Stocks	1004	974	932	864	800

b) Crop Residues

Agricultural and forest wastes are also used as alternative sources of fuel. Technologies have been developed for briquetting waste. About 2500 tones of briquetted charcoal are produced annually from coffee husks by the Kenya Planters Cooperative Union (KPCU). The energy produced by combusting briquettes is used to dry coffee beans. This reduces costs on electricity.

Demand for wood charcoal is increasing, yet availability of forests and woodlands continues to decline at a fast rate due to additional requirements for timber, crop production and agriculture. Briquetting materials will greatly reduce reliance on fuel wood.

5.8.3 Biogas

Livestock waste contributes substantial quantities of methane to the atmosphere. Methane is a good source of energy if tapped in form of biogas. Biogas offers an alternative source of energy in Kenya and is appropriate for the rural areas. It is most suitable in high potential agriculture zones especially where farmers practice zero grazing. Inadequate skills on use of biogas technology have hampered the exploitation of this source of energy. The Ministry of Energy is currently involved in promoting biogas projects around the country. The programme is tailored to local conditions, climate and raw materials availability and hence is viable in areas where population density is high and dairy cattle are fed in stables (zero grazing). The major constraint is inability of most farmers to pay for installation costs.

5.8.4 Electricity

Electricity in Kenya is harnessed from hydropower, geothermal power, wind and conventional thermal and gas and diesel engines. In 1997, the total installed capacity was 815 MW of which only 753.7 MW was actually produced. Of the installed capacity, hydropower contributed 628.5 MW, geothermal 45 MW, thermal 75MW, gas and diesel engines 65.6 MW and wind 0.4 MW. By 1999, the total installed capacity had risen to 872.6MW.

Hydropower contributes about 76% of the total electricity generated in Kenya (Table 5.18). Generation depends on availability of water, which in turn depends on the prevailing climate. Fluctuations in rainfall and temperature can affect evapotranspiration rates, which in turn can affect water reservoirs, the determinants of channel flow and power generation rates. This makes hydropower most vulnerable to climate change effects.

The total hydropower potential in Kenya is over 2000 MW of which less than 50% is harnessed. Because of fluctuations in peak demand for electricity, there have been frequent power supply disruptions around the country, partly attributed to existing extreme weather conditions. The demand growth rate between 1990 and 1997 was 6.7% per year.

Geothermal power is the largest energy reserve in Kenya, with potential running into several thousand megawatts. Olkaria alone has a potential of 500 MW with 180 MW at current site of which only 45MW is exploited. Eburru has 1000 MW, but unexploited although test drilling is going on.

Conventional thermal sources of electricity serve two purposes: First as a stand-by source and secondly, to supplement peak power demands, especially during periods of drought.

Power demands have been increasing by an average annual rate of 5%, but is expected to exceed this by the year 2002.

Electricity consumption rose to 3,787 kWh in 1999 compared with 3,714 kWh the previous year (table 5.19). Domestic and small commercial consumption rose by 5.2% as a result of expansion of the informal sector and increase in human settlement, particularly in urban areas. Large commercial and industrial demand increased marginally to 2,263 million kWh in 1999 and 2,261 million kWh in 1998. The overall increase in this sector is attributed to higher consumption within the irrigation-based agro-production activities, which registered a growth of 66%. Manufacturing, textile, agriculture and tourism all registered declines in electricity consumption due to the depressed state of the economy. Power rationing in the last quarter of 1999 also contributed to this reduction. Street lighting registered an 18.2 % decline, while off-peak and rural electrification recorded an increase of 3.4% and 4.8% respectively. Electricity imports from Uganda declined to 140 million kWh in 1999 compared with 146 kWh in 1998.

Demand scenarios have been developed using regional and national data. The scenarios used were low and high growths (table 5.20.).

Table 5.18: Gross generation and consumption of electricity in Kenya					
			Trends in Energy Consumption		
Power	Capacity Installed (MW) as at 30.6.97	Effective Production (MW)	1994/95 GWh	1994/96 GWh	1996/97 GWh
Hydro					
Tana	14.4	12.4	78	97	84
Wanji	7.4	7.4	27	51	48
Kamburu	91.5	84	485	485	446
Gitaru	145	145	704	701	926
Kindaruma	44	44	213	239	230
KPLC	6.2	5.4	22	29	24
UEB (Imports)	30	0.0	187	149	144
Masinga	40	40	200	225	215
Kiambere	144	144	996	1031	1028
Turkwel	106	106	379	229	353
Total Hydro	628.5	588.2	3290	3312	3498
Thermal					
Kipevu	75	58	216	224	200
Geothermal					
Olkaria	45	45	290	390	393
Gas Turbine					
Nrb. South	13.5	12	16	59	6
Kipevu	30	30	31	112	168
Diesel Station					
Ruiru	1.5	1			3
IPPS	11.4	11	2	1	7
Wind					
Ngong	0.4	0.4	1	1	1
Inter system Total	805	745.6	3848	4100	4274
Isolated Diesel					
KPLC Station	3.8	3.5	10	11	11
REF Stations	5.4	4.6	7	8	11
Total	9.2	8.1	17	19	22
Gross Generation	815	753.7	3865	4119	4296
Source: KPLC(1997)					

The forecast of the reference growth scenario indicates that demand will continuously and steadily increase during the period 1995/96 to 2019/20, while gross energy generation will have to increase annually at a rate of 5.9% to meet the national energy requirements. Average annual growth rates for energy generation until the year 2019/20 were forecasted to be 5.9%, 5.3% and 6.7% for reference, low and high growth, respectively. Peak demand forecast in the scenarios will increase at mean annual growth rates of 6.2%, 5.6% and 7.0% for reference, low and high growth scenarios, respectively.

Table 5.19: Electricity energy supply and demand balance, 1995 – 1999 (Million kWH)					
	1995	1996	1997	1998	1999*
Demand-					
Domestic and small commercial	1,026	1,049	1,116	1,207	1,270
Large Commercial and Industrial	1,995	2,179	2,263	2,261	2,263
Off-peak	124	100	86	89	92
Street Lighting	19	12	10	11	9
Rural Electrification	125	138	150	146	153
Total	3,289	3,478	3,625	3,714	3,787
Transmission and losses and unallocated demand **	630	712	742	871	919
Total demand = Total Supply	3,919	4,190	4,367	4,585	4,706
of which imports from Uganda	172	149	144	146	140
Net generation	3,747	4,041	4,223	4,439	4,566

** Provisional*
Sources : MOE (2000)

Table 5.20.: Demand forecast scenarios for the period 1995/96 – 2019/20

Scenario	1995/96	2005/6	2015/16	2019/20	% Average Growth Rate (1995/96 to 2019/20)
Reference Forecast					
Energy Sales (GWh)	3287.60	5851.5	10569.7	1338.7	6.01
Peak Load (MW)	670.3	1251.2	1687.5	2852.4	6.22
Gross Generation (GWh)	4121.9	7244.8	12996.6	16341.6	5.91
Low Forecast					
Energy Sales (GWh)	3287.6	5481.0	9396.6	11635.5	5.41
Peak Load (MW)	670.3	1175.4	2020.0	2500.5	5.61
Gross Generation (GWh)	4121.9	6806.3	11608.0	14325.4	5.33
High Forecast					
Energy Sales (GWh)	3287.6	6313.0	12246.5	15903.3	6.79
Peak Load (MW)	670.3	1345.5	2607.0	3382.3	6.98
Gross Generation (GWh)	4121.9	7791.1	1498.5	19377.5	6.66

Source: KPLC

5.8.5 Wind and Solar Power

Wind power is mainly used to pump water and drive power mills. Only a fraction is used to generate electricity. Currently, it contributes 0.4MW to the total electricity supply. Wind energy generation is highly variable due to changes in speed with geographical location, landscape profiles, season, altitude, and time of day. Its major advantage is that it does not generate greenhouse gases and therefore its use should be encouraged. However, the sophisticated equipment required, lack of up-to-date data on wind regimes in the country and poor promotion strategies have been the major constraints hampering its exploitation.

An increasing number of homes, hospitals and hotels are using solar water heating systems, while rural households who are not connected to national electric grid find it an attractive option. Solar energy technologies are environmentally friendly and do not contribute to global warming. Major constraints affecting development of this source of energy include lack of standards, high prices of photo-voltaic (PV) systems, inadequate data and inadequate PV technical manpower.

5.8.6 Petroleum

Petroleum fuel constitutes about 22% of the total primary energy consumed and is also the major source of modern energy requirements. It accounted for 72.2% of total modern energy consumed in 1999. Domestic demand for petroleum products increased from 2,199.1 thousand tonnes in 1998 to 2,311.6 thousand tonnes in 1999, a 5.1 % rise (table 5.21). Growth is mainly attributed to the significant rise in demand of kerosene and fuel oil. However, demand for motor spirit (premium and regular), jet/turbo fuel and light diesel oil declined by 2.8 %, 0.2% and 1.0 % respectively. In 1999, the demand for illuminating kerosene rose by 27.8 %, while that of fuel oil went up by 10.6 % compared with 1998. The rise in demand of illuminating kerosene was as a result of increase in usage by independent power producers for power generation, while fuel oil demand rose after tax reduction during the 1999 budget. Kerosene use increased sharply in 2000 due to the electricity shortage that was necessitated by the long drought.

5.8.7 Vulnerability Assessment

Changes in river flows can be attributed to changes in rainfall and hence climate, with high flows being correlated positively with high rainfall upstream of a particular river basin. A typical time series plot of flows for the Embu sub-basin of the upper River Tana basin indicates that there has been a general decline in flows between 1961 and 1995, from an average 50 million cubic metres per second during the period 1961-1971 to just under 25 million cubic metres per second in the early 1990s. This decline shows that climate variability has been sporadic and is expected to continue. However, in 1998, heavy rains pounded

Table 5.21: Petroleum supply and demand balance, 1995 - 1999 ('000 Tones)

	1995	1996	1997	1998	1999*
Demand-					
Liquefied petroleum gas ..	31.2	31.2	30.7	31.3	32.2
Motor spirit (premium and regular)	378.7	399.3	390.6	395.8	384.6
Aviation spirit	5.7	4.6	4.1	3.2	2.5
Jet/turbo fuel	433.7	444.6	431.9	419.4	418.7
Illuminating kerosene ..	243.1	253.8	267.6	318.2	406.8
Light diesel oil	603.1	646.3	615.9	607.5	601.7
Heavy diesel oil	23.5	26.6	47.6	26.4	25.4
Fuel oil	347.5	424.2	386.9	397.3	439.4
Total	2,066.5	2,230.5	2,175.2	2,199.1	2,311.6
Refinery usage	92.7	102.8	93.6	94.1	90.2
Total domestic demand	2,159.2	2,333.3	2,268.9	2,293.2	2,401.8
Exports of petroleum fuels	367.1	450.8	653.0	640.6	627.3
Total demand **	2,526.3	2,784.1	2,921.9	2,933.8	3,029.1
Supply-					
Imports:					
Crude oil	1,680.3	1,412.9	1,833.7	2,157.7	1,132.6
Petroleum fuels	719.7	963.9	893.7	1,387.8	1,250.9
Total	2,400.0	2,376.8	2,727.4	3,545.5	2,383.5
Adjustments***	126.3	407.3	194.5	603.4	645.6
Total supply**	2,526.3	2,784.1	2,921.9	4,148.9	3,029.1

* *Provisional*

** *Difference is due to rounding.*

*** *Adjustment for inventory changes and losses in production*

Source: Ministry of Energy records

most parts of the country leaving a series of damages. This was followed by a drought spell in 2000 which resulted in severe reduction in energy production. It is important, therefore to review the vulnerability and assess the impacts of such variabilities on energy sources so as to formulate policies for managing them. The most vulnerable forms of biomass to the effects of climate change are fuel wood sources since climate controls their distribution and productivity.

Generally, higher rainfall results in higher flow rates and consequently higher power generation since reservoirs and dams will be constantly full of water. Power generation is low during the dry season months (figs. 5.19 and 5.7). However, deviations of water can occur owing to activities upstream of a

Fig. 5.19 Relationship between mean monthly rainfall and power generation for the Tana River Basin for the period 1969-1995

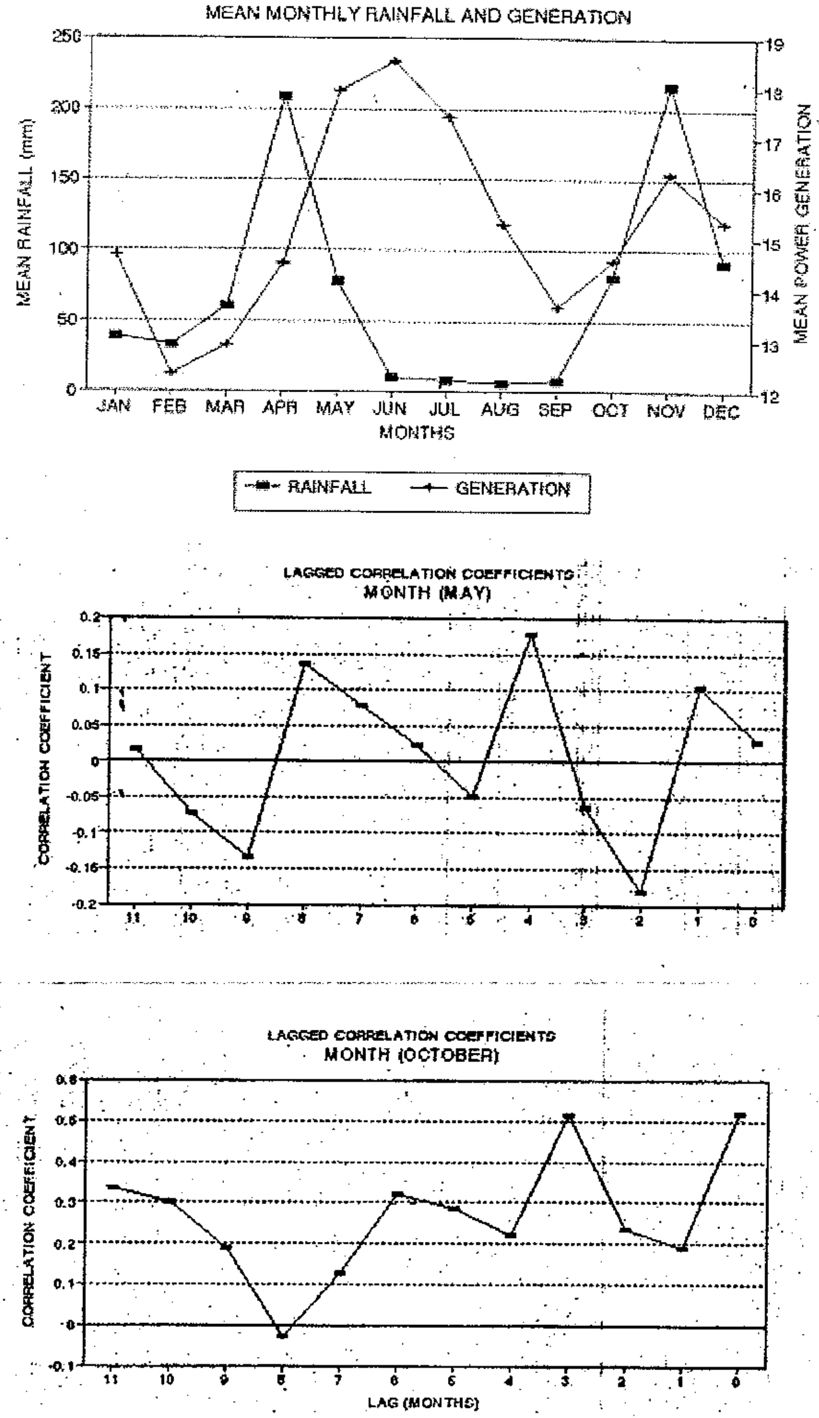


Table 5.22: Impact of climate change on river flows for the upper Tana River basin					
Temp. (T)	Precipitation (P)				
	P+0%	P+20%	P+20%	P-10%	P-20%
T+0° C	Normal	+28.4%	+39.6%	-2.0%	-10.5%
T+1°C	-1.0%	+12.0%	+23.4%	-10.6%	-22.2%
T+2°C	-16.3%	-6.0%	+3.3%	125.9%	-35.6%
T+3°C	-28.2%	-19.7	-11.2%	-36.5%	-45.2%
T+4°C	-31.4%	-23.4%	-15.2%	-39.5%	-47.8%

basin. These activities include land use practices that lead to poor vegetation cover or reduced flows due to diversion of water to irrigation areas.

The water balance model was used to forecast the effects of increased or reduced rainfall, and increased temperature on river flows in the Embu region of the upper River Tana basin. At current temperatures, an increase in rainfall by 20% above the present level is expected to increase flows by up to 40% (table 5.22). However, a reduction in precipitation by the same percentage will decrease flows by up to 10% assuming temperatures remain stable at the present level. The net result will be a negative effect on power generation.

An increase in temperature by 4°C with normal precipitation will lead to a reduction in flows by over 30%. This can be attributed to increased evapotranspiration, aridity and increased use of river water for other purposes such as irrigation agriculture. Reduced river flows will lead to insufficient water in the reservoirs and hence low hydropower production.

The worst scenario, however, is that where climate change will be manifested in temperature increase and rainfall decrease. An increase in temperature by 4°C and decrease in rainfall by up to 20% will decrease river flows by up to 48%. The consequences are paralysis for most operations that use power. In addition, demands for water upstream will more than double, while the combined decrease in rainfall and increase in temperature will aggravate the soil erosion processes in the basin. The result will be a decrease in vegetation cover and increase in sediment load in the water. This will lead to frequent clogging and breakdown of the turbines at the power stations; with resultant frequent power cuts and reduced industrial activity in the country.

Decreased flows are a direct effect of low rainfall and therefore depict conditions of drought. Flows during 1975/76, 1983/84, 1987, and 1993/94 indicate that the country experienced drought, which affected not only agriculture but also power generation. The drought was again experienced in 2000.

Extreme weather events caused by climate change will lead to less reliable supply of electricity. Temperature increase will have a negative effect on power generation from both steam and gas turbines, which rely heavily on availability of cooling water. High temperatures will also lead to an increase in evaporation of water resulting in a decrease in the reservoir levels. Furthermore, there will be an increase in the use of water for irrigation and municipalities upstream of the power stations. The net effect will be reduced electricity production.

Stronger winds will be favourable to plans to expand wind technology and make it affordable to communities. Longer sunshine hours and higher temperatures will favour development of solar power technology, especially in rural areas.

A rise in temperature will necessitate installation of cooling equipment such as air conditioners and refrigerators, thereby increasing demand for power. A decrease in rainfall coupled with a significant increase in water pumping requirements because of increased water need for irrigation, residential, commercial and municipal needs will increase electricity consumption.

5.8.8 Adaptation Options and Strategies

Adaptation options and strategies have been identified for biomass and electrical power production. These are listed below. It must, however, be noted that resources are need to undertake these activities.

5.8.8.1 Biomass

The government in collaboration with other stakeholders showed the intention to:

a) Initiate large-scale aforestation programmes to maintain standing stocks, reduce soil degradation and reclaim soil fertility.
b) Curb deforestation activities.
c) Encourage use of efficient stoves.
d) Encourage use of alternative energy sources such as kerosene, electricity, solar and wind power.
e) Encourage recycling of agricultural crop residues and initiate/support research on large-scale briquetting of rice husks, sugarcane waste and coconut shells for charcoal production.
f) Support and or promote the production and marketing of digesters for biogas production.
g) Coordinate research on energy-related activities between government departments, other institutions and rural farmers.
h) Establish an inventory of fuel wood consumption patterns and practices in Kenya, and also determine rates of deforestation in relation to fuel wood requirements.
i) Encourage agroforestry activities in the rural areas.
j) Encourage research on growth and use of sugarcane, napier grass and papyrus as alternative sources of fuel wood.
k) Encourage production of fuel oil from plants e.g. ethanol from sugarcane, cassava, maize.
l) Intensify efforts to reduce human population growth rate with a view to reducing demand for agricultural land and fuel wood.

These activities will contribute to the sustainable management of biomass resources.

5.8.8.2 Electrical Power Production

The government, in collaboration with relevant stakeholders, will:

a) Support efforts to expand hydropower generation to different parts of the country taking advantage of the various rainfall regimes. The proposed government power development plan for the period 1997-2017 indicates eight additional power generation projects with a combined capacity of 550.5 MW
b) Expand and intensify rural electrification programmes in order to reduce reliance on biomass. The net advantage will be the conservation of forests and vegetation cover as well as protection of the water catchment areas.
c) Expand the exploitation of geothermal reserves in the Rift Valley to reduce reliance on hydropower.
d) Expand electricity production from conventional thermal sources to other towns for use during the dry period. This will reduce transmission costs as well as reduce reliance on hydropower, which is more vulnerable to climate change.
e) Encourage installation of wind power generating equipment for use in generating electricity, and pumping water and driving power mills especially in the rural areas. This will reduce reliance on hydroelectricity.
f) Popularize the use of solar energy for electricity generation and water heating to reduce reliance on hydroelectricity.
g) Expand installation of solar water heaters in residential premises, hostels, hotels, hospitals and industries.

6. CLIMATE CHANGE MITIGATION OPTIONS

6.1 Introduction

Kenya recognizes that it is in her national interest to implement her commitments under the Convention, but the overriding priority is poverty eradication. Consequently, the extent to which Kenya will effectively implement her commitment under the Convention will depend on the effective implementation by developed country parties of their commitments under the Convention related to financial resources (Article 4.3) and transfer of technology (Article 4.5).

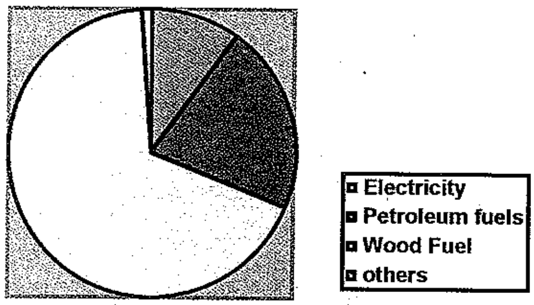
The report of the Climate Change Mitigation study gives a general description of steps taken by Kenya to implement the Convention. With the information provided covering existing policies and legal measures, which abate the increase of emissions of GHGs.

Options for abating increase of GHG emissions are described below for the energy, transport, industry, agriculture, forestry and waste management sectors. Some of the over 70 sectoral statutes in Kenya directly or indirectly contribute to the abatement of emissions of GHG. Most of these statutes were not formulated to specifically address climate change, but the expected positive effects on emissions of GHG are stated.

6.2 Energy Sector

There are three main sources of energy used in Kenya, namely: biomass, petroleum, and electricity. In terms of quantity, wood-fuel accounts for over 70% of the total national consumption and is the principal source of energy for the bulk of the rural population. The wood fuel resource base is rapidly shrinking owing to a great imbalance between demand and supply (figure 6.1).

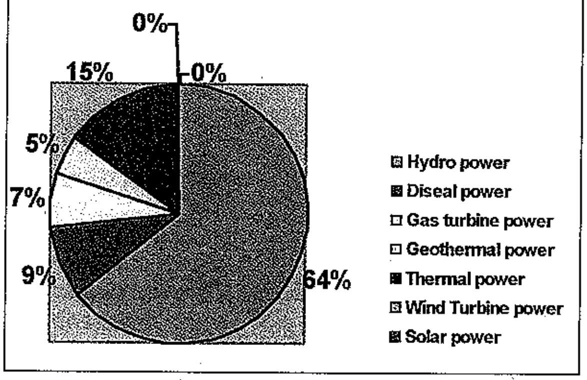
Figure 6.1. National energy consumption



Source: Economic Survey, 2000

Petroleum is the most important conventional energy source accounting for over 23 % of the total national energy consumption. Kenya imports all its petroleum requirements either in form of crude oil or finished petroleum products. Transportation of petroleum products from the port of Mombasa to other parts of the country is via road tankers, rail or oil pipeline.

Figure 6.2. Power generation capacity from various sources as at June 2000



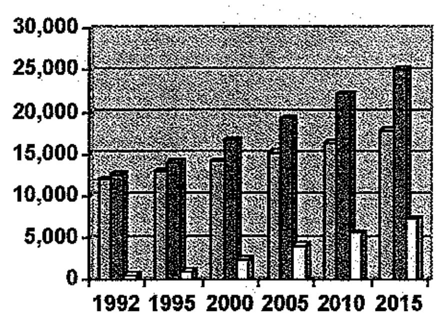
The oil pipeline network extends to the cities of Nairobi, Nakuru, Eldoret and Kisumu. Plans are underway to extend the pipeline to Uganda.

6.2.1 Wood-Fuel

Wood is the major fuel used in the country, particularly by the rural population who make up 80 % of the total national population (table 6.1). However, in terms of modern commercial energy categorization, petroleum-based fuels and electricity are the most important.

Currently, wood-fuel demand surpasses supply. Trends indicate a rapidly diminishing wood-fuel resource base (figure 6.3). Moreover, there is still a widespread use of inefficient conversion devices, including traditional three-stone fireplace for firewood and earth mound charcoal kilns. There is therefore a great potential for energy saving through adoption of improved efficiency stoves and kilns

Fig 6.3. Wood fuel, supply -demand, and deficit



Source: Ministry of Environment and Natural Resources (1994)

6.2.2 Power

Kenya's power generation capacity in the year 2000 was 1048 MW (figure 2.3). Hydropower accounted for over 64 % of the total, while fossil-fired, geothermal and wind accounted for 13.5 %, 5.8 % and less than 0.1 % respectively.

In the short term, diesel-based power generation will gain prominence and is expected to provide an additional capacity of 260 MW compared to 132.5 MW and 128 MW from hydro and geothermal respectively. The bulk of the fossil-based generation will be undertaken by independent power producers (IPP).

6.2.3 Petroleum

Petroleum fuels are an important energy source for the conventional economic activities and contribute about 22 % of the total primary energy consumed. It is also a major source of modern energy requirements. In 1999, it accounted for 72.2 % of total modern energy consumed. Fossil fuel accounts for a significant proportion of the national import bill. The transport sector is the major consumer of the petroleum fuels. In 1999, imports of petroleum products declined to 2,425.8 from 3,585.8 thousand tonnes in 1998 (table 6.2).

6.2.4 Solar, Wind and Biogas Energy Sources

The exploitation of solar, wind, and biogas energy, is still very low in spite of existing great potential. These renewable sources of energy are free of greenhouse gases emissions. Their accelerated use would therefore result in avoidance of substantial GHG emissions. This source should therefore be the preferred climate change mitigation option.

Table 6.1: Energy consumption by primary source for selected years ('000 TOE)

Energy source	1988	1990	1991	1993	1995
Fuel-wood	4,127	4,379	4,510	4,785	5,076
Charcoal	910	998	1,045	1,145	1,256
Coal and coke	79	106	94	88	97
Petroleum oil	1,809	1,830	1,755	1,826	2,067
Electricity	661	731	771	849	872
Total	7,586	8,044	8,175	8,693	9,368

Source: Economic abstract (2001), Ministry of Energy

Table 6.2. Quantity of imports and exports of petroleum products 1995 - 1999 (000 tonnes)					
Imports	1995	1996	1997	1998	1999
Crude petroleum	1680.33	1412.95	1833.73	2157.70	1132.62
Petroleum fuels	719.73	963.85	895.65	1387.81	1250.90
Lubricating oils	24.81	30.92	29.51	38.16	41.50
Lub. greases	4.54	0.39	0.29	2.17	0.80
Total	**2429.41**	**2408.11**	**2759.19**	**3585.84**	**2425.82**
Exports					
Petroleum fuels	367.10	450.80	652.99	640.59	627.25
Lubricating oils	8.71	8.41	9.67	8.13	3.93
Lub. greases	0.28	0.26	0.17	0.19	0.20
Total	376.09	459.47	662.83	648.91	631.38
Net Balance	**2053.32**	**1948.64**	**2096.36**	**2936.93**	**1794.44**
Source: Central Bureau of Statistic (2001)					

a) Solar: The solar energy resource is currently generally under-exploited, though widely regarded as a plausible option to stimulate rural electrification. Solar energy is being exploited in Kenya for lighting (photovoltaic), water pumping (mechanical), refrigeration, and water heating (solar water heaters). By end of 1986, some 30 solar water pumps were operational in various districts, particularly in the arid zones of the country. Adoption of solar energy technologies by the private sector, especially the solar photovoltaic has gradually been picking up momentum. By the end of 1997, some 80,000 solar electric systems had been installed in rural homes. In fact sales of solar electric systems have increased rapidly since 1990s. In 1997 alone, 18,000 solar panels were sold. The solar market is currently estimated to be worth KSh. 250 million per year. A solar photovoltaic policy framework and strategy is being developed under the power sector reorganisation programme.

b) Wind: Wind energy remains largely under-developed and under-exploited. Information about the status of its exploitation is scanty and mostly outdated. Wind energy applications, especially the mechanical aspect have a long history in Kenya. In 1986, there were over 200 working windmills in Kenya of which about 100 were in Lamu and Mombasa districts. Local expertise for fabrication of windmills, especially for water pumping is available in the private sector. The government has renewed attention to the development of wind energy resource. A project on the development of a national wind-zoning atlas is ongoing. This will provide useful information to facilitate private sector investment in this important energy sub-sector.

c) Biogas: Biogas technology for cooking and lighting gained momentum in the mid-1980s during the German-funded Special Energy Project. Active promotion of biogas resulted in an estimated 1,000 biogas plants being constructed and in use by 1995. Most of these plants are found in the agriculturally high potential parts of Kenya.

6.2.5 Energy Conservation

Since mid-1980s, energy conservation has been promoted at domestic, institutional and industrial levels. At the household level energy conservation is being achieved through the use of improved efficient cook stoves. The efficiency improvement is based on existing household energy end-use devices, namely: the traditional metallic charcoal stove and the three-stone fireplace for fuel-wood. For charcoal burning, the Kenya Ceramic Jiko (KCJ) is promoted, while for fuel-wood conversion, two brands of improved stoves are being promoted, namely *Kuni Mbili* and *Maendeleo* Stoves. About 250,000 KCJ had been made and sold by 1986 by the Kenya Renewable Energy Development Project (KREDP). Over 800,000 KCJ stoves had been distributed through direct intervention of government extension service and an estimated similar amount through the private and NGO sectors. It is also estimated that about 400,000 *Maendeleo* stoves were installed in rural homes by end of 1996. Forty (40) *Maendeleo* stove production centres had been established by end of 1994 in various strategic locations throughout the country to serve as commercial promotional focal points.

At the industrial and institutional levels, energy conservation is promoted through the use of energy audits (to identify potential energy efficiency improvements) and improved efficiency institutional stoves. In this regard, the institutional ceramic lined stove models formerly developed by the Bellerive Foundation have been actively promoted in schools and other institutions.

Other energy conservation measures being practised include the use of fireless cookers and a variety of good energy house-keeping practices. The fireless cookers operate on the principle of thermal insulation whereby food is brought to a boil and then transferred into a carefully insulated basket or box to complete the cooking process using the trapped heat. It has been shown that fuel savings of up to 40 % were realizable depending on the nature and type of foodstuff.

6.2.6 Current Policy

The important role energy plays in national development and the need to overcome the present energy resource constraints presents both a challenge and an opportunity to energy policy formulation. The overall national policy objectives in energy are to:

a) Ensure that adequate supplies of energy are made available efficiently and at reasonable costs in line with national development needs.
b) Promote conservation of all forms of energy by eliminating wasteful consumption and maximizing the efficiency with which energy is used in all sectors of the economy.
c) Intensify the search for indigenous fossil energy, particularly oil by maintaining the present incentives and periodically reviewing them as circumstances may dictate.
d) Continue rapid development of domestic hydro and geothermal power for electricity generation.
e) Provide electricity to all parts of the country, cheaply and to as many people as possible, while time ensuring that adequate funds are generated to finance further expansion.
f) Increase wood production under both on-farm and plantation systems and also enhance efficiency of wood fuel utilization at the conversion and end use levels.
g) Encourage, wherever possible, domestic fuel substitution.
h) Promote alternative energy sources to broaden the national energy mix and lessen dependence on imported energy.
i) Encourage regional cooperation in the field of energy development and marketing.
j) Train human resources for all levels to facilitate the development and adoption of relevant energy technologies.
k) Rationalize the institutional arrangements to ensure coordination and avoid duplication of efforts and inefficient use of meager resources.
l) Ensure that an efficient and adequate distribution network exists for all forms of energy.

6.2.7 General Steps taken that contribute to the Implementation of the Convention in the Energy Sector

The energy sector contributes significantly to greenhouse gases emission through combustion of fossil fuels for energy. Various activities have been undertaken in Kenya since the signing and ratification of the UNFCCC, with active participation of NCCACC.

Two GHG inventory studies have been undertaken, namely the US-funded Studies on Climate Change and the UNDP/GEF-funded Capacity Building in Sub-Sahara Africa to respond to UNFCCC. The latter covered the years 1990 to 1995, while the former covered 1989 to 1992. The inventories identified the main types of GHG and their sources.

The initial activity of the Capacity Building project was a review of existing policies and measures that are inherently affecting the global climate change. In the energy sector, the following policies and measures were identified.

a) *Enhanced Importation of Refined Oil Products:* The current national oil refining facility is old and inefficient and contributes substantially to emission of GHG. Refined petroleum products are associated with lower emissions compared to crude oil refining.

b) *Extension of Oil Pipeline:* The oil pipeline is being extended to link up more areas within and beyond the national boundaries. The transportation of white oils through the pipeline reduces fugitive greenhouse gas emissions in addition to reducing the need for road tankers, which would otherwise emit substantial quantities of GHG. It is environmentally friendlier than rail or road transport.

c) *Rapid Development of Domestic Hydro and Geothermal Resource:* The government supports continued exploration and development of hydro and geothermal resources. Since both sources emit low levels of greenhouse gases their development will result in avoidance of emissions compared to fossil fuel-based electricity sources.

d) *Rural Electrification:* Rural electrification efforts have been strengthened with the aim of providing electricity to all parts of the country. If rural electrification can result in reduced burning of kerosene for cooking and lighting then there will be reduced potential emissions of greenhouse gases.

e) The new Electrical Power Act requires environmental impact assessments for all major energy development projects. Under the rural electrification programme, there is a strong emphasis on efficiency-improvement for all system components including system losses reduction and a demand side-management (DSM).

f) Under the rural electrification programme, some 61,436 consumers have been connected to the grid supply as at the end of 1999. Additionally, the stabilization of exports is funding the electrification of the coffee factories through the coffee rural electrification programme (COFREP). Under Phase I of the above scheme 57 out of the 68 coffee factories have been connected to the electric power-grid. KSh. 360 million is earmarked for the COFREP scheme.

g) *Increased On-farm Wood fuel Production and End-use Energy Conservation:* Wood fuel resource base will be enhanced through on-farm fuel-wood production. At the same time consumers are encouraged to use the most efficient fuel devices. The long-term effect will be an increased GHG sink and reduced consumption of wood fuel.

h) *Promotion of Conservation of All Forms of Energy:* The policy encourages rational use of energy through the promotion of improved energy efficient end-use energy conversion devices. These include cook stoves, kilns, fireless cookers and more efficient lighting devices. Other methods of achieving the energy conservation objective will be the promotion and awareness raising on better house keeping measures such as switching off lights when not needed and periodical energy audits.

i) *Encouraging Domestic Fuel Substitution and Development of Renewable Sources of Energy:* The policy supports the development of alternative energy sources, including solar, wind, biogas, and mini/micro hydro. Development of these sources should ultimately increase the share of clean energy in the overall energy supply and thereby result in GHG emission avoidance.

j) *National Energy Taskforce:* A national energy taskforce has been established to articulate the role of the energy sector in light of UNFCCC. This taskforce is made up of representatives of key stakeholders in energy, including line government departments, civil society organisations bilateral and multilateral development partners based in the country, and the private sector. The purpose of the taskforce is to facilitate the sharing of information and ideas in order to enhance each stake holder's participation in the Convention activities.

k) *Ministerial Taskforce:* A ministerial committee has been established to deal with matters of climate change, particularly by sensitizing policymakers about the current climate change issues that require their attention and action.

6.2.8 On-going and Planned Activities

a) *Wood Fuel Resource Promotion and Replenishment Programme:* The programme encourages rural residents to incorporate biomass crops into their farming activities to take care of their future biomass energy needs. If many farmers respond positively then there will generally be an increase in the biomass cover over most parts of the country. This will increase the carbon sequestration.

b) *Research and Development of Fuel-efficient*

Burners: The main component of this programme is the dissemination of KCJ and the "Maendeleo" stove. As more and more households adopt these stoves, consumption of wood or charcoal will fall. The savings can be translated into conservation of woody biomass, which in turn will have a positive impact on GHG sinks. Currently, the level of penetration is in the region of 30 % of the targeted population.

c) *Household Energy, Solar PV and LPG Standardisation Studies:* Three studies are being undertaken to develop a household energy strategy, identify inherent barriers against fast adoption of solar photovoltaic and standardising the LPG cylinders to facilitate easy gas refills. The results of studies will be used to formulate focused policy measures for abating and/or avoiding the potential GHG emissions.

d) *Review of the Petroleum Act:* The Petroleum Act is currently being reviewed in order to strengthen the management of the petroleum industry. The review will focus on environmental safety concerns and stringent measures for curbing pollution. The Environmental Management and Co-ordination Act of 1999 provides for a thorough assessment of energy projects using petroleum products.

e) *Feasibility Studies on Mini/Micro Hydro Technology:* Preliminary results from a pilot mini/micro hydro feasibility study in Meru District, as a stand-alone option for community power supply has been a great success. Consequently, in areas with suitable sites, the mini/micro hydro technology can be a useful alternative source of power for neighbourhoods. This source of energy is GHG emission-free and therefore may positively contribute to GHG avoidance.

f) *Development of Renewable Energy Technology Standards:* Standards are being developed for solar batteries, solar cells and wind generators by the Kenya Bureau of Standards (KEBS) in collaboration with the Ministry of Energy (MOE) and representatives from the renewable energy sector. The standards are intended to remove sub-standard products from the market, enhance efficiency in harnessing solar and wind energy resources and increase competitiveness of Kenyan manufactured solar and wind harnessing devices.

g) *Wind Energy Resource Atlas (WERA):* The wind resource atlas will inventory suitable wind energy potential sites. It will also rank and undertake detailed site investigations on the selected highest potential sites. Potential investors in making investment decisions will use the resulting atlas. Increased investment in the development of wind energy resource will increase Kenya's total clean energy supply.

h) *Regional Power Inter-connections:* The Kenya government is supporting a feasibility study of a power line from Nairobi to Arusha, which is aimed at tapping power generation capacity in the SADC sub-region. If this is achieved, it will result to GHG avoidance from thermal power options in the absence of the inter-connection.

i) *Promotion of Compact Fluorescent Lamps (CFLs):* The Kenya Power and Lighting Company (KPLC), is promoting efficient light bulbs, such as CFLs to replace the incandescent lamps. The former are 75 % more efficient than the latter. If the above action is achieved, it will have positive impact on GHG emission avoidance.

6.2.9 Potential Projects

The energy sector will participate actively in the abatement of adverse climate change effects, while fulfilling the national energy development objectives. In this regard, two projects have been proposed, as described hereunder.

a) Strengthening and Expanding District Energy Development Programme

The project objectives and strategies are to:

i) Strengthen and establish additional energy centres in the most critical districts.
ii) Set up demonstration facilities in each new energy centre. The facilities in each case include improved cook stove training workshop, biogas unit, solar PV, solar box cookers, a multipurpose tree nursery and an agro-forestry demonstration farm.
iii) Establish a district information resource centre in the existing energy centres as well as in those to be established.

iv) Extend the use of fuel-efficient cook stoves to the communities through an organised dissemination programme.

b) Kenya Renewable Energy Technology Development Programme: Solar-based Rural Electrification Project

The goal of this project is to replace kerosene lamps with solar photovoltaic lighting in rural areas, which do not have foreseeable prospects of getting supplied from the national electricity grid system. The project objectives are to:

i) Create an enabling infrastructure for mass acquisition and utilisation of solar photovoltaic for domestic purposes.
ii) Develop local capacity in installation and maintenance of photovoltaic modules.
iii) Develop institutional technical capacity for appraising and evaluating the solar PV modules in the aspects of quality standards.
iv) Enable the government participate and reap benefits from the flexible convention mechanisms.

6.3 The Transport Sector

Motorized road and railway transport are the principal sources of greenhouse gases (GHG). The sector accounts for 56% of the fossil fuels consumed nationally. This is likely to rise in the future due to the rapidly rising demand for motorized road and rail transport. Road transport in Kenya has grown by an annual rate of 4%.

The main GHG from the sector are carbon dioxide (CO_2), non-methane volatile compounds (NMVOC's), NO_x, and nitrous oxide (N_2O). CO_2 is the major GHG. It is, therefore necessary to identify response measures that will lead to the control of CO_2 emission from these modes of transport.

6.3.1 Motorized Road and Rail Transport

Table 6.3 presents an estimate of vehicle population and emissions of carbon dioxide for the period 1992-2001 based on annual growth rates of 3.9% for motor vehicle and 12.6% for CO_2 emission. Kenya's railway network has a 2,700 km long single track, including the Magadi strip. There are a total of 242 locomotives, but only 147 are operational.

6.3.2 Policy and Legal Measures

There are no Policies and laws that directly address GHG emissions. Some provisions in the statutes, which though not enacted specifically for GHG abatement, directly or indirectly, do so. These provisions are in the Traffic Act (Cap 403), the Environmental Management and Coordination Act, and the Local Government Act.

a) *Rule 26 of the Traffic Act*: This rule states that "Every vehicle propelled by an internal combustion engine or a compression ignition engine shall be constructed that the exhaust gases from the engine cannot escape into the atmosphere without first passing through a silencer, expansion chamber or other contrivance suitable and sufficient for reducing

Table 6.3. Statistics on fuel consumption, vehicle population and the carbon dioxide emissions between 1992-2001

Year	Fuel consumed by the transport sector (million tones)	Vehicle Population	CO_2 emission (Gigagrams)
1992	940,224	385,636	714
1993	925,536	398,056	1069
1994	963,498	389,141	1025
1995	967,027	431,344	1074
1996	1,015,138	464,547	1210
1997	1,066,463	482,459	1363
1998	1,124,69	501,062	1535
1999	1,183,031	520,382	1729
2000	1,245,144	540,447	1947
2001	1,311,305	561,286	2194

as far as may be reasonable the noise which would otherwise be caused by the escape of the gases." Leaky and noisy exhaust pipes normally lead to the emission of half-burnt fuels, which are rich in monoxides. Enforcement of this rule will curb this.

b) *Rule 27 (1) of the Traffic Act:* This rule states that "Every motor vehicle shall be constructed, maintained and used so that no smoke or visible vapour is emitted therefrom". This law calls for strict maintenance of vehicles. A well-maintained vehicle has higher fuel efficiency and lower emissions.

c) *Section 51 (1) of the Traffic Act*: The section states that "No fuel shall be used in any motor vehicle except that specified in the vehicle license of such a vehicle." Use of the recommended fuels helps a vehicle meet the efficiency it was made for. High vehicle efficiency is an important abatement factor.

d) *Inspection:* It is a legal requirement for all commercial vehicles to be subjected to annual inspection by the Directorate of Motor Vehicle inspectorate. One of the items in the checklist is smoke emission. This is important, as smoke from the tail pipe is associated with high emissions. There is urgent need to continuously improve and update the inspection technology. The methods currently in use are "visual, audio, touch and feel" which are highly susceptible to human error and external influences. Computerised technology is highly desirable.

e) *Import Duty License Fees:* The government policy is to impose low tax rates on small engine capacities and high rate on big capacity engines. This policy is intended to discourage the high capacity engines as they emit much larger volumes of gases.

f) *Railway Transport:* The government policy is to extend the length of the rail lines in the country considerably. The following lines have been proposed Eldoret-Kerio Valley; Kericho-Kisii and Nanyuki-Meru. This expansion is intended to reduce motorized road transport especially of goods. This is a positive abatement measures, as it will mean more people travelling by rail and also ridding the roads of the heavily emitting trailers.

6.3.3 Non-Motorized and Efficient Transport Flow

a) *ByPasses:* The government is committed to building road bypasses around towns to ease traffic congestion in order to reduce fuel wastage, especially during peak hours. Wasted fuels lead to high emissions. Bypasses in Sagana, Naivasha, Voi and Thika have been a big success.

b) *An Act of Parliament established The Road Maintenance Fund* in 1994 to avail a reliable source of money for maintaining the road network in the country. Properly maintained roads ensure high efficiency of vehicles. Efficient vehicles emit less GHG.

c) *Animal Transport:* The government encourages use of animals for transport, particularly in remote areas. The government in some districts, e.g., Lamu has its own animals with government registration and records to log in their official travel schedules. This is an important abatement factor as vehicles in remote areas are poorly maintained because spare parts are not readily available.

d) *Use of Bicycles:* The government has zero-rated duty on bicycles thereby encouraging their use. Consequently, in some parts of the country bicycles are used as taxis e.g. Busia and Kisumu. This is an important abatement factor as it reduces over reliance on motorized transport.

e) *Walking:* It is government policy to construct pedestrian walking paths in major towns in the country. This is a positive abatement measure as it reduces reliance on driving and overloading of public transport inside the towns.

f) *Hand-drawn Transport:* Handcarts, which are operated in town centres, are required to be licensed through the Local Government Act. This shows that the government recognizes their role. Handcarts are cheap and environmental friendly.

g) *Marine Transport:* Lake Victoria is the biggest fresh water lake in Africa. The three Eastern Africa countries – Kenya, Uganda and Tanzania, share it. The mode of transport on the lake is by hand rowed boats, single engine boats and steamers. The railways, the Police, Fisheries Department and some commercial fishermen, public boat transport owners and the Kenya Railway Corporation that operates a cargo own the motorized boats. The motorized boat statistics is not reliable and cannot therefore be used to assess their level of GHG emissions or their abatement for any useful abatement assessment purposes. Laws on pollution in the lake exist but are not applied strictly. The relevant covenants include the Tripartite Agreement on Inland Water Way Transport (Article IV and V) between Kenya, Uganda and Tanzania.

6.3.4 Adopted Policy Measures

a) Government Policies: The government's vision is to ensure that vehicles on roads meet high environmental standards, especially with regard to emissions of gases that have deleterious effects on climate. To meet these high environmental standards the government has identified some measures for implementations, including the following:

i) Amendment of the Traffic Act (Cap 403).
ii) Enforcement of the Vehicle Inspection Manual (July 1999).
iii) Amendments made in 2000-2001 on pre-shipment inspection requirements for imported vehicles will be incorporated in the vehicle Inspection Manual.
iv) A Coe of Practice for Inspection of Road Vehicles (DSK 06 -1515 – 1999) of the Kenya Bureau of Standards is expected to be adopted and implemented in due course.
v) The Kenya Bureau of Standards K506 – 849 "Road Vehicles – Measure of Smoke Opacity and KS ISO 6718 – 2 "Road Vehicles – Ignition System is under review.
vi) A permanent National Mobile Transport Vehicle Inspection Unit is operational.

The above measures should contribute to well-maintained vehicles and subsequent reduction in emission of GHG.

b) Planning of Estates: Planning of residential estates should enhance convenience with regard to sitting of the roads and footpaths to shopping centres, schools, offices, etc. Planning should also lessen travel distances and encourage less driving and consequently lessen GHG emissions. The Land Act, the Nairobi City Council By-laws, The Nairobi Metropolitan Growth Strategy (1973) and the ongoing Kenya Urban Transport and Infrastructure Project set the general growth patterns for the City of Nairobi.

c) Construction of Fly-over, Ring and By- Pass Roads: In major towns such as Nairobi and Mombasa, there are systems of bypasses for use by inter-city traffic to reduce traffic congestion. Congestion, especially during peak hours leads to wasted fuels. It was estimated that at least 50 million vehicle-hours would be lost in year 2002. This translates to an estimated 63 million litres of fuel worth US$ 25m. This will lead to much more emission of CO_2. Constructions of bypasses will lead to CO_2 abatement.

d) Missing Road Links: The government policies are for the development of road links that reduce distances traveled not only within Kenya, but also with countries in the Greater East African Region.

6.3.5 Measures Under Consideration

a) *Encouragement of Mass Transport:* Employers will be encouraged to provide home to office transport with attractive incentives. Similarly, more school transport companies will be encouraged. This will lead to less vehicles on the road and less emissions.

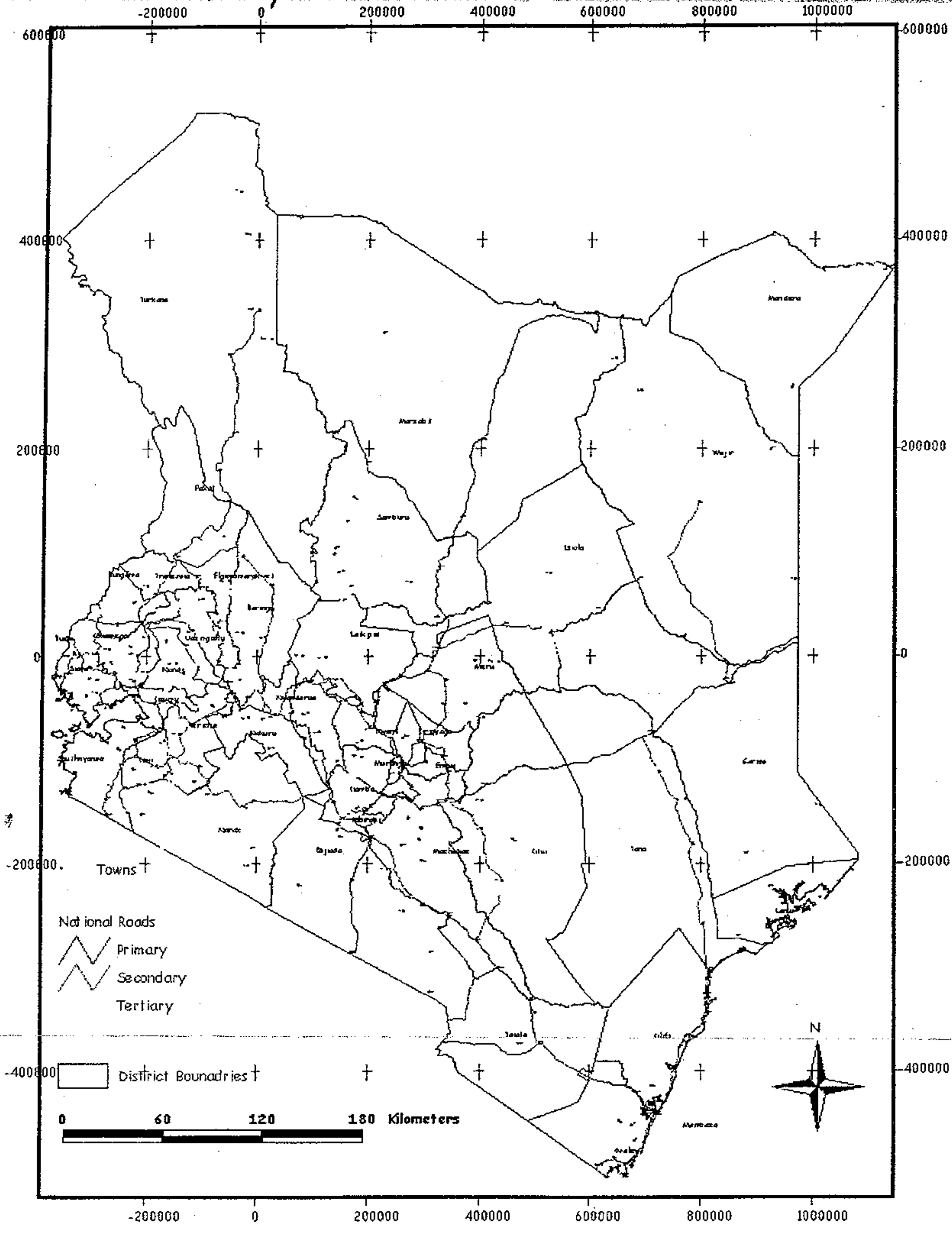
b) *Tuning of Vehicles:* Campaigns on the advantages of keeping cars well tuned for economical use of fuel and reduction of emissions is actively being considered for promotion through driving schools.

c) *Improvement of Telecommunications to Reduce Commuting by Vehicles:* It is necessary to popularize and give incentives to the people to use facilities like e-mail, telefax, mobile phones and teleconference to reduce business trips. This will reduce unnecessary usage of motor vehicles and consequently CO_2 abatement.

d) *Traffic Management:* To ease the congestion of vehicles during peak hours, some of the following measures will be undertaken: improving and making traffic lights more effective, construction of bays for buses, pedestrian lanes, bicycle lanes, etc. Other measures include bicycle-parking areas. The popularization of these measures through campaigns will need to be initiated and sustained. By avoiding vehicle pile-ups during peak hours, the level of emissions of GHG, which is at its worst during pile-ups, will be lowered.

e) *Non-motorized Transport:* The national development plan for 2001 – 2008 incorporates climate change concerns. It promotes the use of appropriated technology in the production of non-motorized transport equipment. This effort has been supplemented by NGOs who are already

Kenyan National Road Network



implementing some pilot projects, including development of a multipurpose bicycle by the Intermediate Technology Development Group of Nairobi. The bicycle is now in use in western Kenya. The Kisumu Innovation Centre and the Kenya Network for Draught Animal Technology have been concerned with technology for animal power transport and work on the farm.

f) *Course on Fuel Efficiency in Driving Schools Curricula:* The inclusion of a course on fuel efficiency use should lead to reduced GHG emission. The National Road Safety Council and the Petroleum Institute of East Africa will provide leadership in the revision of the driving course curricula to include fuel efficiency.

g) *Better Parking Arrangements in Major Towns:* It has been suggested that parking spaces should be developed at the outskirts of the major towns so as to decongest the town centres from traffic jams. The motorists would be encouraged to park in these spaces and either walk to their offices or take public transport.

h) *Environmental Standard for Transit Vehicles:* The regulations of the Common Market for Eastern and Southern Africa (COMESA), the East African Community (Article XI) and the Northern Corridor Agreement (Protocol number 6), say that a citizen/enterprise of a member state, engaged in transit operations through another, shall comply with the national laws and regulations of the transit country. This mitigating measure should be strictly applied.

i) *Compulsory Inspection of All Vehicles:* The government will make annual inspection of all vehicles mandatory. This move will ensure that all vehicles on the roads are in good condition and consequently emissions are reduced. The technology for inspection will be continuously updated for good results.

6.3.6 Measures Being Implemented

a) *Promotion of Rail Transport:* The Kenya Railways Corporation is conducting a campaign to popularize rail transport and is also considering giving out incentives to potential clients. Railway transport if popularized, will reduce the heavily emitting road trailers. Railway commuter services, which are available in Nairobi, are planned for other major towns.

b) *Fuel Pipeline Transport:* The Kenya Pipeline Company has so far built an oil pipeline from Mombasa to Kisumu and Eldoret. Plans are underway to extend it form Eldoret to Uganda. This mode of transport provides the economy with an emission-free, reasonably safe, cheap and reliable mode of transport, which also contributes to the reduction of road damage. It is envisioned that the pipeline will reduce the number of trailers that haul oil to neighbouring countries. The number of trailers, which have been replaced by the pipeline in a year, is not known, but its advantages over road transport are enormous.

c) *Taxation and Registration Fees:* Fuel consumption levy imposes a burden that increases with a vehicle's relative fuel consumption. This measure offers incentives to buy energy efficient vehicles and thereby reduces the relative CO_2 emissions per km. The government also seeks to strengthen the anti-dumping laws. A tax has been introduced for all imported vehicles not older than 8 years. Importation of vehicles older than 8 years has been banned. The tax increase is intended to discourage importation of old vehicles, which heavily emit gases.

d) *Protection of Environment from Transport Pollution:* The Environmental Management and Co-ordination Act which came into force in January 2000 addresses the issue of pollution of the environment by the transport sector, amongst others issues.

6.3.7 Conclusions and Way Forward

Transportation encompasses a complex set of activities operating at different geographic scales. Future studies should adopt several approaches, each directed at different questions, different decision makers, and different scale analysis. The studies should focus on:

a) *Demand Forecasting:* Projections on travel and freight movement and impacts of changes in fuel prices on economic activity or on the amount of travel or freight movement and hence GHG emissions.

b) *Vehicle Stock Analysis:* Impact of change in the vehicle technology (fuel economy, fuel type, emission controls) on fuel use and emissions.

c) *Transport Planning and Management:* Management of infrastructure and vehicle flow to reduce congestion and improve efficiency. The study should also give an indication on the investments needed to meet additional demand for transportation or to improve efficiency.

d) Data: Data needs to be collected and to be exchanged between the various authorities that deal with transport, e.g., the Registrar of Motor Vehicles, the Ministry of Road and Public Work, and the Ministry of Transport and Communication.

e) Models: There is an urgent need for trained manpower in the area of modeling.

f) Technology: There is need to acquire and update technology, especially in the area of motor inspection..

g) Funding: There is need for funding to undertake the various activities.

6.4 The Agriculture Sector

Kenya relies heavily on agriculture for food security, economic growth, employment creation, stimulation of growth in off-farm employment, and foreign exchange earnings. About 80% of Kenya's population live in rural areas and depend directly or indirectly on agriculture for their livelihoods.

Tremendous development has been realized in the agriculture sector due to a number of factors, such as expansion in area under cultivation albeit of more marginal quality and easily degraded land, subdivision of large farms in high potential areas into more intensively cultivated small-scale farms, government investment in research and development (R&D), training of personnel and adoption of high yielding crop varieties and animal breeds.

There have been noticeable cases of land degradation. For example, improper use of agro-chemicals have polluted water sources, poisoned and compacted soils. At the same time, inappropriate tillage methods and cropping practices have accelerated environmental degradation. Unsustainable land-use practices have severely reduced the potential of some areas. There is therefore need for efficient and appropriate use of fertilizer, pesticides, tillage methods, and cropping practices in order to reduce or control degradation. However, agricultural intensification is likely to put additional pressure on water, soil, forestry and wildlife resources and has potential to increase emissions of anthropogenic greenhouse gases (GHG) into the atmosphere.

6.4.1.1 Baseline Situation

Over 75% of agriculture is practiced by smallholders farmers presently characterized by use of low farm inputs, low yields, low level of crop and animal husbandry. Fertilizer application is low, averaging 25kg/ha. Application of synthetic fertilizers is the largest source of nitrous oxide in the agriculture sector. The most commonly used fertilizer include N-based, phosphates and sulphates. They are used in the production of major crops such as maize, tea, coffee, sugar cane, and rice. Maize is cultivated in all the high and medium potential agricultural zone, but is more intensively grown in parts of Rift valley, Nyanza and Western provinces. Tea and coffee are grown in central Kenya and parts of Rift Valley, Nyanza and Western provinces. Rice is cultivated mainly in irrigation schemes such as Mwea, Ahero, Kano, Bunyala, Perkerra and River Tana delta. The area under paddy rice cultivation is approximately 9,000 hectares. The main types of fertilizers used to enhance rice production include sulphate of ammonia and triple super phosphate. Livestock development encompasses beef cattle, dairy cattle, sheep, goats, pigs, camels, donkeys and poultry. Livestock development activities contribute to emission of methane into the atmosphere. Methane is also emitted from sugar cane cultivation and bagasse production.

The methane emission from agriculture in 1992 was 576 Gg. Enteric fermentation and synthetic fertilizer are the largest sources of methane and nitrous oxide respectively in the agriculture sector.

6.4.1.2 Existing Policies and Legal Measures

The framework Environmental Management and Coordination Act of 1999 has provisions for the protection and proper use of land. Other environmental management measures are found in various statutes. Some of the provisions, which directly or indirectly mitigate climate change, are described below.

a) Agriculture Act (Cap. 318): The Act gives the minister responsible for agriculture extensive powers to make rules for purpose of conservation of soil and good land management. Soil conservation measures emphasize tree planting and prohibit crop cultivation on land with steep gradients. These provisions contribute directly to mitigation of climate change since trees act as sinks for CO_2 and undisturbed soils are a reservoir for carbon.

b) Water Act (Cap. 376): The Act mandates the minister responsible for water resources to ensure that certain water catchment areas are protected. The minister is also mandated to declare such areas as water catchment areas. Water catchment areas are mainly located in forested lands and by protecting the forests, the Water Act contributes indirectly to sequestration of CO_2.

c) *River Authorities Act (Cap. 443):* The Act empowers all existing river authorities to, inter alia, construct any works necessary for the protection and utilization of water and soils of areas along riverbanks. Fallow land acts as a reservoir of terrestrial carbon, while trees and vegetation growing along riverbanks sequester carbon dioxide.

d) *Maritime Zone Act (Cap. 371):* The Act provides that Kenya's Exclusive Economic Zone extends up to 200 nautical miles. The coastal zone is the home of wetlands and mangrove forests, which act as sinks of GHG, while the seabed is known to contain different types of vegetation such as sea grass that sequester carbon dioxide.

e) *Grass Fires Act (Cap. 327):* The Act prevents the starting of fires without authority.

6.4.2 Sources of GHG

The main sources of methane emissions into the atmosphere from the agriculture sector include animal husbandry (enteric fermentation and animal wastes), sugar cane plantations and bagasse production. Enteric fermentation and synthetic fertilizer application have been the largest sources of methane and nitrous oxide respectively. Nitrous oxide is produced primarily from microbial processes, nitrification and denitrification in the soil. The main source of nitrous oxide emissions in Kenya is application of synthetic fertilizers. Methane and nitrous oxide are also released into the atmosphere in the process of burning savannah grasslands and scrubland.

6.4.2.1. Methane from Rice and Sugar-cane Production and Animal Husbandry

Paddy rice is grown mainly for local consumption and on an area approximately 9,000 hectares. The main types of fertilizers used to enhance rice production are triple super phosphate (TSP) and sulphate of ammonia (SA). TSP is used during transplanting, while SA is used for top dressing. Two bags each of 50kg/acre of TSP and three bags each of 50kg/acre of SA are used respectively to grow Basmati rice in Mwea Irrigation Scheme, while in Ahero, West Kano, and Bunyala three bags each of 50kg/acre of SA are used to grow non aromatic rice.

Methane emissions from sugar cane cultivation and bagasse production have not been estimated in Kenya. However, technologies exist for harnessing methane from these sources for heating purposes. Bagasse production from Chemelil, Muhoroni, Mumias, Nzoia, Sony, Miwani, and West Kenya sugar companies for the period 1994 –1998 are shown in table 6.4.

Animal husbandry emits methane from two main sources: enteric fermentation (the digestive processes of animals) manure management processes, and anaerobic decay. The number of livestock producing methane are 3,203,900 dairy cattle, 8,952,500 beef cattle, 6,054,210 sheep, 9,626,263 goats, 182,598 pigs, 858,438 camels, 3,186,250 poultry, and 317,280 donkeys. Enteric fermentation emissions depend mainly on the quality and quantity of feed consumed by ruminant animals. Non-ruminant livestock, which include horses and poultry, produce relatively small amounts of methane from enteric fermentation. Enteric fermentation is the largest CH_4 emitter in the agriculture sector, contributing 549 Gg.

Manure related emissions of GHG result from the anaerobic decay of organic material in livestock

Table 6.4. Bagasse production in Kenya (tons)

Name of factory	1994	1995	1996	1997	1998
Chemelil	160,164	210,749	260,879	260,637	-
Muhoroni	43,244	128,060	134,405	101,416	127,782
Mumias	628,270	744,220	667,925	696,758	894,068
Nzoia	132,128	175,053	121,925	214,847	-
Sony	177,027	207,210	250,075	234,430	-
Miwani	-	83,191	68,236	95,542	85,569
West Kenya	-	-	68,236	70,423	57,702

Source: Kenya Sugar Authority, Statistics Year Book (1998) manure. In Kenya, among the pastoralist communities, most animal manure is left uncollected. On the other hand, farmers who practice mixed agriculture, compost and use animal waste manure. In zero grazing systems, commonly practiced in the Kenya highlands, animal wastes are collected and composted and later applied directly as crop fertilizer. Emissions from animal wastes contribute 23.4 Gg of methane.

Biogas produced from animal manure could be used for household cooking and lighting purposes. The slurry/liquid effluent is used as farm fertilizer. Biogas technology is environmentally friendly and once installed is easy to maintain. There is therefore need to make the technology more affordable to rural households in order for them to benefit from its use. Biogas technology has limited application in Kenya due to high costs of installation.

6.4.3.2 Nitrous Oxide

Fertilizer is the dominant farm input in Kenya and its application averages about 275,839 metric tons/year. The Ministry of Agriculture and Rural Development is promoting appropriate N-based fertilizer management practices that enhance crop growth and quality, protect quality of surface and ground water and reduce emissions of N_2O into the atmosphere. However, the current high fertilizer prices are forcing farmers to limit their uses. Between 1992 and 2000, annual fertilizer use in Kenya ranged from 232,895 tons to 358,644 tons/year.

6.4.3.3 Carbon Dioxide

Carbon dioxide emission is avoided by practices, which promote improved management of soils and discourage burning of crop residues as well as cultivation of wetlands.

6.4.4 Mitigation Options and Strategies

The government has adopted wide-ranging measures and policy instruments that also address GHG emissions in the agriculture sector. These include economic instruments such as subsidies/taxes, regulatory measures, and information sharing and research and development projects. The government and civil society organisations are actively involved in promoting use of organic fertilizer. Information and education will continue to be provided in order to improve agricultural productivity, and promote good agricultural practices and encourage GHG mitigation options for the agriculture sector.

The major constraints to the implementation of mitigation options in the agriculture sector include high financial costs, lack of quality data and information, inadequate extension services, inappropriate technologies, inadequate policies and lack of economic incentives. Approaches to overcome these constraints include provision of financial resources, timely dissemination of quality data and information and availability of economic incentives, access to appropriate technologies, and formulation of appropriate policies.

There is need to have demonstration projects to show farmers and the public at large the effectiveness or benefits (economic) of mitigation options in the following agricultural practices: rice cultivation, animal husbandry, inorganic fertilizer application, and soil carbon in cultivated soils.

a) Rice Cultivation

i) Intermittent draining during rice growing season requires adequate water supply. The technology is available and there are minimal financial implications.
ii) Better water management in rice paddies is a desirable option even without consideration of climate change mitigation options.
iii) Introduction of new rice cultivars: The Kenya Agricultural Research Institute (KARI) in conjunction with the National Irrigation Board (NIB).

b) Animal Husbandry

i) *Recovery and use of methane:* The use of biogas as an alternative energy source, is one way to alleviate fuel-wood shortage, minimize destruction of forests and woodlands, and increase carbon sequestration while abating increases of methane emission by transforming into carbon dioxide and thus reducing the methane warming potential. Methane is the most significant GHG emitted in the agriculture sector. Technology for methane recovery and its use is locally available. However, costs for construction and installation of biogas plants are prohibitive. Promotion of biogas technology requires financial resources, while interested households may need economic incentives to induce them to adopt the technology. Socio-cultural constraints, mainly cultural beliefs could prolong the implementation period of this mitigation option.

ii) *Animal breeding, disease control and genetic improvements:* Animal breeding, disease control and genetic improvements could result in reduced emissions of methane gas into the atmosphere. The technologies associated with animal breeding, diseases control and genetic improvement are available with R&D institutions such as KARI.

c) Inorganic Fertilizer Application

i) *Balanced N Applications:* Balancing of nitrogen applications into the soil can result in reduced emission of nitrous oxide into the atmosphere. The technology for applications is readily available with relevant R&D institutions. However, financial resources are required to popularize this technique through provision of extension services.

ii) *Promote legume cropping to boost system Productivity:* Legume cropping enhances natural nitrogen fixation into the soil for increasing crop productivity, and abates increase of N_2O emissions into the atmosphere. Legume cropping is widely practiced by farmers. However, inadequate financial resources would constrain popularization and adoption of this mitigation option through extension services.

iii) *Promoting organic farming, better soil management and use of lower external input systems:* Organic farming is beneficial to farmers since it is inexpensive, improves soil structure and texture besides reducing emissions of N_2O into the atmosphere.

d) Soil Carbon in Cultivated Soils

i) *Recycling of agricultural wastes and residues:* Recycling of agricultural wastes and residues such as coffee husks and bagasse could improve soil texture, while abating increase of emissions of carbon dioxide into the atmosphere. There would be minimum financial implications associated with implementation of recycling of agricultural wastes and residues.

ii) *Mulch application:* Mulching is known to form good organic manure after its decomposition besides improving soil texture. Mulching materials are also available to farmers at minimal cost. Mulching is therefore one mitigation option, which could be implemented with no financial constraints.

iii) *Promotion of conservation tillage practices in ASAL:* This mitigation option would increase carbon sequestration into the soil besides decreasing the rate of land degradation in marginal lands.

iv) *Promotion of conversion of marginal agricultural land to grassland, forests or wetlands*: Conversion of marginal agricultural land to grasslands, forests or wetland where appropriate could increase carbon sequestration into the soils besides decreasing land degradation in the marginal lands.

v) *Curbing of Biomass and Crop Residue Burning:* Burning of biomass and crop residues results in emission of GHG into the atmosphere. Curbing of biomass and crop residue burning would therefore result in reduced emissions of GHG into the atmosphere. Implementation is possible since there are no cost implications. Biomass and crop residues form suitable organic manure after decomposition.

vi) *Returning plant residues into soils:* crop residues decompose when returned into the soil. There are no cost implications in implementing this mitigation option.

vii) *Diversification of crop rotation with forage crops:* Substituting forage crops with other crops would mean reduced disturbance of the soils through cultivation and therefore retention of carbon in the soils. This mitigation option is recommended for use only by farmers practicing agro-pastoralism. There are minimum financial constraints for implementation of this mitigation option.

viii) *Erosion and runoff control:* Control of soil erosion involves digging of bench terraces, planting of various types of grasses, construction of gabions, etc. All these measures have monetary implications and require provision of technical advice to the farmers and other stakeholders.

ix) *Development of a code of agricultural practice for land-users*: Development of a code of agricultural practice for land users requires availability of financial resources. Provision of extension services is also necessary for disseminating practical agricultural advice to land users.

6.4.5. Conclusions

There are a number of technological, financial, social and economic constraints associated with the implementation of proposed mitigation options. These include funding in areas such as R&D, awareness creation, extension services, and acquisition of appropriate technologies. Other constraints include data acquisition and information exchange, accessing appropriate models for integrating environmental and socio-economic impacts into climate change mitigation options.

6.5 The Industrial Sector

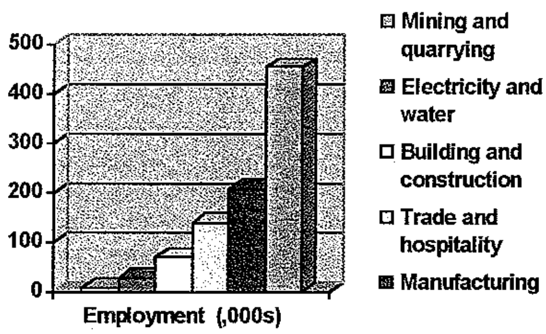
Industrial activities include manufacture of goods, mining and quarrying, building and construction, electricity generation, food processing and hospitality services. The products and services provided by the industrial sector include domestic and industrial consumables which range from personal care consumer products and processed foods to industrial consumables such as cement, plastics, rubber, chemicals, intermediate capital goods, paper, synthetic packaging material and hospitality services. Emission measures have been implemented by some industries in Kenya for considerations other than climate change.

6.5.1 Baseline Situation

Figure 6.5 shows the significance of the industrial sector to the Kenyan economy in terms of GDP and as a provider of employment. During the 1990s when growth stagnated or declined, manufacturing was the most resilient (table 6.6).

In 1994, carbon dioxide emission from industrial processes in Kenya was estimated at 1021 Gg. Chemical processes that use coal and residue fuel

Figure 6.5. Contribution of industrial sector to GDP and employment in 1993



Source: Republic of Kenya - National Development Plan 1989-1993

Table 6.5 Selected key economic and social indicators

Activity	Contribution to Economy (in K£ millions)				
Economic Activity	1994	1995	1996	1997	1998
Manufacturing output (K£mn)	19,428	23,074	28,820	33,762	38,836
Tourism earnings (K£mn)	1,405	1,250	1,280	1,132	875
Tea (K£mn)	209	245	257	221	294
Coffee (K£mn)	82	96	103	68	51
Growth of GDP at constant prices (%)	3.0	4.8	4.6	2.4	1.8

Source: Adapted from Republic of Kenya, National Development Plan 1997 – 2001 *and* Economic Survey 1999

Table 6.6. Inventory of greenhouse gas emissions in Kenya

Industrial Process	Production Quantity (tones)	Emission Estimates in gegagrams				
		CO_2	SO_2	NO_x	NMVOC	CO
Cement Production		979.4	0.45	0	0	0
Lime Production	30.7	24.2	0	0	0	0
Soda Ash (Trona) Production	181.3	17.6	0	0	0	0
Pulp and Paper Production	513.6	0	3.6	0.8	1.9	2.9
Bread Production	98.8	0	0	0	0.8	0
Sugar Production	371.8	0	0	0	3.7	
Beer (hl)	3686000	0	0	0	0.13	0
Spirits (hl)	14803	0	0	0	0.12	0

oil, especially in cement and lime manufacturing and crude oil refining are the major source of carbon dioxide emissions from industrial sector (Table 6.6).

Kenya is endowed with the abundance of soda ash at Lake Magadi. Soda Ash is the main ingredient for the manufacture of caustic soda, a basic industrial chemical used in the manufacture of many other chemicals, e.g. in paper industry, soap and detergent, leather and textiles, etc. Industrially, Pan African Paper Mills produces caustic soda in small amounts. In 1999, Magadi Soda produced 232,000 tones of soda ash and 32,000 tones of table salt.

The Kenyan industrial sector also uses carbon dioxide mined from natural sources. The naturally occurring carbon dioxide is mined for industrial purposes such as the making of "dry ice" for the shrinking of metals, preservation of grains and cut flowers, for beer brewing, bottling of carbonated soft drinks, etc.

6.5.1.2 Existing Policies and Legal Instruments

The *National Development Plan 2001-2008* seeks to establish harmony between environmental conservation and industrialisation for sustainable development. Minimising consumption of fossil fuel and promoting afforestation and reforestation programmes will significantly mitigate emission of carbon dioxide into the atmosphere. Environmental concerns are also considered in the Sessional Paper No 2 of 1997 on the Industrial Transformation to the Year 2020. This includes the promotion of environmental conservation with regard to all natural resources and the observance of appropriate environmental protection requirements including the control of emissions to the environment. The industrial sector is developing mechanisms to adopt the ISO 14000 EMS series of standards to meet the requirements of this policy. Twenty-one companies are already ISO 9000 series standards certified. Four companies are working towards ISO 14000 series certification. Some of the legislation which contribute to mitigation measure are described below:

a) Environment Management and Co-ordination Act: The Act came into force in 2000. Part VII of the Act requires all industrial concerns to have an annual environmental audit. This provision has greatly strengthened the requirement for energy audits on an annual basis.

b) The Factories and Other Places of Work Act (CAP 514): Part V of the Act requires the inspection of all pressure vessels including steam boilers annually. In complying with the requirement of this Act factories carry out a comprehensive service to their boilers, which in turn makes the boilers more efficient. This enhances boiler efficiencies and reduces the consumption of fuel and hence the abatement of the release of carbon dioxide into the atmosphere.

c) The Local Government Act (CAP 265): The Act regulates all local authorities and empowers them to perform certain duties and exercise certain powers. Local authorities have powers to "control, prohibit all business, factories and workshops that by reason of smoke fumes, chemical gases, dust smells, noise, vibration or other cause may be or become a source of damage, discomfort or annoyance to the neighbourhood and to prescribe the conditions subject to which such business, factories and workshops be carried on". The by-laws have been invoked from time to time on offending industries forcing them to re-tune their oil-fired boilers to reduce smoke, hence abating the emission of carbon dioxide to the atmosphere.

d) Public Health Act (CAP 242): The Act requires factories or trade premises to operate in clean environment free from offensive smell. It prohibits release of smoke or any gases, vapours, dust or impurities injurious or dangerous to health.

e) Finance Act of 1994/95 and Trade Liberalization: The Finance Act of 1994/95 allowed duty free importation of anti-pollution devices, which is a tax-free reduction for environmental clean-up operation. This, in the long term will contribute to the control of emission of GHG.

6.5.3 Initiatives by Industry

Mitigation of climate change in Kenya has benefited from some of the local industrial initiatives. These initiatives include fuel switch, modification of combustion processes, energy efficiency, and the growing of commercial forests.

a) Fuel Switch: Different fuels have significantly different emission characteristics. Emissions can be reduced by switching to lower sulphur fuel (e.g. changing grades of fuel oil) or by changing fuels altogether e.g. to liquid petroleum gas (LPG). LPG has lower carbon dioxide emission per unit energy compared to the residue fuel oil (RFO).

As a result of the *El Nino* rains, many lodges in the national parks that rely on thermal electricity generators for their electricity requirements underwent power shortages as diesel could not reach the lodges due to impassable flooded roads. In their current renovations, the lodges and hotels are switching to solar energy for lighting and water heating. The lodges have also taken tree planting very seriously. Many lodges now use wood from the nearby forests for room hot water system. For example, an NGO, "Friends of Conservation" is giving seedlings to the Masai Mara community to plant so as to supply the lodges with wood. It is therefore in the lodge's interest to support such programmes.

About 90% of all coal imported into Kenya is used for the production of cement. The rest of the coal is used mainly in the steel industry. The cement industry now depends on RFO and coal only for production.

b) Refinements and Modifications of the Combustion Process: Modifications can be made to the combustion process for the purpose of reducing pollutant emissions. These changes have considerable effect on combustion efficiency. Major tea factories in Kenya use old wood-fired locomotive boilers. In general, the conversion efficiency of these boilers is only 16% to 20%. Some of these factories have managed to modify the combustion chambers of these boilers and are getting conversion efficiency of 33% to 40%. This translates into a reduction of consumption of wood by as much as 50% and the associated abatement of carbon dioxide emission. It also means that the factories' private forests can mature longer which increases the calorific value of the wood and hence the trees sequester more carbon dioxide.

c) Energy Conversion and End Use Efficiency: Changes to a combustion system to increase efficiency have the additional benefit of reducing emissions. Reduction occurs simply because less fuel is burnt. Measures to reduce fuel consumption result in financial savings. As a result of energy audits some hotels are changing from central air conditioning to individual room air conditioning to be more energy efficient and thus being more environmentally friendly.

d) The KAM Energy Efficiency and Energy Conservation in Industry: Kenya Association of Manufactures (KAM) has an on-going programme on energy efficiency and conservation in industry that started in 1992. The project has so far saved up to 8% of the projected annual consumption of fuel oil. The amount of fuel oil used has fallen from an annual 254,443 tones in 1992 to 207, 298 tones in 1997 (table 6.7). The programme has already identified major potential projects that if implemented will further abate the release of carbon dioxide into the atmosphere from industrial sources. Some of the measures which if implemented will realise fuel saving are shown in table 6.8.

f) Commercial Forests as Carbon Sinks: A number of industries that require wood products for processes have their own forests. The tea industry leads in this. Tobacco production too has encouraged tobacco farmers to plant own trees for tobacco drying. Pan African Paper Mills supports efforts of the Forest Department in reforestation. These forests act as carbon sinks and reduce the dependency on natural public forests.

Table 6.7. RFO Consumption in selected industrial sub-sectors in tones

Sub-sector	1992	1993	1994	1995	1996	1997
Manufacture	254,443	232,998	249,254	215,912	237,874	207,298
Tourism	2,554	2,214	1,980	1,954	1,945	2,264
Agriculture	30,203	36,629	49,591	46,428	65,799	55,905
Energy	34,721	38,455	53,037	37,371	75,632	60,505

Source: Industrial survey by KAM

Industrial Sub-Sector	Energy Efficiency Activities	Annual Consumption (tones)	Anticipated Fuel Savings (tones)
1. Cement Manufacture	Energy Management Programme (EMP)	175,000	70,000
2. Lime Production	EMP	150,000	50,000
3. Soda Ash Production	Kiln Insulation and EMP	13,888 1,154	1,300 -
4. Paper Manufacture	Insulation of hot and cold pipes/ Recovery of flue gas. EMP	160,000	60,000
5. Textile	Insulation hot heat, Recovery. Redesign and combustion efficiency.	152,000	5,000
6. Tea Processing	Replacement of Boiler Recovery of heat, from flue gases and EMP.	20,000	4,000
7. Sugar Production	Insulate hot pipes/Replacement of Boiler and EMP	1,002	400
8. Beer Brewing	Replacement of Boiler/Insulation of hot and cold pipes and EMP	1,063,495	100,000

Table 6.8. Selected measures to save fuel in selected industries

Source: KAM Energy Conservation Programme

6.5.4 Planned Projects

Kenya intends to be an Newly Industrialised State (NIS) by the year 2020. It is therefore expected that GHG emissions will increase. Environmental impact assessment regulations are being developed to enable industry to undertake assessments and improvements. Additionally, the following projects if implemented will have considerable effect in the abatement of the release of carbon dioxide to the atmosphere:

a) Replacement of Old Wood-fired Boilers: The cost of tea production using fuel-wood fired boilers is by far much cheaper than using fuel oil. This option could further benefit from development of early maturing tree plantations with high calorific value with coppicing capability. However, there is need to improve efficiency of wood-fired steam boilers used mainly for tea drying and associated industries. These inefficient boilers should be replaced as they are depleting both the commercial and public forests at a much faster rate. The wood they use come from nearby commercial forests and public forests.

b) Afforestation Programme: An afforestation programme is being initiated in the tea growing regions to cater for tea drying and associated industries. The programme should include early maturing tree plantations, preferable with 3-5 year cycle and with coppicing ability.

c) Efficient Use of Forest Products: The Kenya Forestry Research Institute Strategic Plan for 1999-2004 includes a study to promote efficient use of wood products. The study would consider possible uses of saw dust, which is now left, to rot causing the release of methane. Sometimes the sawdust is just burnt causing the release of carbon dioxide to the atmosphere.

d) Co-generation of Electricity: In some tea growing areas there is potential for mini- hydroelectricity generation. The Demand Side Management (DSM) of KAM and the Electrical Load Management of Kenya Power & Lighting Company are jointly working on an initiative to improve the electrical load management in tea growing areas. The net effect would be a reduction in the demand of electricity from both the national grid and the electrical energy demand at factory level. The reduced use of thermal power stations for Electricity Load Management by the Kenya Power and Lighting Company and the reduced use of thermal power plants at factory level have the combined benefit of abating the release of carbon dioxide to the atmosphere.

Among the sugar factories in the country, only Mumias Sugar factory generates its electrical energy requirements by co-generation during its operations. Chemelil Sugar factory generates only 40% of its electricity requirements by co-generation during its normal operation.

Sugar factories are being encouraged to go into co-generation as a means of reducing production costs by using the readily available bagasse to generate electricity. These factories commonly leave the bagasse to rot in the fields causing the release of substantial methane into the atmosphere..

e) Emergence of Energy Service Companies: The liberalisation of the energy sector has created a conducive environment in Kenya for the development of Energy Service Companies (ESCOs) as the industrial sector becomes more conscious of energy conservation. The Kenya Industrial Research and Development Institute (KIRDI) and the Kenya Energy Management Programme (KEMP) at KAM conduct energy audits free of charge for its members. There are also private that companies have been established to conduct energy audits.

f) Ecologically Sustainable Industrial Development for Jua Kali Sector: The Kenya Federation of Employers (FKE) has carried out a survey on sustainable industrial development for selected Jua Kali enterprises. It is hoped that under the current UNDP support programme to Kenya (Year 2000-2005) this survey is going to be extended to cover a wider section of the Jua Kali sector including their potential for energy conservation.

g) Emphasis on Energy Efficiency and Energy Conservation in Industry: The KAM-GEF project on Energy Efficiency and Energy Conservation in Industry started in the year 2000. The project aims at creating and maintaining a strong institutional (government, NGOs, business organisations, and academia) training and human resource capacity (i.e., technical and managerial) for developing and implementing policy and strategy for energy efficiency and energy conservation in industry. The project should facilitate learning-by-doing in applying project formulation methodologies and building the national capacities for energy conservation and energy efficiency in industry. It will enhance the on-going KAM project on energy efficiency and energy conservation in industry and further reduce the emission of carbon dioxide to the atmosphere from industrial sources. The project has the added advantage of looking at process emissions and technological issues of CO_2 emission in Kenya.

h) Recycling: Kenya has a well-developed recycling industry, particularly in glass, paper, plastics, iron and steel. The glass industry prefers to use recyclable glass (cullets), as cullets are cleaner raw material and for the purpose of saving energy. The only handicap seems to be the collection of the used recyclable material. The energy requirement per unit of recycled material is much lower than the energy intensity used on virgin material. Recycling is encouraged under the industrialization policy.

The manufacture of sheet glass is a potential area for investment in view of the fact that the required raw material such as soda ash, high quality silica sand, feldspar and sodium sulphate are locally available in ample quantities. The Kenya Government is looking for a partner to develop this sheet glass industry.

i) Elimination of CFCs in the Industrial Sector: The importation of CFCs has drastically reduced and is controlled. In the manufacturing sub-sector, most of the technologies that require use of CFCs is being replaced. Retrofitting of equipment using CFCs technologies is likely to accelerate CFCs phase out momentum once the issue is addressed. A project is being formulated to address the retrofit of equipment still using CFCs and transition gasses.

6.5.5 Conclusion

The industrial sector has the potential to contribute considerably to emission of GHG – carbon dioxide, methane, nitrous oxides, and chlorofluorocarbons. Existing policies and legal instruments used to manage the environment have provisions that contribute to mitigating GHG emission. However, there is need for clearly spelt out legal provisions for mitigating GHG including enforcement mechanisms.

The industrial sector should greatly benefit by adopting GHG emission management measures and by employing continuous improvement programmes. The private sector should be encouraged to access other sources of funds such as CDM to comply with the requirements of the newly enacted Environmental Management and Coordination Act.

6.6 The Forestry Sector

Forest ecosystems represent an important component in carbon sequestration and conservation. Forest can store from 20 - 100 times more carbon than other vegetation on the same land area, or around 30 - 60 tons of carbon per hectare. The forestry sector is a major contributor of GHG exchanges in Kenya. A recent analysis shows that forests in Kenya are a net sink with an estimated net emission of -28 262 Gg of CO_2 (using 1994 as the base year).

Large-scale deforestation can lead to dangerous emissions of greenhouse gases into the atmosphere. It is only through planned land use changes, proper forestry activities and policies that a greenhouse gas retention level can be reached that will ensure low level of emission to the atmosphere.

6.6.1 Baseline Situation

The total area under wooded land in Kenya is estimated at 48.6 million hectares. Of these, 1.3 million are under natural forest, 0.17 million are forest plantations, 9.5 million are farmlands and settlements and 37.6 million are woodlands, bush lands and wooded grasslands. The distribution of the closed canopy forest is as follows:

a) Coastal forest region consist of 82,500 ha of indigenous forest with 3,200 ha of plantations;
b) Dry zone forest region consist of 211,000 ha of indigenous forest with 8,200 ha of plantation forest;
c) Montane forest region has an area of 748,500 ha of indigenous forest with 10,200 ha of forest plantations; and
d) Western forest region has an area of 49,000 ha with 18,600 ha of forest plantations.

Most of these forests including natural forests are considered as sources or sinks of GHG because of direct human-induced land-use changes alongside forestry activities. Tables 6.9, 6.10 and figure 6.6 show the estimated carbon uptake and release based on 1994 forestry inventory data. Human activities in forests have increased emission of carbon dioxide (table 6.10).

The total carbon released from commercial forests was estimated at 254 Gg. The amount is relatively low because there is no official logging in natural

Table 6.9 Carbon dioxide release from forest conversion

Cover type	*Amount of burnt Biomass Gg CO_2*	*Biomass decay Gg CO_2*	*Soil carbon release Gg CO_2*	*Total Carbon dioxide Gg CO_2*
Primary Moist*	-	-	-	-
Secondary Moist*	512	186.75	210.83	909.58
Primary seasonal**	-	-	-	-
Secondary seasonal	779	577.5	916.67	2.273.17
Primary dry				
Degraded	29	21.45	110.00	160.45
Total	**1,320**	**785.70**	**1237.50**	**3,343.20**

* *Montane and western rainy forests*

** *Woodlands on medium to high potential land (e.g. coastal)*

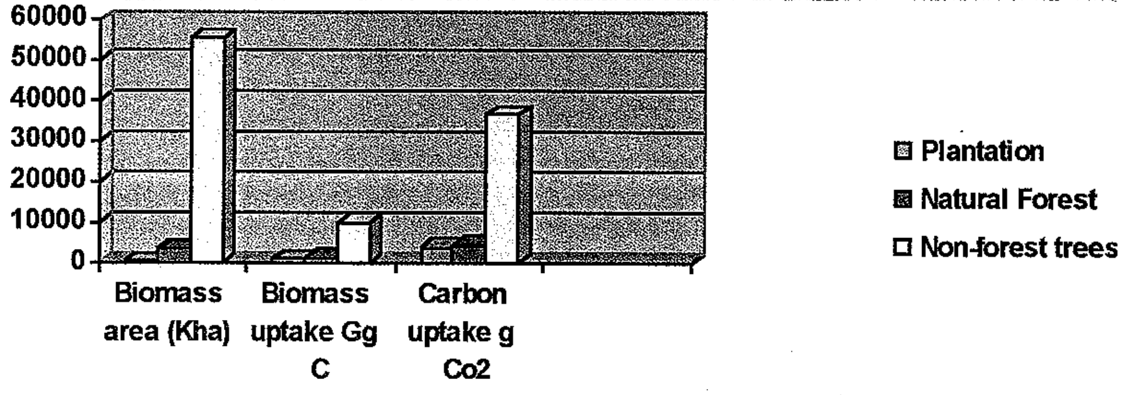
*** *Isolated closed forests surrounded by shrubland*

Table 6.10 Carbon release from biomass harvests, 1994

Harvest category	Total Biomass removed (Kt dm)	Carbon release Gg C	Annual Carbon release Gg CO_2
Commercial harvest	433.15	194.92	714.51
Fuel wood consumption	17.00	7.65	28.05
Wood from forest conservation	-296.50	-133.43	-489.24
Total wood consumed	**153.65**	**69.14**	**253.51**

Source: Ochanda (1998)

Figure. 6.6. Carbon uptake by biomass increments



forests. The plantations are also small in hectarage and biomass harvested is not significant as the amount released is easily absorbed by the growing biomass (figure 6.6)

The forest cover as described earlier is declining in both area and quality. The decline is usually a function of human activities. Kenya's population was estimated at 28 million in 1999 and projected to double by the year 2025. This increase has continued to raise pressure on the forest resources through a growing demand for forest products and land for agriculture.

6.6.1.2 Existing Policies and Legal Measures

Policies that have direct bearing on land-use change and forest development include the national energy policy, the national food policy, and the Policy on Environment and Development. Most of these policies have been strengthened by the Environmental Management and Co-ordination Act of 1999. Section 46 of the Act provides for reforestation and afforestation of hilltops, hill slopes and mountainous areas, while section 47 prescribes measures for the sustainable use of hilltops, hillsides and mountainous areas. This Act will also harmonize and strengthen the implementation of sectoral legislation for better environmental management. A brief description of some of the legal instruments is given below:

a) Forest Act (Cap. 285) of 1962 (revised 1982 and 1992): The Act regulates gazettement, degazettement and alteration of forest reserve boundaries. It also sets the gazettement of and regulations of nature reserves. Issuing of licenses for various forms of forest use and setting of royalties and fees under the Forest (General) Rules are also regulated by the Act. The Act is explicit on the activities prohibited in a forest area and the penalties for breaches.

b) Timber Act (Cap. 386) of 1972: This Act provides for control of the sale and export of timber by means of grading, inspection and marking, and provides for the control of timber in transit.

c) Wildlife (Conservation and Management) Act (Cap. 376 of 1976) amended (1989): The Act provides for the protection, conservation and management of wildlife in Kenya, including the conservation of forests occurring within national parks, national reserves and sanctuaries, and all wild animals occurring in the forests.

d) Fisheries Act (Cap. 378) of 1989: The Act contains two provisions relevant to indigenous forests; it regulates trout-fishing in forests, and protects fish breeding areas (of relevance to mangrove management).

e) Agriculture Act (Cap. 318) of 1980 (revised 1986): The Act provides for soil conservation and the prevention of destruction of vegetation. The Act empowers the Provincial Administrative Officers and Committees to enforce rules for land conservation and control of activities, which can destroy vegetation, or require the afforestation or reforestation of land, in order to protect the soil.

f) Registered Land Act (Cap. 300) of 1985 (revised 1989): The Act provides for registration of title to land, including state land and trust land, and rights of land properties, which is important in protection of forests.

g) Trust Land Act (Cap. 288) of 1962 (revised 1970); Land Adjudication Act (Cap. 284) of 1968 (revised 1977); Land (Group Representatives) Act (Cap. 287) of 1968 (revised 1970): The Trust Land Act provides for general conservation and protection or controlled utilization of trees and other forest produce on land other than the forest areas under the Forest Act. The Land Adjudication Act and Land (Group Representatives) Act provides for ascertainment and recording of rights and interest on trust land.

h) Chiefs' Authority Act (Cap. 128) of 1970 (revised 1998): The Act empowers Chiefs to enforce implementation of various environmental and conservation provisions within the local limits of their jurisdiction, including controlled use of tree resources on private land. This act is important because it checks the activities at grassroots level.

i) Science and Technology Act (Cap. 250) and State Corporation Act (Cap 446): The Kenya Forestry Research Institute (KEFRI) was established in 1986 under the above two acts to undertake research and development activities in forestry and allied natural resources. KEFRI has over the years carried out research, build human capacity, developed infrastructure, conducted in-service training, and formed partnerships with many institutions and stakeholders. These efforts of KEFRI have contributed positively to forest development and further research is currently addressing four core programmes, namely: farm, natural, dry land and plantation forestry.

Improved forestry management is likely to be achieved through the on-going pilot policy on joint ownership of forest estates with the communities living adjacent to them. This approach is being tested by the Forest Department, KEFRI and UNESCO in partnership with some communities in certain parts of the country e.g., Arabuko Sokoke, Mukogodo and Wamunyu. People living adjacent to the pilot forest areas are involved in the development, management, protection, and utilization and in benefit sharing.

6.6.2 Challenges

Population pressure on forests comes from three clearly defined but overlapping user groups:

a) Forest adjacent communities using the forest as an additional resource to their economic and farming activities.
b) Forest dwellers and squatters whose livelihoods depend solely on forest resources.
c) Small or large scale commercial users whose main market for forest products is found in urban areas and centres of high population.

In addition to extraction of forest products, there is pressure to convert forestland to other uses, mainly agricultural purposes, but also for housing, industrial and human settlement development.

Forest utilization by communities adjacent to them is mainly concentrated within the peripheral areas and other areas adjacent to access routes. Communities adjacent to forests cause degradation through overgrazing, uncontrolled extraction of resources for fuel wood, construction and commercial purposes, e.g., charcoal burning, cutting and splitting of poles and posts, pit sawing, and encroachment into forest land for cultivation. These activities have no regard for sustainable use or biodiversity conservation. Illegal commercial users have a preference for certain species in the natural forests. The extraction has endangered some species such as camphor in Mt. Kenya. The following are other specific challenges faced by the sector.

i) Institutional Capacity: The Forest Department has been constrained for a long time by inadequate personnel and other resources necessary for proper management of forests.

ii) Policy and Legislation: The policy does not address the role of forests in socio-economic development and rural development, including the role of forest adjacent communities. The Forest Act has penalties, which do not deter offenders. Illegal activities continue after offenders are arrested, charged in court and fined. In addition, the Act does not provide for use of revenue from sale of forest produce in forestry management.

iii) *Poverty:* Most communities living adjacent to forests are generally poor. They depend on cultivation and livestock keeping on small farm holdings, which are not enough to support their livelihoods. Consequently, their livelihood activities destroy forests through illegal cultivation, extraction of forest products and charcoal burning.

iv) *Forest Fires:* Fires cause a lot of damage to forests during dry spells. The fires are caused by either carelessness during honey harvesting, *shamba* preparation and other careless use of fire or through arson.

v) *Human/Wildlife Conflict:* Due to population growth and hunger for land, people have settled in wildlife migration corridors and other alternative habitats used by wildlife either for breeding or during very wet seasons thus restricting the wildlife seasonal movement. Apart from agricultural crop destruction, wildlife (particularly the elephant) destroys forests. In some areas, this has caused total destruction of whole forest blocks.

vi) *Excisions:* There are many poor and landless families. The government is under pressure to alleviate their lack of shelter and subsistence, by settling them in forest area. Some of these people are living in forests as squatters.

6.6.4 Tree Planting Programmes

Two basic types of abatement options in forestry sector are being implemented - expansion of stands of trees (e.g., afforestation, reforestation, farm forestry) and conservation of existing stands (i.e. protection and maximization in recovery).

The estimated area covered by forest plantations is about 164 000 ha of which 148 000 ha are under exotic softwood tree species and 16 000 ha are under indigenous/hardwood trees. The Forest Department's annual planting target has been placed at 6000 hectares. Planting programmes have been constrained by lack of resources. The poor survival rate of new plantations has been attributed to poor tending techniques, poor timing of tree planting, inadequate protection and occasional low rainfall in some years. The actual annual planted area of forest is estimated to be less than 3000 ha. The forest land that remains unplanted due to any of the problems mentioned above form part of the abandoned managed lands. These categories of land are eventually covered with natural vegetation but with a much reduced carbon sequestration capacity. Such land areas should be targeted for reforestation to increase the carbon uptake.

Values for estimating expansion of carbon pool through reforestation were estimated from general national data, which were then interpolated, to the sectoral resolution level and in some cases down to the unit forest area (table 6.11). The key assumptions are described in the following sections.

a) *Reforested Land (Baseline and Mitigation):* The reforestation scenario has been developed based on an assumption of planting 6,000 ha per year. This assumption has been arrived through another assumption that a similar acreage of forest lost (in baseline scenario) can be planted. However, this assumption is not based on sound data.

b) *Wasteland:* This is forest land that is not currently under any forest cover. They are mainly clear felled plantations that have not

Table 6.11: Estimated carbon sequestered by reforestation of 180 000 ha

Total Carbon Pool (TC)	1991	1992	1993	2030
Annual Incremental C Sequestered	696000	696000	696000	69600
Baseline Scenario				
Wasteland	61657680	61657680	61657680	61657680
Mitigation Scenario.	62353680	63049680	63745680	89497680
Wasteland	61069680	60481680	59893680	38137680
Reforested Land	1284000	2568000	3852000	51360000

been replanted, areas, which have been replanted, but with high mortalities, and areas of natural forests that have been heavily degraded.

c) *Yield in Plantations:* Annual increment volume of 20 m^3 was used in the assessment for plantation forests. This is quite comparable to Tanzania whose plantations yield is 17 m^3.

d) *Costs of Mitigation:* Baseline costs have been computed based on realistic estimates from current government budget lines.

e) *Benefits:* The benefits of reforestation is based on the value of timber and other products from plantations. The benefits from wastelands are based on value of grazing, fuel wood, and non-timber products. In all scenarios, a discount rate of 12% has been used.

From these estimates it is suggested that the future policy for forestry development and enhancement of carbon sequestration will include:

i) Planting rates that exceed harvesting rates.
ii) Increasing the production per unit land area by planting the most appropriate tree species and varieties.
iii) Promotion of forest development technologies that will minimize resource in-put into plantations and stop fallowing of forest areas, e.g., natural regeneration.
iv) Expansion of tree planting into marginal agricultural and pasture lands.
v) Large wood-based companies should have their nuclear areas of supply where they have to encourage, support and monitor tree planting exercises and management for the sustainability of the products.

Most of these changes will be achieved through the current trend where forestry is being strengthened at farm level. Research is already playing a big role in moving forestry to non-traditional areas using new technologies.

6.6.5 Social Forestry

Social forestry refers to all tree planting activities by people for their own needs outside the gazetted forest area. It usually covers farm forestry (agroforestry) and amenity plantings in urban centres. Although the total area under farmland and settlement is estimated at 9.5 million hectares it has been the most active area in terms of tree planting activities under social forestry. It is estimated that farmlands produce 9.3 m^3/ha of wood biomass and it is likely to increase due to improved tree planting awareness and expansion of farmlands into marginal dry areas.

In the last two decades, the area of social forestry has been aggressively promoted by the Forest Department, KEFRI and NGOs. The Forest Department is the lead agent in extension services, with extension officers in over 50 districts in the country. NGOs have provided support to social forestry promotion programmes and activities, including training of farmers and organized groups in nursery activities, tree planting, management and marketing. It is estimated that local nurseries produce over three million seedlings annually. Since 1997 the Forest Department and KEFRI have collaboratively participated in the development of social forestry extension services, mostly in arid and semi-arid lands. The project releases information to the communities through newsletters, mobile shows, seminars, training and field personnel.

The Forest Department and KEFRI carried out a social forestry training programme from 1987 to 1997. The training provided skills to extension officers, farmers, teachers and forestry leaders on social forestry management. KEFRI is involved also in other projects such as agroforestry for Integrated Development in Semi-arid Areas of Kenya (ARIDSAK) and Agroforestry Network for Eastern Africa (AFNETA). The projects aim to develop agricultural and agroforestry technologies for poverty alleviation. ARIDSAK is active in Kajiado and Makueni districts, while AFNETA is being implemented in Vihiga, Kakamega, Siaya, Kisumu and Embu districts.

6.6.6 Protection Forestry

Indigenous closed forests cover about 1.3 million hectares and are mostly distributed as coastal forest (66 700 ha), dry forests at high altitudes (163 000 ha), montane forests (387 000 ha) and western rain forest (43 000 ha). Other forests are found along the five major drainage areas namely: the Lake Victoria, Rift Valley, Athi River, the Tana River and Ewaso Nyiro Basins. Since 1985 there has been an official ban on the felling of live trees in natural forests.

6.6.7 Methods for Estimating Carbon Pool through Protection Mitigation Option

Two scenarios have been used: a business as usual (baseline) and a comprehensive protection (mitigation) of the 1,090,619 ha of the high canopy indigenous forest area. Since there is no systematic assessment of yield in the indigenous forests, growth increment of 1% has been used. This estimate is based on studies in other countries with comparable forest conditions.

a) *Total Above Ground Biomass:* Total above ground biomass was assumed to be the total of pole wood and timber stocking per hectare multiplied by the area of forest cover. A mean standing volume of $183m^3$ per ha was used for non-degraded indigenous forests. For wastelands, the standing volume has been estimated at 25% of that of non-degraded forests. Since there is no data on soil biomass in Kenya, the values used are arbitrarily estimated: 95tC for the protection option and 80tC for the reforestation option. Other non woody vegetation and shrubs are assumed not to stock carbon for a long period, as they have short life cycles.

b) *Opportunity Cost:* The figure adopted represents values when forest land is converted to agriculture.

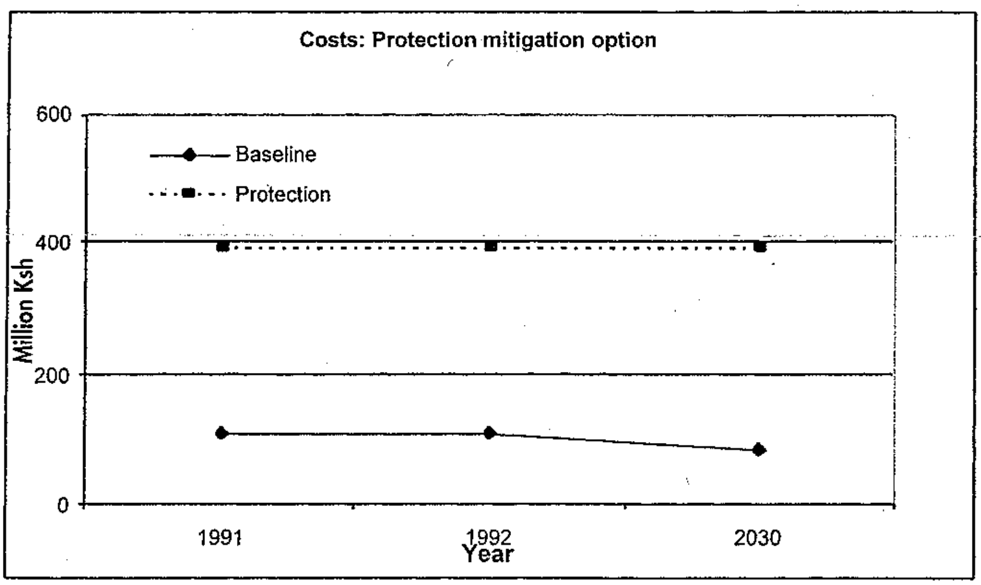
c) *Benefits (Baseline):* The benefits of indigenous forests are based on the estimated values of tourism, catchment value and value of non-timber resources.

d) *Mitigation Scenario:* An assumption of improvement of 20 % in forest condition was used, and thus improved the catchment value by the same margin. It was also assumed that the entire non-wood products are sustainably managed. It was further assumed that the number of tourists remain the same but now spend all day in the forest.

Figure 6.7 illustrates the costs of sustaining the indigenous forest under both baseline and mitigation scenarios. Most of the costs incurred under baseline scenario relates to staff payments for patrolling and supervision, while the cost under mitigation is for better management and infrastructure development. Up to Ksh.150 million is spent under baseline scenario against Ksh. 400 million under mitigation option.

Figure 6.8 illustrates the benefits accrued under baseline and mitigation scenarios in protection forestry. The difference in monetary gain tends to be small and in certain years mitigation scenario appears to be lower than the baseline. This is so

Figure 6.7: Cost of protection as mitigation option



because of increased costs on staff involvement and infrastructure development. However, there are more hidden benefits which are environmental and could not be quantified, such as enhanced scenery, erosion control and water catchment. More benefits through mitigation are expressed when carbon sequestered is taken into account (table 6.12).

Under mitigation scenario, a total of 191 million tons of carbon is sequestered against 105 million tons in the baseline situation. The policies for natural forest development and protection include:

i) Re-defining land-use policy to classify areas for agriculture, settlements, pastures and forests.
ii) Classifying forests according to uses and developing management guidelines.

These policies should lead to proper management of natural forests and sustained enhancement of carbon sinks.

6.6.8 Renewable Sources of Wood

It is assumed that plantations will be used to provide energy. The growing wood will use carbon dioxide emitted into the atmosphere. Such efforts are likely to be promoted as peri-urban forestry or under social forestry in private farms. These policies should assume that the nucleated settlement areas have high emissions of carbon dioxide from industries, transport sector and domestic utilities.

6.6.9 Recovery of Forest Products and Maintenance

Increased efficiency in the conversion and use of forest products results in avoidance of emission of GHG. Efficient conversions increases the recovery per unit tree, while reducing the number of trees being harvested and wastes such as excessive release of saw dust. Policy on utilization of forest resources need to be reconsidered with a view to achieving

Figure 6.8: Benefits from protection as mitigation option

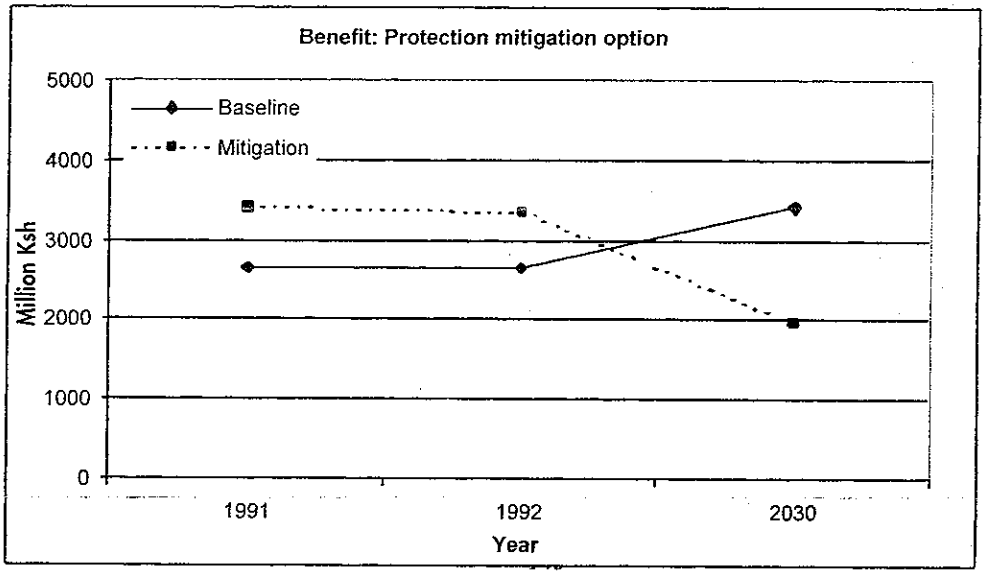


Table 6.12: Estimated carbon sequestered by protecting 1090619 ha of forest					
Total Carbon Pool (tC)	**1980**	**1990**	**1991**	**1992**	**2030**
Annual Incremental C Protected			2723260.107	5452098.8	85797561.17
Baseline Scenario C Pool	160258790	147511672.8	146263529.5	145024558.7	105307793.8
Mitigation Scenario C Pool		147511672.8	148986789.6	150476657.5	191105355

maximum benefits. The policy should consider, among other things, the following issues:

a) Calculation of royalty for forest products to enhance maximum use by entrepreneurs.
b) Encouraging wood-based industrialists to adopt better wood processing technologies.
c) Researching on wood waste for total utilization and production of commodities with added value. Better policies on commercialization should be suggested.
d) Recycling of waste paper.

The assumptions under mitigation scenario discussed above are:

i) Planting rates will be increased to reach annual planting targets, including in glades in the natural forest, open gazetted and areas marked for gazetting.
ii) Farm forestry will take over a good percentage of forest estate lost from wetlands, woodlands and bushlands due to new settlements.
iii) National parks and national reserves will remain unchanged and protected.
iv) Integrated harvesting with latest improved technologies will be applied in forest exploitation to reduce waste.

6.6.10 Conclusions and Way Forward

According to the national inventory of greenhouse gases compiled under UNDP/GEF Capacity Building Project, land used for forestry activities in Kenya constitute a net sink for CO_2; the emission in 1994 being - 28,262 gigagrams. To maintain this status, further mitigation options in the sector have been considered and some of them are being implemented. Furthermore, two basic types of mitigation options, namely: reforestation and protection were assessed against appropriate baseline scenarios. Results from the assessments indicate that although both reforestation and protection options are both viable, reforestation is likely to be the better option for Kenya, since the benefits are much higher than the protection alternative. In addition, other supplementary efforts that will improve forest cover in the country such as farm forestry are recommended. Finally, proper planning and clear definition of land use policy including classification of forests and their management strategies should lead to sustainable development and enhanced carbon storage.

Farm forestry is a key area in afforestation programmes. However, this area has no existing policy relating to inventories of trees grown. Consequently, there is a need to undertake research in various agro-ecological zones with good tree planting culture with a view to developing:

a) The best policy for collecting data on trees planted in private and trust (communal) lands.
b) Biomass productivity tables for at least 10 widely planted tree species to assist in estimating carbon sequestration levels.
c) The best approach to enhance community participation in establishment, management and use of forest resources.

The proposed research activities will be implemented countrywide with KEFRI playing the lead role.

6.7 The Waste Management Sector

In Kenya, waste generation has increased considerably due to rapid increase in human population, industrial development, and consumption patterns. Socio-economic activities have since the 1960s increased the volume and complexity of waste with organic waste constituting by far, the largest portion. Organic wastes generate most of the greenhouse gases emitted into the atmosphere.

Wastes are found around urban centres, especially around industrial sites and residential areas. Agricultural wastes are generally distributed throughout the country. However, inorganic wastes, which include chemicals, heavy metals, salts, and detergent residues usually end up either in the water, land or air. The decomposition of some of them may release greenhouse gases such as nitrous oxide, carbon dioxide, and methane. Treatment and disposal of waste paper, plastics, polythene materials and liquid hydrocarbons (oil, grease and other petroleum products) results in emission of either CH_4 or CO_2.

Municipal solid waste contains on average, about 30% recyclables in form of paper, glass, metals and plastics and over 50% by weight of organic matter derived from food and animal wastes. As much as 70-80% of waste can be recycled. Adoption of sound management policies and approaches by local authorities founded on increased waste recycling and reuse will reduce demand for less collection and disposal and ensure that development is made compatible with environmental protection. Techniques are available, but research and information dissemination is needed to identify promising, socially acceptable, and cost-effective forms of waste recycling and reuse relevant to Kenya.

6.7.1 Baseline Situation

Waste can be categorized by type i.e. solid, liquid, and gaseous. It can also be categorized based on sources and chemical composition. These categories are industrial, domestic, municipal, and agricultural. These categories could generate GHG, which can be considered on four levels, namely:

a) Sources and processes of generation and
b) Type of wastes (chemical or organic).
c) Treatment disposal.
d) Persistence and the rate of biodegradation and expected GHG emitted.

Waste management poses a big challenge to the environment in the country, legal provisions not withstanding. Improvements are needed in the following aspects:

i) Enforcement of existing laws and regulations, unrealistic penalties, inadequate human resources to monitor and enforce regulations.
ii) Discharge standards and methods for quality control and monitoring
iii) Inadequate incentives to encourage adoption of efficient waste management technologies.
iv) Low priority and status given to waste management and sanitation.
v) Inadequate disposal equipment, sites and infrastructure.

6.7.1.1. Liquid Wastes

Liquid wastes contain a wide range of chemical and physical components, the breakdown of which generate varying amounts of GHG to different types of decomposition. The amount of GHG emitted depends on organic loading in the wastewater measured as biochemical oxygen demand (B.O.D), chemical oxygen demand (COD), suspended solids, and volatile organic matter. It also depends on the extent to which the organic material degrades under anaerobic conditions.

In Kenya, methane is emitted by domestic sewage and industrial waste streams which are often unmanaged. However, the rates of emission from wastewater treatment conditions is not fully documented even for large urban areas such as Nairobi, Nakuru, Eldoret and Kisumu municipalities.

There is no waste reporting requirements for industries and services. Consequently, each industry, or human settlement is only expected to treat its waste before discharge into a water course. Management of liquid wastes is often constrained by:

a) Inadequate discharge standards and methods of measuring the quality and quantities of effluents for majority of sources.
b) Overloaded sewerage networks and treatment facilities.
c) Lack of incentives to adopt recycling technologies.

Constructed wetlands are popular low-input facilities for treating liquid waste in Kenya.

6.7.1.2 Solid Waste Disposal

Solid waste in almost all urban centres of Kenya is disposed off in open dumps or crude sanitary landfills, burned, or left to decompose in open places. In low-income residential areas, collection is very poor. The commonest method of disposal is dumping along streets, playfields and between houses. Burning is practiced in some estates thus leading to emission of gaseous like CO_2, NO CH_4 and smoke among other pollutants.

There is scarcity of disposal sites in most municipalities. Most of the disposal sites are open to the public and animals, creating dangerous health risks. The collection efficiencies in most towns are also poor. A lot of waste is left uncollected thus generating GHG through fermentation processes.

6.7.2 Existing Policies and Legal Measures

Legislation controlling wastes include:

a) The Public Health Act (Cap. 242): Section 116 of the Act requires every local authority to "take all lawful, necessary and reasonably practicable measures for maintaining its district at all times in a clean and sanitary condition, and for preventing the occurrence therein of, or for remedying or causing to be remedied, any nuisance or condition liable to be injurious or dangerous to health, and to take proceedings at law against any person causing or responsible for the continuance of any such nuisance or condition." Where the above is performed, abatement of GHG is implied.

b) The Water Act (Cap. 372): Sections 145, 158, 160 and 182 of the Act deal with the disposal of wastes of any nature and from any sources in any way as to cause pollution of water resources. Pollution of water resources by improper disposal of wastes is an offence under this act. The proper handling of wastes contributes to abatement of greenhouse gas emissions.

c) The Local Government Act (Cap.265): The Act is particularly important with regard to solid waste management in terms of conferring powers, and its scope and relevance. Section 5 of the Act gives powers to establish local authorities. This Act stipulates the powers and duties of the local authorities with regard to solid waste management. Section 160(a) of the Act gives local authorities power to "establish and maintain sanitary services for the removal and destruction of, or otherwise dealing with, all kinds of refuse and effluent and, where any such service is established, to compel the use of such service by persons to whom the service is available." When the above is accomplished, abatement of GHG is implied. In addition, Section 201 of the Act gives local authorities power "to make by-laws in respect of all such matters as are necessary or desirable for the maintenance of the health, safety and well-being of the inhabitants of its area or any part thereof and for the good rule and government of such area or any part thereof and for the prevention and suppression of nuisances therein." The enforcement of the by-laws contributes to abatement of GHG.

d) The Chief's Authority Act (Cap. 128): The Act empowers a Chief to make orders and/or make regulations where necessary to achieve certain purposes, e.g. control of environmental nuisances like undesirable emissions. When these regulations are made and enforced, abatement of GHG is implied.

e) The Mining Act (Cap. 306): Part VI section 92 (XX) of the Act states that the Minister responsible for mining may make regulations regarding poisonous or noxious by-product resulting from mining operations.

f) The Factories and Other Places of Work Act (Cap. 514): Part IV and VII of the Act deal with health, safety and welfare of workers. Section 51 requires that fumes from a factory be free of dust and other undesirable emissions before discharge. The requirement that such waste be managed properly has an impact on abatement of GHG.

g) The Environmental Management and Coordination Act of 1999: The Act provides a framework for the coordinated management of the environment. It deals with waste management including standard setting, disposal site licensing, the control of hazardous, industrial and hospital waste and environmental impact assessments. Storage, treatment and collection of hospital, industrial and hazardous wastes is the responsibility of those who generate them. However, final disposal for all types of wastes remains the responsibility of local authorities. Section 86, empowers the Standards and Enforcement Review Committee, in consultation with the relevant lead agencies, to recommend to the Authority measures necessary in:

i) Identifying materials and processes that are dangerous to human health and the environment.
ii) Issuing guidelines and prescribing measures for the management of the materials and processes.
iii) Prescribing standards for waste, their classification and analysis.
iv) Formulate and advise on standards of disposal methods and means for such wastes.
v) Issuing regulations for the handling, storage, transportation, segregation and destruction of any waste.

Adhering to the above standards and guidelines should contribute to abatement of GHG emissions. Section 87 (1) says that no person shall discharge or dispose of any wastes whether generated within or outside Kenya, in such manner as to cause pollution to the environment or ill health to any person.

Section 87 (3), says that every person whose activities generate wastes shall employ measures essential to minimize wastes through treatment, reclamation and recycling. Adhering to the above should contribute to abatement of GHG emissions.

6.7.3 Waste Management Initiatives

Waste generators in human settlements have developed initiatives to clean up their immediate environments. These initiatives are intended to improve cleanliness and health, but have some indirect bearing on abating GHG emission. There are also economic and environmental benefits to these initiatives. Specific initiatives are described below.

6.7.3.1 Community Based Solid Waste Management (SWM) Projects

Many local authorities have been overwhelmed by the amount and types of wastes generated. As a result, communities have initiated solid waste management activities particularly in the informal settlements of major towns. These activities are primarily intended to clean community neighbourhood. The activities have in addition become self-help income generating projects as well as for mitigating GHG emissions. In Nairobi alone where the solid waste generation stood at 1600 ton/day in 2000 with organic fraction of over 50%, there are over 15 groups involved in composting and recycling. This is mainly concentrated within the low-income areas constituting 53% of the total population of 2.1million. The community groups collect and dispose municipal solid waste of about one ton each day for each group. Generally, out of the total generated waste, 5% of it is composted. These activities have had some indirect abatement of GHG to the environment by reducing the amount of solid waste left uncollected which could get fermented and generate GHG.

6.7.3.2 Resource Recovery by Scavengers

The types of material recovered by scavengers in Nairobi are more than 30. The major ones are ferrous metals (tin and iron), plastics, bottles, bones, paper, textile, and non-ferrous metals. The impact of scavenging has not been quantified, but 7% of the waste generated is estimated to be scavenged and removed from the waste streams.

Substantial quantities of scavenged materials end up in the recycling industries. They are contributing to environment conservation through resource recovery by purchasing of recovered materials from scavengers. Leading recycling companies are involved in manufacture of iron and steel, plastics and paper. For example, two factories in Nairobi produce five tones of plastic goods per day using left over from other plastic manufacturers. Kenya Paper Industries, Chandaria Industries, and Pan African Paper Mills in Webuye, produce 10 and 15 tones of paper goods per day using waste paper. An iron and steel company produces 40 to 80 tones of steel bars per day from recycled metal. These recycling activities were not initiated to solve climate change problems but they indirectly serve to minimize emissions of GHG by reducing the amount of waste left in the open. The activities have supplemented the municipalities involvement in waste collection such that, there is reduced amount of waste to be collected. Health problems associated with degrading wastes are generally reduced and there is employment creation to the waste pickers.

6.7.3.3 Private Sector Involvement in Solid Waste Management

The amount of waste generated by Nairobi population of 2.1 million people in 1999, was 1600 tons/day. Out of the generated amount, 20% is collected and disposed of by the Nairobi City Council.

The City Council of Nairobi has accepted its inability to efficiently manage this amount of waste. It has, therefore realized the need to involve others in waste management; it started by contracting out waste collection in the central business district. Concurrently, other private waste collection companies started to operate within residential estates and other commercial areas. The participation of the private sector has been formalized through a policy that aims at providing an enabling environment for the sector, while limiting the city authorities to providing regulatory services.

The new waste management arrangement is showing promising results. It has resulted in clean environments for residents, removed the heaps of garbage, and thus abated GHG emissions. The involvement of the private sector is now replicated in other major urban centers of Kenya.

6.7.3.4 Proposed Actions – Integrated Approach to Waste Management

Integrated solid waste management approach based on a logical hierarchy of actions of minimization of production, maximization of recycling and reuse, promotion of safe disposal, and expansion of waste collection and disposal services if implemented by local authorities, would impact positively on the amounts of wastes to be managed. Such integration include minimization of waste generation, maximization collection rates and expansion of disposal facilities.

a) *Minimization of waste production:* This would use both voluntary and compulsory approaches, including the following:

i) Environmental impacts assessments for all major development activities;
ii) Introduction of time bound environmental audits

as both voluntary and legal requirements;

iii) Introduction of ISO 14000 environmental management systems (EMS) certification schemes;

iv) Encouraging enterprises and services to introduce cleaner production principles; and

v) Awards such as company of the year awards (COYA) and hotel classification among others.

b) *Waste Recycling and Reuse Maximization:* Maximization of waste recycling and reuse has considerable benefits. The positive impacts of waste recycling and reuse are many. They range from reduced production costs to conservation of the natural resources of the country. Waste recycling is also provided for in the Environment Management and Coordination Act. This should ultimately influence climate change positively.

c) *Promotion of Safe Disposal:* All forms of waste disposal have some residual negative impact on the receiving environment. Waste disposal practices by local authorities are therefore made to incorporate measure for mitigating these impacts. Consequently, requests for additional budget allocations for waste management are now being considered favourably by many local authorities.

d) *Expansion of Collection and Disposal:* There is a strong need to expand the coverage by solid waste collection and disposal services, in particularly in low-income urban areas, where most urban people live. Poor waste disposal services lead to poor sanitation thus contributing to disease outbreaks. Improved waste collection and disposal services will enhance public health and lower health budgets. It is necessary to estimate costs of all these proposed actions so that the government/local authorities can appropriately budget for them. To facilitate this, environmental management tools such as environmental economics and accounting are increasingly being incorporated in day-to-day environmental activities.

6.7.4 Conclusions and Way Forward

Promotion of waste reuse and recycling and raising public awareness should have a positive impact in the mitigation of greenhouse gases emission as most of the waste is organic which when it degrades, produces CH_4 and CO_2. Inadequate resources for provision of equipment, logistics and also raising public awareness, building human capacity is hampering sustainable waste management. This results in low level of reuse/recycling as well as waste generation reduction.

The objective of future plans is to promote economically sound practices for managing municipal wastes that take advantage of waste reuse and recycling thus abating emissions of GHG. Currently, there are a number of recycling activities and composting of various waste streams that only need to be promoted to minimize waste at source. The following projects are proposed:

Overall, the enforcement of the Environmental Management and Coordination Act will go a long way in ensuring harmonization of environmental policies in Kenya including facilitating implementation of the mitigation options. There is need for additional financial resources, provision of economic incentives, intensified R & D activities and promotion of information sharing approaches, access to appropriate technologies, capacity building and policy formulation in order to facilitate the implementation of the mitigation options for all the sectors.

7. RESEARCH AND SYSTEMATIC OBSERVATIONS

7.1 Introduction

One of the major concerns on climate variability and change in Kenya is its manifestation through impacts of extreme events such as droughts and floods on social, economic and physical environments. An example is the devastation caused to all sectors of the economy by the 1997/98 ENSO (El-Niño Southern Oscillation) phenomenon. Climate change and variability research should therefore lead to development of technological capacity to enable Kenyans to reduce impacts brought about by such extreme events.

A number of research works have been carried out on impacts of climate change and weather variability on sectors such agriculture, forestry, health, fisheries and industry. However, there are many issues that need to be investigated within current and continuing initiatives, including, regional and global modeling techniques of the climate system. Research works are often hampered by lack of good quality data associated with problems highlighted below.

7.2 National Weather and Climate Information

The Kenya Meteorological Department is mandated to collect, analyse, archive and disseminate surface environmental data within the country and part of the West Indian Ocean. This is achieved through a network of radiosonde, meteorological, agrometeorological, climatological and rainfall stations scattered around the country. The data elements collected include atmospheric pressure, temperature, rainfall, radiation, cloud cover, sunshine, evaporation, humidity and wind. Additional data collected include soil moisture and temperature at various depths from some selected stations in the country. The department maintains a data bank for all the above parameters mentioned above. The department is also responsible for:

a) Providing meteorological and climatological services to agriculture, forestry, water resources management, civil aviation, industry, commerce and public utilities.
b) Providing meteorological services to shipping in the western Indian Ocean including the issuing of cyclone warnings for the safety of merchant and other ships.
c) Providing meteorological services to military aviation for the safety of the Kenya Air Force aircraft for national defence.
d) Managing surface and upper air meteorological observations within its area of responsibility.
e) Publishing meteorological information.
f) Maintaining an efficient telecommunications system for rapid collection and dissemination of meteorological information required for national and international use in accordance with the World Meteorological Organization (WMO) and the International Civil Aviation Organization (ICAO) procedures.

In order to carry out these responsibilities effectively, the department has a network of 39 stations spread countrywide. These stations collect meteorological and agrometeorological data and transmit these datasets to the headquarters in Nairobi. In addition, there are many voluntary stations that are equipped with rain gauges to observe rainfall under the guidance of KMD and transmit the information to the headquarters at the end of each month. These are called rainfall stations. A spatial examination of the station network, however, reveals that most of the stations are clustered around urban centres and in the settled parts of the country. Relatively very few stations are found in the arid and semi-arid environments, forests, mountains, lakes, islands and other parts of Kenya with harsh climate. There has also been a rapid deterioration in the rainfall station network over the country. The network has shrunk from about 2500 stations in the 1960s to just about 850 in mid 1990s. Figure 7.1 summarises the year-to-year changes that have taken place in the rainfall observational network.

The Kenya Meteorological Department (KMD) has various satellite ground receiving stations, which include the Automatic Picture Transmission (APT) stations of which one is the HRPT (High Resolution Picture Transmission) and the other; the PDUS (Primary Data User Station). The PDUS receives environmental data in the visible, infrared and water vapour channels from the Meteosat; whereas the HRPT receives data on Normalized Difference Vegetation Index (NDVI). Meteosat imageries are used mainly in forecasting, while those from NOAA are used in the assessment of vegetation conditions on a near real time basis.

The Meteosat series has been operational since 1977; it generates images of the earth's atmosphere every half-hour in three spectral channels, primarily to observe the evolution of cloud formations. Raw data collected is processed before being relayed to users. Additionally, the Meteosat acts as a communication satellite, carrying 66 data channels for relaying environmental data.

The meteosat data collection system (DCS) is part of a large international DCS that are either automatic or semi-automatic weather stations, including the ARGOS system (operated by NOAA series of satellites – for sea/ocean data; the ASDAR (Aircraft – Satellite – Data relay) system for collecting data from commercial aircraft; the ASAP (Automated Shipboard Aerological Programme) system – for collection of data over oceans. Data distribution among users is also enhanced by the MDD (Meteorological Data Distribution) system particularly in Africa and the Middle East.

The Meteosat DCS, DRS and the MDD facilities are collectively referred to as MOSAIC (Meteosat Operational System for Meteorological Data Acquisition and Interchange). The type of products generated from Meteosat data include cloud motion vectors, cloud top heights, sea surface temperatures, upper tropospheric humidity, cloud analysis, precipitation index and a climatological data set.

7.3 Participation in Global Initiatives

The Kenya Meteorological Department participates in a number of global initiatives, including management of a regional telecommunications hub, collecting meteorological data from Africa and relays the same to other users worldwide within the global network.

The department also hosts the Drought Monitoring Centre, a project of the Horn of African countries. The centre provides early warning information on the eastern African region. The Kenya Meteorological Department houses the centre and provides a number of highly qualified staff. The department contributes to running of the African Centre of Meteorological Application for Development (ACMAD), by regularly releasing staff to work at the centre. The RANET (Radio and Internet) project supplements efforts of disseminating climate information to rural communities. The department and ACMAD jointly implement the project.

7.4 Hydrological Monitoring

The Department of Water Development is responsible for stream flow, water quality and groundwater monitoring. There are about 500 gauging stations for stream flow monitoring in Kenya. The Department of Water Development, the Kenya Meteorological Department as well as research institutes such as Kenya Agricultural Research Institute (KARI), carries out collection of hydrometeorological data.

7.5 Environmental Monitoring

The Department of Resource Surveys and Remote Sensing (DRSRS) uses satellite images such as LANDSAT, TM, SPOT and aerial photographs to provide baseline resource data inventories to planners and decision-makers that enables them to prepare economically viable and ecologically sound development programmes; and to provide planners and decision-makers with knowledge regarding land-use, crop production (maize and wheat), livestock and wildlife numbers, and vegetation cover (foliage), as well as their spatial distribution.

The department receives up to date data on weather and vegetation from the High Resolution Picture

(HRPT) unit of the Kenya Meteorological Department. There exists a microwave link between the HRPT of KMD and the Department of Resource Surveys and Remote Sensing (DRSRS). The data is used for monitoring land use, crop harvest and livestock numbers.

The Central Bureau of Statistics has continued to work toward improving crop monitoring and forecasting by venturing into new areas of research that incorporate weather influences on crop growth, development, and yields. The methods developed by CBS follow the FAO model. They are based on a cumulative ten-day water balance established over the entire growing season for the given crop. The agrometeorological forecasts provide timely indications of the cropping season. The model, using ten-day time periods, requires calculation of the following parameters:

a) Normal precipitation;
b) Actual Precipitation;
c) Number of days of rainfall;
d) Potential evapotranspiration;
e) Crop coefficients at each stage of crop growth (i.e. real evapotranspiration of the crop); and
f) Water reserves in the soil.

Thus, CBS has played a lead role in developing a systematic food monitoring system. Since 1976, CBS has been involved in crop forecast for both the short rains and the long rains seasons. They provide some of the most valuable socio-economic data required for those institutions involved in drought monitoring, mitigation and recovery. Their information is disseminated in form of bulletins. A series of surveys are carried out to obtain early indicators of crop area planted, income, expected production and other socio-economic data. The surveys are conducted in June-July and December – January to cater for the two rainy seasons. The marginal areas are however not included in the surveys.

7.6 The Mt. Kenya GAW Station

The increasing human activities involving high demand for the fossil fuels consumption and biomass burning, among others, have resulted to increased emission of carbon dioxide, methane and nitrous oxide emissions which are referred to as greenhouse gases (GHG). The GHG are expected to increase the earth's temperature, thus causing global warming. Climate change compounds the problem of the ODSs, which are depleting the Ozone Layer, which protects the biological diversity on the earth from the harmful ultra-violet radiation.

The purpose of the Global Atmosphere Watch (GAW) station in Kenya is to carry out and make available measurements of GHG and the Ozone. The GAW is based mainly on two World Meteorological Organization (WMO) networks of global and regional stations, namely the Global Ozone Observing System (GOOS) and the Background Air Pollution Monitoring Network (BAPMon) established in the mid 1950s and 1960s respectively. The GAW activities have been established in a few selected member countries of the WMO. The Mt. Kenya GAW station located along the equator is one of the three equatorial stations of the globe, namely the Indonesia and Brazil GAW stations.

7.7 Cooperation at the Regional and International Levels

There are efforts at a regional level to address issues related to systematic observations in order to provide the necessary information for climate variability and change studies. Kenya is an active participant in these initiatives. The two most notable efforts are those by the Global Climate Observing System of WMO which is organizing workshops at the regional level to identify national and regional needs and deficiencies for climate data including needs for assessing climate impacts, conducting vulnerability analyses and undertaking adaptation studies. Under this initiative, a regional action plan has been developed for eastern and southern Africa to address deficiencies and possible ways of overcoming these deficiencies.

Another initiative is that of the World Weather Watch programme of WMO. This initiative has developed a sub regional strategy to address observation needs of Africa. A number of project proposals are under development to assist in financing some of the strategies aimed at ensuring that systematic observations are undertaken over the continent. One of the main areas of focus is the implementation of automatic weather stations in remote areas and in existing stations that do not operate at night. Kenya is again an active participant of this initiative.

Kenya is also a host of the Preparation of the Use of Meteosat Second Generation in Africa (PUMA) project. This new generation of meteosat satellites will be launched in 2002. They are meant to replace the old generation but have the added advantage of responding to the needs and requirements of users for more and good quality data and information. Users will broadly receive information at twice the rate at which they are receiving it now and with a much better resolution. A project proposal has already been developed for funding to ensure that all the countries of Africa acquire the ground receiving equipment.

7.8 Information on Research on Climate Change

7.8.1 Climate Change

Instrumental data on weather elements such as rainfall, temperature, humidity or radiation can be analysed to obtain general trends for regional or local climate. Changes in the mean characteristics (or conditions) of the measured weather elements can either be attributed to normal climate variability or change depending on the significance and persistence of these changes and their causative factors. Detection of climate change is done through analysis of instrumental data, proxy records or through use of climate models.

The space-time patterns of climate over Kenya is quite complex due to the existence of complex topography and the existence of many large inland water bodies, including Lake Victoria, which is one of the largest lakes in the world. There is also very strong variability in the temporal and spatial patterns of climate, especially rainfall over the country. In addition, rainfall depicts strong seasonality in harmony with changes in the generating mechanisms. In this respect, significant differences would be expected in the patterns of any future climate change signals over Kenya. Any future climate changes are likely to be reflected in space-time changes in the patterns of one or more of these climate-controlling systems. Generally, there is no appreciable change in mean temperature throughout the year but there is a considerable variation in temperature geographically, diurnally and seasonally due to altitude. Over two-thirds of the country receives less than 500mm of rain per year and 79% has less then 700mm annually. Only 11% of the country receives more than 1000mm per year.

Climate change studies in Kenya have been limited due to data problems. Such data problems include poor data observation network, relatively short duration of the available climate records, missing values in the available records, changes in instrument site, type, routines, etc. These data problems sometimes make archived meteorological data not to be strictly comparable. Such problems pose serious challenge to any current efforts towards the detection and attribution of climate change signals. Most of the past studies of climate change signals in Kenya based on instrumental time scale have relied largely on rainfall and temperature records.

The characteristics of maximum and minimum temperatures over some stations in Kenya have shown a general warming trend in the minimum (night time) temperatures over some inland stations. The minimum temperatures over the coastal areas and Lake Victoria region generally showed decreasing trends. The maximum (daytime) temperatures over most inland stations depicted slight increase in trend, which was steep for areas bordering the major water bodies. There was also a general decrease in the temperature range arising from sharp increases in the minimum temperature and relatively gentle increases in the maximum temperature.

7.8.2 Climate Impacts studies

Climate impact studies carried out in 1989 include the possible impacts of the changes in the greenhouse gases on the climate of East Africa; expected change in East African coastal region as a result of global warming and sea level rise and possible impacts of the greenhouse gases on climates of East Africa. UNEP has further carried out several researches on the potential impacts of climate change on Kenya's various sectors including human settlement, agriculture, infrastructure and tourism.

a) Land and Marine Environments

Research relating climate and marine environments has been carried out specifically targeting erosion of coastal environments and also inland river systems in Kenya including nutrient pollution in lakes. Some studies have also focused on fertilizer use in cropped fields. Results of this work is readily available from the relevant institutions such as the Kenya Agricultural Research Institute (KARI) and Egerton University.

b) Industry and Energy Research

Some research work has focused on environmental impacts of geothermal power generation and on environmental consequences of choice and citing of industrial establishments. Geothermal research has also focused on the determination of oxygen and hydrogen isotope compositions of some low enthalpy geothermal systems whose local meteoric water are heated at depth and rise to the surface without much interaction with the country's isotopic equilibrium with local meteoric waters. Detailed results of such studies is found in relevant institutions, particularly Moi University. Other research work has involved investigation of the effect of oil pollution at the Kenyan coast.

Research on pollution in rivers and lakes due to industrial effluent has also been undertaken focusing mainly on the paper and sugar industries. Public research institutions, especially the Kenya Marine and Fisheries Research Institute (KEMFRI) and Moi University, Eldoret, keep reports of these studies.

Other energy related research has focused on alternative sources such as wind utilization, biogas, wood fuel and solar energy systems in the country. Research has focused on energy efficiency and conservation strategies, such as fireless cookers, solar cookers, heaters and driers.

c) Climate Variability and Cropping Research

The impact of climate variability on cropping research in semi-arid Kenya is well documented. Most work has been conducted at the Katumani National Dry land Farming Research Centre of KARI. Soils and weather influences such as amount and distribution of rainfall have created difficulties in the interpretation of the results.

Another programme on response farming has used crop-weather simulation to assess conditional strategies, and then the benefits of conditional strategies of crop management. The programme also examined simulations with plantings made at onset of the short-rains season and for various delays after onset, to identify an optimum planting strategy. The general prospects for nitrogen fertilizer use in the region were examined in terms of set strategies, and then the benefits of conditional strategies with fertilizer inputs linked to forecasts of season potential were assessed. Detailed results of these simulations, which were carried out for ten years beginning in 1955 are available at the Kenya Agricultural Research Institute. The other focus on research in arid and semi-arid lands has been on livestock production. A fragile environment characterizes the ASAL. These unfavourable soil conditions and the characteristic heavy rainstorms result in high run-off yields, soil erosion and land degradation.

Land degradation comprise physical and economic processes. Although it is difficult to quantify the interlinkage, it is possible to infer and estimate from rainfall and temperature maps land degradation and vulnerability due to climatic stresses. Information on degradation assessment for the country is available in various institutions in government and also at the United Nations Environment Programme (UNEP).

Forestry research was initially geared to introduce fast growing exotic species, mainly *Cuppressuss* and *Pinus* spp. Species trials have spread to dry land and agroforestry species. This information is available at Kenya Forestry Research Institute (KEFRI) and Forest Department Technical Notes.

d) Climate and hydrological systems research

Significant amount of research work has been devoted to determination of water balances in Kenya and East Africa as a whole. Work has also been carried-out on stochastic modeling of rainfall-runoff for some river basins in the country. With regard to the latter, results have showed that the runoff predictions from the best-fitted mean models gave good skill in the daily runoff forecasts. The models were also able to produce the main features observed in hydrographs especially during extreme flood events.

e) Human Health

The health information system (HIS) unit of the Ministry of Health, publishes statistics in annual reports and periodical bulletins based on data collected from various health institutions throughout the country. UNICEF in 1991 carried out a study on malaria in Kenya and found that malaria contributed a high proportion of total morbidity in Nyanza, Coast and Western Provinces, which are tropical lowland warm areas; and a comparatively lower proportion in Central Province, which is a highland area. Malaria is endemic in Kitui, Kwale and Mombasa (Coast Province); and around lake Victoria (Kisumu, Siaya and South Nyanza) where it is the primary cause of morbidity. The disease is also highly endemic in the semi-arid zone along the Tana River. Central Province on the other hand, had the highest incidence of respiratory infections, reflecting cooler climatic conditions.

A study based on several GCM scenarios indicates that future climate change in Kenya will result in an increase in mean annual temperature of 2.5° to 5° c and 0 to 25% increase in precipitation. These changes are expected to have various direct and indirect impacts on the health of the Kenyan population.

7.9 Climate Research

7.9.1 Mandate of KMD

The Kenya Meteorological Department has a full-fledged Division responsible for research-related matters. The Research Division is charged with the responsibility of coordinating all research activities in the Department and the public Universities and also working closely with the National Research Institutions and relevant government departments and ministries. The Division disseminates research findings through organising of international conferences, workshops and seminars that are held fairly frequently. The Division takes the lead in developing projects in priority areas designed to advance sustainable human development in Kenya. Key priority areas of research are in the fields of weather prediction, climate variability and change and in applied meteorology.

For the future, it is the intention of the Kenya Meteorological Department and the Institute for Meteorological Training and Research in particular; to create an effective research infrastructure which would enable meteorologists and other allied professionals to focus on national meteorological research needs based on relevant programmes with the potential for generating appropriate technologies for development.

7.9.2 Studies on Drought and Its Impacts

Extreme climate events have recently received remarkable attention because of the adverse impacts that they have on society and the awareness that has been created. Such extreme impacts include floods, droughts, strong winds, heat waves, cold spells, etc. Recent studies in climate change and attributions matters have revealed the tendency for these events to occur more frequently and to be more severe than before. This has mainly been attributed to the influence of mankind on the environment. Recent examples are the severe floods that were observed during 1997/98 and were related to the strong El-Niño episode. These were immediately followed by one of the longest and severest droughts in the history of the country that commenced in mid 1998 and lasted till 2001. This drought situation in which some locations recorded their lowest rainfall in history was related to the LaNiña event. The impacts associated with the two extreme climate conditions are still fresh in the minds of many. Millions of dollars are, for example, required to rehabilitate the roads that were destroyed during the 1997/98 floods. Of the two extremes, drought affects more people, covers wider areas and is a slow onset disaster. It is mainly inherent in climates with high rainfall variability. The main causes of drought are changes in the general circulation of the atmosphere. Such changes take different forms since the rainfall generating systems are largely regional-specific. In Kenya, drought has mainly been due to anomalies in some of the major regional/synoptic factors which control climate over the country. These include:

a) Anomalies in the monsoon winds
b) Reversal in the upper airflow patterns e.g. the Quasi-Biennal Oscillation (QBO)
c) Anomalies in the intensity, location and orientation of the maritime semi-permanent anticyclonic systems which are the sources of the wind systems
d) Anomalies in the structure and intensities of squall lines, easterly waves
e) Variations in the frequencies and tracks of tropical cyclones
f) Anomalies in the Sea Surface temperatures of surrounding oceans namely Atlantic and Indian Oceans.

7.9.3 Rainfall Variability and Its Relation to ENSO Events

Other causes of climate anomalies have been linked to regional/global tele-connection systems. One of the major systems which has been tele-connected with drought episodes in Kenya is the El-Niño / Southern Oscillation (ENSO) and La-Niña events The El-Niño or warm episode refers to anomalous warming of the eastern equatorial Pacific Ocean while La-Niña is the cold episode arising from cooling of the same ocean basin. The Southern Oscillation is the sea-saw in pressure patterns between the western and eastern Pacific Ocean. Statistical analyses have established significant relationships between ENSO events and extreme rainfall anomalies. The studies have shown that ENSO can account for more than 80% of rainfall anomalies in some seasons and locations. It should however be noted that ENSO is not the only cause of extreme climate events in the country. For example the 1961/62 floods were not related to an ENSO event.

7.9.4 Collaborating Institutions

Because of the diverse nature of water use activities in Kenya and the impact that climate has on a number of sectors, the Kenya Meteorological Department collaborates with a number of institutions in studies related to climate variability and change with emphasis on the extreme climate events such as droughts. These institutions include the Drought Monitoring Centre – Nairobi, the Arid Lands Project of the office of the president, the National operations Centre of the Office of the President, the Ministry of Agriculture, Water department, Kenya Electricity Generating Company (KENGEN), Ministry of energy, Kenya Forestry Research Institute (KEFRI), Ministry of health, the Kenya Medical Research Institute, the International Livestock Research Institute, Kenya Agricultural Research Institute (KARI), Nairobi City Council, Department of urban planning, public universities, United Nations Environment Program (UNEP), Kenya Marines and Fisheries Research Institute (KEMFRI), International Research Institute for Climate Prediction (IRI), European Centre for Medium Range Weather Forecasting (ECMWF), among other relevant institutions that are affected by climate.

7.9.5 UNDP / GEF Regional Capacity Building Project and US Country Study Programme

A recent project mounted by UNDP/GEF had the objective of assisting Kenya to build its human resource and institutional capacity in order to undertake climate change activities under the UNFCCC. In this study, the recent trends of rainfall and temperature were investigated using the available rainfall and temperature records. Rainfall records used were largely monthly rainfall totals, while the temperature records included daily maximum, minimum, and daily temperature range. The analyses at any location were carried out for the four standard seasons of June-August (N.H. summer), December-February (N.H. winter), September-November (N.H. autumn) and March-May (N.H. spring) respectively.

The climate records for the specific seasons were then subjected to linear trend analysis and higher order statistics for the various 30 years normal sub-periods, which included 1901-30, 1931-60, 1961-90, 1957-86, and 1951-80 wherever data was available. Analysis of annual and seasonal rainfall trends over Kenya have indicated recurrences of below/above normal precipitation in association with anomalies in the large-scale patterns of the climate system. The analysis of annual rainfall series in Kenya based on instrumental records showed that Kenya was mostly characterised by dry conditions in the 1950s and early 1970s while the wet conditions occurred in early 1960s and late 1980s.

Most lake levels in Kenya were significantly raised during the high precipitation of the 1960s. The rainfall totals for a 36 months period ending 1964 was 140% that of the average between 1931 and 1960 and surpassed 250% in some places.

7.10 Proposed Areas for Climate Research

a) Development of appropriate data sets for climate variability and change studies.
b) Detailed analyses on trends of climate with emphasis on the frequency and intensity of extreme events.
c) Multi-disciplinary research on the impacts of climate variability and change on various socio-economic sectors.
d) Studies on possible adaptation methods.
e) Estimation of climate parameters from remote sensing techniques in data sparse areas especially the marginal areas.
f) Development of dynamical climate change models.
g) Studies in environmental friendly technologies including the use of alternative energy sources such as wind, solar, hydro, geothermal, biogas.
h) Attribution of climate change signals derived from trend analysis.
i) Integration of climate information into the other socio-economic sectors.
j) Downscaling of the projected climate change scenarios and impacts.

7.10.1 Constraints / Gaps

There are a number of constraints to researchers who wish to carry out studies in various fields. These include:

a) Non-availability of good quality data.
b) Inaccessibility of relevant institutional and interdisciplinary data because of limitations

imposed by the sources.

c) Lack of relevant up to date reference material in specific areas.

d) Inaccessibility to publication opportunities.

e) Lack of exposure of the researchers.

f) Poor facilities to carry out research.

7.10.2 Training Needs

Training requires to be undertaken to build the capacities of potential researchers in specialized fields such as climate modeling, climate change detection and attribution, impact assessment, adaptation, database management etc. There should also be efforts to create awareness in the general public as well as the policy makers on the potential impacts of climate change and the dangers of some of the common practices of destroying the natural ecosystem.

8. EDUCATION, TRAINING AND PUBLIC AWARENESS

8.1 Introduction

Most development activities impact on the environment to varying degrees. In order to minimise or mitigate the negative impacts, laws have been enacted to regulate development activities. In particular, the Environ-mental Management and Co-ordination Act of 1999 has provisions for environmental standards, impact assessment, environmental management, including issues relating to climate and climate change. However, regulations work well if they are complemented by a proactive, and persistent environmental education, training and public awareness programme.

8.2 Baseline Situation

8.2.1 Formal and Non-formal Training

A number of institutions are directly or indirectly involved in training activities that relate to climate and climate change. Some of the training activities are described below.

a) Aspects of climate are infused in primary school subjects such as geography, science and agriculture. However, issues relating to human contribution to climate change, especially greenhouse gases are rarely discussed. This is partly because the school curriculum does not provide for it. Additionally, teachers lack relevant information on climate change since the subject is not part of the teacher-training programme. At the secondary school level, greenhouse effect is only given cursory attention in the biology, chemistry, agriculture and geography syllabi.

b) The East African Institute of Meteorological Training and Research conducts a course on climate modelling, extreme climate events, drought monitoring and impacts.

c) The Kenya Medical Training Centre incorporates climate and climate change issues in its training programme. Special attention is given to the science of climate change, greenhouse gases and climate change impacts on the environment.

d) Meteorological courses at the University of Nairobi have climate change as an important component at undergraduate and graduate level. Other degree courses that incorporate climate change include those undertaken by the Faculty of Environmental Studies at both Kenyatta and Egerton Universities and School of Environmental Studies at Moi University.

e) The GEF funded Capacity Building and the United States funded Country Studies Projects trained Kenyan professionals from many disciplines drawn from government, civil society organisations and the private sector. The training included development of inventories of greenhouse gas sources and sinks, assessment of climate change, mitigation strategies and adaptation measures for different sectors of the economy. These training exercises provided opportunities for practical experience on such areas as data collection, analysis and interpretation. In addition, the capacity building project included national public education and awareness raising workshops targeting decision makers.

8.2.2 Public Awareness

Many governmental and civil society organisations have initiated public awareness programmes on the environment. Some of these programmes emphasise climate change. These programmes include:

a) Soil and forest conservation programme implemented by the Permanent Presidential Commission on Soil Conservation and Aforestation. Contributiing to the enhancement of Sinks.

b) Workshops on climate change issues were organised by the National Climate Change Activities Co-ordinating Committee (NCCACC) within NES between 1995 and 1998. The workshops targeted decision makers in both public and private sectors. In addition, NCCACC maintains a collection of a wide range of national, regional, and international reports, books and other publications on climate change for use by students, researchers, academicians and other members of the public. NES has also been organising exhibitions on climate and climate change during national and provincial agricultural shows. Additionally, the Ozone project within NES addresses issues of ozone layer depletion, some of which touch on global warming. The ozone project has a robust awareness programme.

c) The Kenya Association of Manufacturers (KAM) has been promoting energy efficiency among manufacturing industries with the practices advocated contributing to reduction of green-house gas emissions.

d) Climate change issues are included in environmental education programmes of the National Museums of Kenya (NMK). The programmes emphasise the importance of forest conservation as natural carbon sinks and highlights the use of carbon free environmentally friendly technologies in the energy sector. Worksheets on climate change information are given to students who visit the nature centres. In addition, video films on climate change are regularly shown to pupils visiting the museums.

e) Aforestation/reforestation programmes are undertaken by the Forest Department (FD). The department also undertakes catchments conservation programmes in many parts of the country and promotes awareness about trees and their contribution to environmental conservation.

f) Agroforestry and social forestry programmes are promoted by the Ministry of Agriculture with a view to enhancing conservation and sustainable use of the land resource.

g) The Ministry of Education, Science and Technology has been organising workshops for policy makers in the transport, industry, thermal power generation enterprises, etc. on climate change issues.

h) The national print and electronic media regularly publish articles prepared by experts on different environmental issues that are of local, national and global importance.

i) ECONEWS Africa has initiated a community-learning programme on environment with emphasis on soil and tree conservation for sustainable development.

j) The Kenya Forest Working Group (KFWG) provides a forum for exchange of information on the forestry sector, and promotes sound forest management. KFWG has been involved in advocacy against activities that lead to indigenous forest destruction e.g. illegal excision, encroachment, etc. The organisation has set up a forest telephone hotline in order to quickly receive and/or relay information on issues that enhances or threatens forest conservation.

k) Climate Network Africa (CNA) has organised workshops on climate change issues in addition to producing a popular publication: *Impact - The CNA Newsletter.*

l) Solarnet promotes environmentally friendly energy uses and sources through ad hoc public displays Solar Day held usually in the month of September. It also publishes a newsletter.

m) Care-Kenya has been promoting tree planting in rural areas and energy saving *Jikos* (cooking stoves). The primary focus has been on energy development and conservation.

n) Action Aid has been promoting and undertaking tree planting in rural areas as well as food security coping mechanisms during adverse weather conditions. This includes selection of appropriate planting materials in dry environments.

o) The Kenya Meteorological Society (KMS) conducts public education and awareness activities on the use of meteorological information. It also produces a monthly public awareness newsletter titled *"The Weatherman"* which focuses on current weather /climate events.

8.3 Planned Actions

8.3.1 Primary, Secondary and Teacher Training

The Kenya Institute of Education intends to give increased emphasis to climate and climate change in the school curricula. This follows the recommendations of a training needs assessment study for the environment sector. The study recommended incorporation of climate change in the geography / agriculture or biology syllabus for high schools.

Issues of climate change will also be incorporated in the primary school curriculum starting from primary level 5 as well as in the curriculum for teacher training colleges. The course will focus on human activities that influence the composition of the atmosphere in ways that are changing the climate system, including greenhouse gases and their sources, mitigation measures, and adaptation strategies for climate changes.

The above issues will be infused in the teaching of maths, science, geography, agriculture and any other relevant subject. Pupils will be engaged in authentic scientific investigations at or near school in study areas such as atmosphere, land cover, biodiversity, etc.

Instructional modules will be developed by the Ministry of Education in collaboration with relevant lead agencies. The modules will include posters on greenhouse gases, effects, impacts, and mitigation and adaptation strategies. The modules will cover global warming issues both at a global scale and also giving specific examples emerging from local studies on climate change. All these will be prepared taking into consideration their relevance to the training curricula.

8.3.2 Formal and Non-Formal Training

There are proposals to offer training on climate change to trainers in teacher training colleges in order to equip pre-service teachers with knowledge about climate change. Modules for training of trainers (TOT) in teacher training colleges are to include topics on GHGs. In-service training seminars for teachers will be organised by the Kenya Institute of Education in collaboration with the National Environment Management Authority (NEMA) and relevant lead agencies focusing on current issues relating to climate change.

Trainers in other tertiary institutions such as polytechnics, medical training institutions, forestry colleges, agricultural colleges, driving schools, and industrial training institutes will be sensitised on climate change issues through workshops and seminars. Training of technical personnel within local authorities will include courses on the design and implementation of resource management plans, in areas such as urban transport, industry and other sectors that relate to climate change.

At university level, efforts will be made to infuse climate change issues in a wide range of degree programmes. This is necessary since all areas of human activity will be affected by climate change.

Other formal and non-formal education activities will be carried out. For example, Kenya Forestry Working Group (KFWG) plans to strengthen community involvement in forest management by training communities' to undertake monitoring of forest resources in their areas. Efforts will also be made by NEMA and relevant lead agencies to publish results of local studies on climate change. These publications will be availed to training institutions in order to ease access to local climate change information. In addition, local experts will be encouraged to prepare project proposals on climate change issues for possible funding. This will enhance understanding of impacts of climate change on local environments as well as build capacity.

8.3.3 Public Awareness

Awareness campaigns will be designed to reach a wide cross-section of the public. Some of the activities proposed include:

a) Workshops for leaders of local authorities on the environment generally, but including climate change issues. Local government officers will be targeted by awareness seminars on topics such as transport and climate change, housing, energy efficiency and climate change, etc.

Experiences gained by local authorities that have participated in localising Agenda 21 will be shared with other local authority leaders and technical personnel.

b) Awareness workshops for information media workers will be organised in consultation with relevant lead agencies, including the Ministry of Information and media houses.

c) Public lectures and barazas will be organised and delivered by relevant institutions and individuals to sensitise and update the general public on current issues relating to climate change.

d) Awareness seminars for the business community will be organised in collaboration with the Kenya Association of Manufacturers, Federation of Kenya Employers, trade unions, etc.

e) An award scheme will be launched to recognise and reward governmental, non-governmental and private sector institutions developing and adopting best practices in the area of environmental management (including climate change issues such as energy efficiency).

f) Competitions will be organised for those in industry e.g. tourism, to identify the resorts and operators that are best involved in climate system protection.

g) Awareness seminars on climate change will be organised for agricultural extension officers and farmers.

h) Frequent awareness seminars will be organised for policy makers, and decision- makers at community levels.

i) More public awareness activities will be undertaken during the WMO and World Environment days in collaboration with relevant public and non-governmental institutions.

j) Public awareness activities highlighting the need for increased use of public and non-motorised modes of transport will be organised in collaboration with relevant governmental, non-governmental and private organisations.

k) Permanent and temporary exhibitions on global warming and climate change will be mounted at public institutions such as the National Museums of Kenya, Agricultural Society of Kenya shows and other public fora.

l) Video scripts and films will be prepared and presented to various audiences.

m) Publications including leaflets and handbooks will be produced to disseminate information widely on current climate change issues.

n) An empirical survey will be carried out to establish citizens' knowledge and attitudes in regard to greenhouse gases effect and its consequences.

o) Projects in the cities and rural areas that protect the climate system will be documented in a database.

8.4 Mechanisms for Disseminating of Information to End Users

Mechanisms for disseminating climate information in the formal education system have been primarily through teachers who use a wide range of teaching aids. In-service training of teachers will use a variety of aids such as relevant text books, reports, posters, radio and video programmes and on the local environment, while seminars and workshops will be used to train and disseminate information as part of an aggressive effort to build capacity at all levels.

Non-formal education programmes commonly use traditional approaches that have previously been successful. These approaches will be strengthened. In this connection, public awareness efforts will use resource persons, posters and radio programmes, as well as newsprint.

Dissemination of information among adult learners is through the use of literacy centres, chief's barazas, teachers, women groups, and exhibitions at shows and during literacy days. KFWG organises monthly meetings to discuss issue relating to forests, including the environmental services. It also publishes a newsletter, which is widely circulated to members. The introduction of a telephone hotline on forest is an added means of rapid information dissemination.

8.5 Training Needs

Curriculum developers, teacher trainers and community educators require training to enhance their knowledge and skills in developing and implementing programmes on climate. The training will include short in-service courses, and educational tours so as to learn from experiences elsewhere. A training of trainers is essential as it has a multiplier effect. In the non-formal sector, staff need training in organisational and environmental management, including on climate change.

8.6 Constraints Affecting Implementation of Activities

The main constraint is the lack of a national strategy on environmental education and training. Consequently, climate issues receive minimal consideration in formal education. Lack of climate issues in school and college curricula effectively exclude it from inclusion in formal courses.

Hands-on experiences has only been available to few experts in the country. Publications generated from previous studies on climate change issues locally have not been widely disseminated to public and private institutions that would meaningfully put them into good use.

Inadequate funds has limited efforts to organise regular and targeted awareness seminars for policy-makers, transport operators, industry, agriculture and other sectors that are priority areas in climate change. Even though there are a few articles on climate change that appear on the print and electronic media, the capacity to sustain this mode of public awareness has been weak. There are very few journalists in the country who are properly sensitised on climate change issues.

Production of audio-visual materials such as videos that reflect local situations has been constrained by inadequate financial resources. Production of regular newsletters has also been severely constrained by limited financial resources. Major public awareness activities have been very sparingly undertaken due to costs involved in preparation of exhibitions and organising workshops.

8.7 Proposed Actions

8.7.1 Formal Education

Climate change has not been addressed meaningfully in the formal school and college curricula. The need to do so has been identified by training needs assessments of the environmental education sector. Consequently, the following actions are proposed:

iii) Revise and develop curricula for schools and colleges that incorporate climate change issues.
iv) Produce learning materials e.g. posters, handbooks, audio-visual materials, video-cassettes, slide-tape programmes for use by pupils in schools.
v) Organise in-service seminars and workshops for practising teachers and trainers in teacher training colleges, curriculum developers and workers in other sectors of development e.g. forestry, agriculture, industry, health etc.
vi) Develop training modules for pre-service teachers and their trainers, and for other sectors such as agriculture, industry, forestry, health etc.

8.7.2 Public Awareness

It has been noted that the wider public working in different sectors of the economy are unaware of their day-to-day, individual or collective contribution towards accelerating global warming and climate change. They are largely unaware of development pathways that they could pursue in order to enhance economic growth and ensure prudent environmental management - without destabilising the climate system. They are also unaware of the feasible adaptation strategies that require to be undertaken in order to pursue sustainable livelihoods in the event of climate change in future. In light of the above, a key objective of this proposal will be:

a) To present climate change issues to the public through enjoyable, relaxed, less didactic, life size permanent exhibitions in museums in the country. The exhibitions will portray local examples of sources of greenhouse gases, present and futuristic impressions of effects of climate change, feasible mitigation measures and cost efficient and locally available adaptation strategies in the event of a future when climate will have changed.
b) To produce audio-visual, materials, e.g., videocassettes, and slide-tape programmes, for wider public use.
c) To produce popular publications on climate change, e.g., brochures, posters.
d) To organise public lectures, barazas and debates on climate change issues.
e) To organise awareness workshops for local

authority leaders and their technical officers, community educators, journalists and other relevant personnel.

8.7.3 Survey of Knowledge and Attitudes on Global Warming and Climate Change

Even though it is recognised that the public is largely unaware of climate change issues, i.e. sources of greenhouse gases, mitigation measures, impacts and adaptations, the depth and scale of this lack of awareness needs to be clearly established. This will help in determining the intensity and scale of the required action to address it. In view of the above, the following objectives will be pursued:

a) To prepare and undertake an empirical study on the publics' knowledge and attitude on climate change issues.
b) To produce a report that provides a rational basis for undertaking actions required in the area of public awareness and education.

9. SUMMARY OF PROPOSED PROJECTS

During the implementation of the GEF funded Capacity Building Project and the United States funded Country Studies Program, areas were identified for which there is need to develop projects for improving data availability and quality, including emission factors for GHG inventory studies, abating GHG and carbon dioxide emissions as well as for public education and awareness activities. The following is a summary of the proposed projects that will address identified issues:

9.1 Project Title: Improvement of Inventories of Greenhouse Gas Sources and Sinks

The Environmental Management and Coordination Act addresses issues of emission of greenhouse gases, among other pollutants. In addition, Kenya has ratified the UNFCCC, which calls for regular inventory of greenhouse gas emission characteristics in the major economic sectors of the country. During the inventory exercise undertaken earlier, large uncertainties in emissions were identified. This project is intended to address those uncertainties and thereby support decision-making in undertaking climate change mitigation measures. The project objectives are: to build institutional capacity in order to facilitate cooperation in data collection; to enhance national technical capacity to undertake data collection and greenhouse gas inventories; to obtain a comprehensive activity data in the important socio-economic sectors; and to establish a data bank

Project Duration	:	24 Months
Project Budget	:	US$300,000

9.2 Project Title: Public Education and Awareness Raising for Sustainable Development

Sustainable development is closely interlinked with climate change issues. Well-informed communities who are also the main stakeholders would be more motivated in effectively undertaking actions that are needed to address climate change. Public awareness of climate change impacts reduces vulnerability. The project objectives are: to provide a comprehensive education and awareness programmes on potential impacts of climate change targeting most vulnerable regions and groups, and to demonstrate best practices for adaptation and mitigation.

Project Duration	:	36 months
Project Budget	:	US$400,000

9.3 Project Title: Climate Change Mitigation through Development of Carbon Sinks

The increase in population has resulted in increase in demand for fuel wood, which is the main source of energy for rural farming communities. This has resulted in destruction of forest areas and consequently reduction of carbon sinks. Agro-forestry practices have been scientifically demonstrated to enhance the environment. However, communities need to be facilitated and encouraged to adapt agro-forestry practices through on farm demonstration and provision of crop friendly seedlings. The objectives of this project are: to increase wood fuel supplies to local communities through demonstration of positive impacts of agro forestry systems; to reduce the use of fuel wood through design and demonstration of energy efficient stoves and making them available to local communities at affordable prices and to increase carbon sinks.

Project Duration	:	48 Months
Project Budget	:	US$600,000

9.4 Project Title: Promotion of Application of Biogas Technology

The vast majority of people living in rural areas rely heavily on the fuel wood to meet their household energy needs. This demand leads to deforestation and reduction of carbon sinks. Biogas technology has not realised its full potential in Kenya due to high upfront costs. The use of biogas, especially in the high potential areas of the country can reduce fuel wood demand and reduce deforestation. At the same time it can reduce emissions of methane into the atmosphere thereby mitigating climate change. The objectives of the project are: to improve the technology for construction of biogas digesters and thereby reduce their costs; to undertake public training and education on the benefits of using biogas fuel and biogas effluents as organic manure. This will eventually translate into contributing to sustainable development through improvement in agriculture, that is backbone of the economy, and enhancement of carbon sinks.

Project Duration	:	48 Months
Project Budget	:	US$750,000

9.5 Project Title : Replacement of Wood-fuel Boilers for Tea Drying

Tea production using fuel wood-fired boilers is by far cheaper than using fuel oil. However, the wood fuel supply must be sustainable. The boilers presently in use are old and inefficient. The objectives of the project are: to replace the old boilers with modern technology and wood-fuel efficient ones; to establish a sustainable industrial afforestation programme in the tea growing areas; to adapt some boilers to use wood by-products such as saw dust.

Project Duration	:	60 Months
Project Budget	:	US$ 20M

This has potential for qualifying as a Clean Development Mechanisms(CDM) project

9.6 Project Title: Promotion of Waste Re-use and Recycling

Kenya has a well-established waste recycling industry, especially in glass, plastics and steel. The handicaps seem to be collection of used recyclable material. The energy intensity per unit of recycled material is much lower than the energy intensity used on primary materials. Because of the country's policy of development to newly industrialized country (NIC) status by year 2020, recycling is going to be promoted. The objectives of the project are: to enhance public education and awareness of the benefits of recyclable materials; to demonstrate economic benefits of recycled material industry; to promote recycled materials industrial development; to reduce fossil fuel energy consumption; to reduce accumulation of waste materials.

Project Duration	:	48 Months
Project Budget	:	US$ 1.5M

9.7 Project Title: Promotion of Solar Based Rural Electrification

Over 90% of rural house holds do not have access to grid-connected power supply and are unlikely to do so in the foreseeable future in spite of the existence of rural electrification programme since 1974. Solar Photo Voltaic (PV) technology has been developed, tested and found to be feasible and a policy framework to facilitate its faster adaptation is being finalized. Extensive use of PV energy sources will reduce deforestation rate and also minimize use of wood fuels as sources of domestic energy. The project objectives are: to create enabling infrastructure for mass acquisition and utilization of solar photovoltaic for domestic use; to develop local capacity for installation of technical evaluation and maintenance of PV modules; to enable Kenya participate benefit from the flexible convention mechanisms.

Project Duration	:	36 Months
Project Budget	:	US$ 1.2M

9.8 Project Title: Removing Barriers to Energy use Efficiency in the Urban Transport Systems

About 60% of fossil fuels imported into Kenya are consumed in the transport sector. Most of the vehicles in Kenya operate on urban roads. Because of increasing urban population, most vehicles in urban areas are used to transport people either as private or public service vehicles. Fossil fuel consumption in urban areas is associated with significant wastage on account of operation inefficiencies. These inefficiencies arise due to road conditions, vehicle mechanical conditions and bad driving practices. The objectives of the project are: to establish the patterns of fuel consumption in the transport sector by fuel types; to establish barriers to efficient fuel consumption; to develop good practices in the transport sector that will lead to increased fuel consumption efficiencies.

Project Duration	:	36 Months
Project Budget	:	US$1.2M

9.9 Project Title: Development of Climate Change Adaptation and Mitigation Strategies in the Wildlife and Tourism Sectors

Kenya is well endowed with wildlife resources. Recognizing the importance of wildlife as a resource, the country's wildlife policy states that the fundamental goal with respect to wildlife is to optimize returns from this resource taking account of returns from other forms of land use. The government has set-aside about 8% of the country's total land areas as protected areas. There are 65 national parks, national reserves, marine parks and reserves and national sanctuaries. These areas are the main centres of attraction for tourism, which is one of the main economic sectors of the country. Most of these areas are in the semi-arid regions of the country and are therefore vulnerable to extreme climate conditions. The project objectives are: to establish climate change vulnerability indicators in the wildlife and tourism sectors; to assess adaptation and mitigation strategies in the two sectors; to build capacity of the institutional and public stake holders to effectively implement adaptation and mitigation strategies.

Project Duration	:	36 Months
Project Budget	:	US$ 750,000

9.10 Project Title: Development of Climate Change Adaptation and Mitigation Strategies in the Coastal Zone

Kenya's coastal environment and habitats represent the boundary between land and sea. It supports some of the most diverse resources in the country. The resources include natural systems, mangrove forests, coral reefs, sea grass beds, and rocky shores together with their unique species. In addition, it has important economic sectors such as agriculture, aquaculture, major urban centers as well as tourism. The coastal region often suffers serious flooding resulting in displacement of large numbers of people as a result of heavy seasonal rainfall occurring on highlands in the hinterland. Impacts of climate events are expected to increase in severity with climate change. The project objectives are: to establish vulnerability indicators in the coastal zone; to establish vulnerable areas, socio-economic sectors and natural ecosystems; to develop sustainable coastal zone management strategies for effective adaptation to and mitigation of climate change; to undertake institutional capacity building and public education and awareness raising programmes for effective implementation of adaptation and mitigation strategies.

Project Duration	:	36 Months
Project Budget	:	US$ 750,000

9.11 Project Title: Development of Strategies for Sustainable Adaptation to Climate Change in the Health and Public Safety Sectors

Health and public safety are vulnerable to climate events in the country. Because of increasing population and the resulting demand for land, more and more people are settling in areas that are prone to climate related hazards such as landslides, floods, and droughts. In addition, incidences of water and vector borne diseases that are prevalent in the country are exacerbated by extreme weather and climate events. With the expected global warming and changes in other climatic factors, the patterns of incidences of these diseases will change. There is therefore need to develop adaptation strategies in order to enhance the public health and safety in the various human settlements in the country. The project objectives are: to establish climate related hazards prone areas; to establish the impacts and vulnerability of extreme climate events in these areas; to develop adaptation strategies for the various health and public safety hazards; to enhance institutional capacity and public awareness for effective implementation of the strategies.

Project Duration	:	36 Months
Project Budget	:	US$300,000

9.12 Project Title: Integrated Household Waste Management and Process

The municipal solid waste in the cities of Nairobi, Mombasa and Kisumu are disposed of in landfills without any treatment. The projects goal is to propose a sustainable way of disposing of this municipal solid waste. This will involve the installation of three units for processing waste within the three cities. Each unit will generate methane, which in turn will be used to generate electricity that will be sold to the natural grid.

The objective of this project is to manage the waste in the three cities and in the process reduce greenhouse gas emissions arising from the untreated waste and to utilize the methane for electricity. Additionally, the bio-waste generated from the treatment process will be used as fertilizers on gardens/lawns and farmland. It is hoped that the increased use of bio-waste for fertilizer will reduce the use of chemical fertilizers on the land.

Project Budget	:	US$4.5M
Project Duration	:	3 years

9.13 Project Title: Nairobi City Traffic Flow Improvement Project

Nairobi is rapidly growing into a mega city. The main driving factors are rural to urban migration associated with economic opportunities and industrial growth as promoted by the national policies of rapid industrialization to create employment and alleviate poverty. There is an increasing population that lives in the suburbs and commutes to/from the city for the daily socio-economic activities. The transport mode is largely a mix of buses, mini-buses (matatus) and to a small extent the railway. The number of small vehicles has increased resulting in traffic jams. The project objective is to improve the efficiency in the use of fossil fuel in the transport sector leading to reduced greenhouse gas emissions. The specific project objectives are: to collect and analyse information on vehicular emissions; to formulate policies for improving the transport system; to reduce/change the travel modes from private to mass transit system; and decongest the city centre of vehicles and commercial activities.

The expected outputs include:

a) A cleaner more efficient transport system environment with less vehicular emissions
b) Evolution of other more environmentally friendly transport systems
c) Reduced GHG emissions from the transport sector

The stakeholders include *matatu* (mini-bus) operators, Road Transportation Board, Ministry of Transport and Communication, Kenya Railways Corporation, Kenya Airways, Nairobi City Council, Nairobi Central Business District Association, Nairobi Neighbourhoods Association, Kenya Tourism Board, Kenya Roads Board, University of Nairobi, Ministry of Environment and Natural Resources, Petroleum Institution of East Africa and Automobile Association of Kenya.

Duration	:	2 Years
Project Budget	:	US$ 210,000

9.14 Project Title: Education, Awareness, Training and Curriculum Development on Climate Change

It is expected that there will be increase in extreme weather events and their adverse impacts. As seen from the 1997-1998 El Nino, climatic variability can have disastrous impacts on the socio-economic systems. The country needs to be better prepared for changes in climate and weather events to minimize disruptions to their activities and losses resulting from them.

The main objective of the project is to improve public awareness and education in the field of climate change with a focus on the importance of observational data as a basis for tackling the issue of climate change. Training at the community level needs to be addressed to ensure that various communities are also aware of the climate change and variability issues and the use of climate data and information acquired through systematic observations. Awareness needs to be raised at various levels of the society about the importance of climatic information for improved management of their socio-economic activities. The specific objectives are: to develop appropriate learning material for primary and secondary school levels; to incorporate climate change issue into courses run by universities and technical colleges; and to identify, educate and raise awareness of stakeholders (communities, decision and policy makers) about the importance of climate observations in finding solutions to socio-economic problems.

The expected outputs include:

a) The primary and secondary level: (i) updated school curricula, (ii) updated textbooks and other learning material, and (iii) school children better educated in the field of climate change.
b) Education at the tertiary level: (i) updated or new courses incorporating climate change issues, (ii) new or updated learning material, and (iii) better educated tertiary level students.
c) Public awareness: (i) training material for target groups of stakeholders, (ii) better educated general public, (iii) better informed media, and (iv) various articles/programmes on climate change in the media.

Project Budget	:	US$300,000
Duration	:	3 Years

Annex 1 (a). Estimated emissions from Industrial Processes

Sources and sink categories	Activity data	Emission estimates						Aggregate emission factors				
	A Production Quantity (kt) or hl	B Full Mass of Pollutant (Gg)						C Tonne of pollutant per tonne of Product (t/t)* or kg/hl**				
	CO	CO2	CH4	N2O	NOx	NMVOC	CO	CO2	CH4	N2O	NOx	NMVOC
A Iron and Steel												
B Non-Ferrous Metals												
Aluminium												
Other												
C Inorganic Chemical												
Nitric Acid												
Fertilizer Production												
Other												
D Organic Chemicals												
Beer Production	3027000***						0.106					0.035
Spirits	16740***						0.251					15.0
Bread Making	156.27						1.25					0.008
Sugar Processing	3038.70						3.04					0.01
E Non-Metallic Mineral Products												
Cement	1541.72		943.69						0.6121			
Lime	30.47		24.07						0.79			
Soda Ash	224.20		21.75									
Pulp and Paper	364.80	2.043				0.55	1.35	0.0056			0.0015	0.0037

* = t/t = tonne of pollutant per tonne of product
** = kg per hectalitre
*** = hectalitres (quantity of measurement used for beverage)

Annex 1(b). Methane and nitrous oxide emissions from domestic animal wastes in Gg			
STEP 4			
Animal waste management system (AWMS)	A Nitrous excretion Nex $_{(AWMS)}$ (kg N/yr.)	B Emission factor for AWMS EF_3 (kg N_2O-N/kgN)	Total annual emissions of N_2O (Gg)
			C=(AxB)[44/28]x10^{-6}
Anaerobic lagoons	ND	0.001	
Liquid systems	ND	0.001	
Dairy spread	ND	0.000	
Pigs (solid & dry lot)	295780.32	0.02	0.009295953
Rest (Pasture range and paddock	854636.20	0.02	0.026859994
Other	ND	0.005	ND
Totals			**0.0361558=0.036**

Annex 1c. Methane emissions from flooded rice in Gg					
Water management regime	A Harvested area (m^2 x 10^{-9})	B Scaling factor for methane emissions	C Correction factor for organic amendment	D Seasonally integrated emission factor for continuously flooded rice without organic amendment (g/m^2)	E CH_4 emissions (Gg)
	1.5*10^8	1.0	1	20	E=(AxBxCxD)
Irrigated Continuously Flooded Single Aerated Intermittently Flooded Multiple Aerated	— — —	— — —	— — —	— — —	— — —
Flood prone rained Drought prone	0 —	1 —	20 —	0 —	— —
Deep water	Water depth 50-100cm				
	Water depth >100cm.				
Total					3.0

Annex 1d. Emissions from the burning of agricultural wastes in Gg				
	Step 3		Step 4	
	I Carbon fraction of residue	J Total carbon released (Gg C) J=(HxI)	K Nitrogen Carbon ratio	L Total nitrogen released (Gg N) L=(JxK)
Wheat	0.4853	0	0.012	0
Rice	0.4144	0.046218	0.014	0.000647
Coarse grain				
Barley	0.4567	0		
Oats	0.4567			
Maize	0.4709	0.25584	0.02	0.0051168
Oats				
Millet	0.4709	0.004864	0.16	0.0000778
Sorghum	0.4709	0.005057	0.02	0.000101
Potatoes	0.4226	0	0.157	
Sweet potatoes	0.4226	0	0.157	
Groundnuts	0.5	0.03098	0.015	0.0000532
Sugarcane	0.4709	0.0026648	0.02	0.0000532
Total		0.3456		0.00646605

Annex 1e. Emissions from the burning of the agricultural wastes in Gg				
	Step 6			
	M Emissions ratio	N Emissions (Gg C or Gg N)	O Conversion ratio	P Emissions from field burning of agricultural residues (Gg)
			N=(JxM)	P=(NxO)
CH_4	0.005	0.001728	16/12	0.0023404
CO	0.06	0.03073	28/12	0.04837
			N=(LxM)	P=(NxO)
N_2O	0.007	0.0000452	44/28	0.000071
NO_x	0.121	0.000782	46/14	0.002569

Annex 1f. Direct nitrous oxide emissions from agricultural fields excluding cultivation of histosols in Gg			
	Step 1		STEP 2
Type of N input to soil	AQ Amount of N input (kg N/yr.)	BR Emissions factors direct emissions EF1 (kg N_2O - N/kg N)	CS Direct soil emissions (Gg N_2O-N/yr)
			$C=(AxB)\times10^{-6}$
Synthetic fertiliser (F_{SN})	51812520	0.0125	0.000648
Animal Waste (F_{AW})			
N-fixing crops (F_{BN})			
Crop residue (F_{CR})			
TOTAL			

Annex 2. GHG emissions from the wastes sector			
Type of site	W Proportion of wastes (by weight) for each type of SWDSs	X Methane Correction factor (MCF)	Y Weighted average MCF
			Y = W*X
Managed Unmanaged – deep (> 5m waste Unmanaged – shallow (< 5m waste)	1	1.0 0.8 0.4	0.4
Total	1	2.2	0.4

Annex 2(b). GHG emissions from the solid waste sub-sector				
A Population whose wastegoes to SWDSs (Urban or persons)	B MSW generationrate (kg/capita/day)	C Annual amount of MSW generated (Gg MSW)	D Fraction of MSW disposed to SWDSs (Urban)	E Total annual MSW disposed to SWDSs (Gg MSW)
		C=(A*B*365)/106		E = (C*D)
5,000,000	0.4 (Results from Nairobi)	730	0.5 (Research estimates)	365

Annex 2(d): Methane emissions from domestic and commercial wastewater and sludge treatment					
STEP 1					
A	B	C	D	E	F
Region or City	Population (1,000 persons)	Degradable Organic Component (kg BOD/1000 persons/yr	Fraction of Degradable Organic Component Removed as Sludge	Total Domestic/ Commercial Organic Waste water (Kg BOD/yr)	Total Domestic/ Commercial Organic Sludge (Kg BOD/yr)
				E=[BxCx(1-D)]	F=(BxCxD)
KENYA	5000	13505	0.01 Total	66,849,750 66,849,750	675,250 675,250

Annex 2(c). GHG Emissions from the solid wastes sub-sector

STEP 1		STEP 2				STEP 3			STEP 4			
A	B	C	D	E	F	G	H	J	K	L	M	N
Total Annual MSW Disposed to SWDSs (Gg MSW)	Methane Correction Factor (MCF)	Fraction of DOC in MSW	Fraction of DOC which Actually Degrades	Fraction of Carbon Released as Methane	Conversion Ratio	Potential Methane Generation Rate per unit of Waste (Gg CH_4/Gg MSW)	Released (Country specific Methane Generation (Gg CH_4)	Gross Annual Methane Generation (Gg CH_4)	Recovered Methane per Year (Gg CH_4)	Net Annual Methane Generation From solid wastes (Gg CH_4)	One Minus Methane Oxidation Correction Factor	Net Annual Methane Emissions (Gg CH_4)
						G=(C*D) *E *F)	H = (B*G)	J = (H*A)		L = (J-K)	N = (L*M)	
					16/12							
365	0.4	0.15	0.77	0.5		0.077	0.0308	11.242	-	11.242	0.6	6.7452

Annex 2(e)): Estimation of emission factor for wastewater handling systems					
STEP 2					
A	B	C	D	E	F
Water handling system	Fraction of waste water treated by the handling system	Methane Conversion Factor for the Handling System	Product	Maximum Methane Producing Capacity (kg CH_4/kg BOD)	Emission Factor for Domestic/ Commercial Wastewater (Kg CH_4/ Kg BOD)
			D=(Bx C)		F = (D x E)
Sewer	1.0	0.5	0.5	0.25	0.125
Systems with anaerobic treatment					
	Aggregate MCF	0.5	0.25	0.125	

Annex 2(f): Estimation of emission factor for wastewater handling systems					
STEP 3					
A	B	C	D	E	F
Sludge Handling System	Fraction of Sludge Treated by the Handling System	Methane Conversion Factor for the Handling System	Product	Maximum Methane Producing Capacity (kg CH4/kg BOD)	Emission Factor for Domestic/ Commercial Sludge (kg CH4/ Kg BOD)
			D = (B x C)		F=(D x E)
-	1.0	0.5	0.5	0.25	0.125
		Aggregate MCF			0.125

Annex 2(g): Estimation of methane emissions from domestic/commercial wastewater and sludge (Sheet 5.6)					
STEP 4					
	A	B	C	D	E
	Total Organic Product (kg BOD/yr)	Emission Factor (kgCH_4/kg BOD)	Methane Emissions Without Recovery/ Flaring	Methane Recovered and/or Flared	Net Methane Emissions (Gg CH_4)
	from worksheet 6-2, Sheet 1	From Work sheet 6,2, Sheets 2, 3	C=(A x B)		$E=(C-D)\times10^{-6}$
Wastewater Sludge	66,849,750 675,250	0.125 0.125	8,356,219 84,406	0 0	8.356 0.084
				Total	8.44

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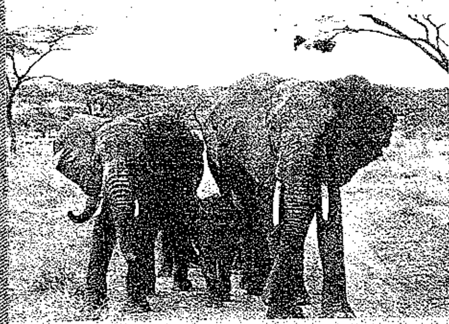

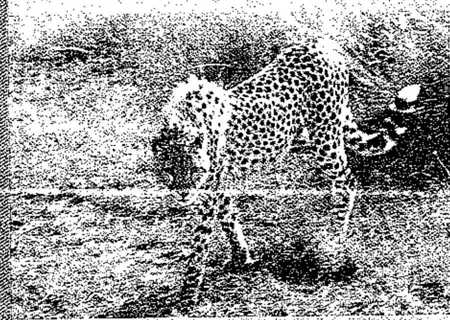

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